Physical Characteristics for Age Estimation of Male White-tailed Deer in Southern Texas

Mickey W. Hellickson,[1] *D. B. Warnell School of Forestry and Natural Resources, The University of Georgia, Athens, GA 30602-2152*

Karl V. Miller, *D. B. Warnell School of Forestry and Natural Resources, The University of Georgia, Athens, GA 30602-2152*

Charles A. DeYoung, *College of Agriculture and Human Sciences, Campus Box 156, Texas A&M University-Kingsville, Kingsville, TX 78363*

R. Larry Marchinton, *D. B. Warnell School of Forestry and Natural Resources, The University of Georgia, Athens, GA 30602-2152*

Stuart W. Stedman, *Wesley West Cattle Company, P.O. Box 7, Houston, TX 77001*

Robert E. Hall,[2] *Caesar Kleberg Wildlife Research Institute, Campus Box 218, Texas A&M University-Kingsville, TX 78363*

Abstract: Criteria for visually estimating age of live white-tailed deer (*Odocoileus virginianus*) in the field are becoming more important as the popularity of non-traditional deer management programs increase. We measured gross Boone and Crockett Club (BCC) score, number of antler points, inside antler spread, main beam length, antler basal circumference, chest girth, stomach girth, shoulder height, head length, and interorbital width and evaluated which characteristics had the greatest potential for use as predictors of age for <766 live-captured males and live and dressed mass for <65 harvested males. Most antler measures differed ($P < 0.05$) for age classes 1.5, 2.5, 3.5, 4.5, and >5.5, while most body measures differed only for age classes 1.5 and >2.5. Multiple regression models incorporating gross BCC score and number of antler points, or gross BCC score, number of antler points, and stomach girth had highest R^2 values. Percentage of each age class classified as unharvestable by various criteria within our data set is provided. Additional research is needed to test appropriateness, precision, and accuracy of these characteristics in the field.

Key words: age estimation, white-tailed deer, *Odocoileus virginianus*

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 62: 40–45

Quantitative criteria for visually estimating age of live white-tailed deer in the field are becoming more important as the popularity of non-traditional deer management programs increase. Quality management promotes restraint in the harvest of young males (Miller and Marchinton 1995), while trophy management promotes restraint in the harvest of both young and middle-aged males (Weishuhn 1983). Thus, reliable characteristics are needed to identify young and middle-aged males in the field prior to harvest.

The ability to accurately classify live deer while conducting aerial and ground-based surveys is also important in some areas for prescribing and evaluating harvest strategies (Brothers and Ray 1975), assessing herd population demographics (McCullough 1994), and providing information on recruitment and mortality rates (Gilbert 1978). During aerial surveys, observers routinely classify males into young, middle-aged, and mature age classes, while antlerless deer are classified as fawns or adults (DeYoung 1998).

Antler measures are increasingly used by state agencies at the county or statewide level to establish minimum harvest criteria for males. However, criteria based on only one to two antler measures can have negative consequences (DeYoung 1990, Strickland et al. 2001). For example, if criteria are set too low, many young males will be subject to harvest, failing to maximize quality or trophy production. If criteria are established based on larger antler sizes, then some older-aged males with relatively small antlers will be protected.

A simulation model indicated that selective-harvest criteria designed to protect 1.5-year-old males from harvest reduced antler size for that cohort in subsequent years when harvest rates of unprotected males (i.e., large-antlered 1.5-year-old males) were high (Strickland et al. 2001). Thus, harvest criteria must be region specific. Additionally, the approximate percentage of each age class that will be protected (and unprotected) for each criterion are important.

Considering the increasing popularity of non-traditional management programs and the widespread dependence on classification surveys by state agencies and private entities to monitor and manage deer populations, criteria used to distinguish age classes are surprisingly absent from the literature. Kroll and Jacobson (1995) described characteristics for estimating ages of both sexes,

1. Present address: King Ranch Production Office, P.O. Box 1090, Kingsville, TX 78364-1090.
2. Present address: Whitewing Farms, P.O. Box 692, Crystal City, TX 78839.

but did not provide data on their reliability. DeYoung et al. (1989) successfully classified 329 of 369 (89%) male white-tailed deer sighted during 28 helicopter flights. Sighted males, which were previously marked and aged by tooth replacement and wear were placed into two age groups (<3.5 or >4.5 years old) based on antler size and body musculature. They considered antler spread well beyond the tips of the ears, heavy appearance of the antlers, long tines, thick necks and front shoulders, and a blocky appearance as indicative of older-aged males. Other researchers have compared antler size trends, but most reported considerable overlap among age classes, especially for males >3.5 years old (Roseberry and Klimstra 1975, McCullough 1982, DeYoung 1989a, 1990).

Our objectives were to determine the relationship of a variety of antler and body measures to the estimated age of live white-tailed deer in southern Texas, develop predictive equations of age, and determine the percentage of each age class protected by selected criteria.

Methods

The study was conducted on the 18,020-ha Faith Ranch in Dimmit County, part of the Western Rio Grande Plains region of Texas. Mean annual minimum and maximum temperatures were 15 and 29 C, respectively and annual mean precipitation was 54.6 cm. The gently rolling terrain was dominated by guajillo (*Acacia berlandieri*), blackbrush (*A. rigidula*), guayacan (*Porlieria angustifolia*), and honey mesquite (*Prosopis glandulosa*).

We randomly captured (Leon et al. 1987) 766 free-ranging male deer during September-November 1985–1997 using the helicopter drive-net (Beasom et al. 1980) or net gun (DeYoung 1988) techniques. Each male was placed into one of eight age categories using tooth replacement and wear (TRW; Severinghaus 1949). We chose TRW over the cementum annuli technique because it is less intrusive, less time consuming (DeYoung 1989b), and is the primary method used by managers and hunters (Brothers and Ray 1975, DeYoung 1998).

Each male was ear tagged and tattooed for identification. Main beam length, number of antler points (>2.54 cm), antler basal circumference, and tine lengths were measured on both antlers and combined with inside antler spread. Remaining antler circumferences were estimated to obtain gross BCC scores according to Nesbitt and Wright (1997).

During 1992–1997 captures, chest girth and shoulder height were measured on 410 males. Fifty-two harvested males, including eight not previously captured, were also measured. Chest girth was measured immediately behind the front shoulder. Shoulder height was measured from the apex of the shoulder to the tip of the front hoof. During 1995–1997 captures, stomach girth (n = 196), head length (n = 246), and interorbital width (n = 245) were measured. Stomach girth was measured at the point half the distance between the distal portion of the front shoulder and the front of the thigh. Head length was measured from the highest point of the sagittal crest to the proximate point of the nose pad. Interorbital width was measured as the furthest point between the ridges above the eye orbits. A retractable steel tape was used and all measurements were along body curves and to the nearest 0.32 cm.

Live and/or dressed mass were measured on 65 males >4.5 years old harvested during hunting seasons from 15 November–4 February 1993–94–1996–97. Live mass included body mass minus blood loss from the gunshot wound. Dressed mass was determined after body cavity contents were removed. All mass measurements were to the nearest pound (0.45 kg) using a spring scale.

One-way analysis of variance (ANOVA) using PROC GLM and Tukey's studentized range test (HSD) were used to test for differences among year, month of harvest, and age effects (SAS 1996). Coefficients of variation were used to determine variability within each measure. We used Spearman's correlation coefficients between age and each of the 14 measures because assigned ages were ordinal. Stepwise multiple regression was used to determine best (highest R^2 value) 2-, 3-, and 4-variable combinations to use in additional models predicting age. Type III sum of squares were used in ANOVAs. Age was the dependent variable in all analyses (Dapson 1980) and statistical tests were considered significant at $P < 0.05$.

Results

No yearly (n = 13) differences were found for mean age (F = 0.07; 12, 88 df; P = 1.000), any antler measure ($F < 0.34$; 12, 88 df; $P > 0.976$), or any body measure ($F < 1.59$; 2, 14 and 5, 41 df; $P > 0.228$). All antler measures except inside spread peaked at age 6.5 years, but did not differ after age 5.5 years (Table 1). We therefore combined deer >5.5 for further analyses.

Most body measures peaked at age 7.5 years, but did not differ after age 1.5 years for stomach girth and interorbital width and after age 2.5 for other body measures (Table 2). Thus, body measures were excluded from regression analyses due to non-linearity (Dapson 1980).

Results of ANOVAs and Tukey's studentized range post hoc test indicated that age classes 1.5, 2.5, 3.5, 4.5, >5.5 differed for inside antler spread (F = 297.3; 4, 59 df; $P < 0.001$), main beam length (F = 278.7; 4, 59 df; $P < 0.001$), gross BCC score (F = 260.2; 4, 59 df; $P < 0.001$) and basal circumference (F = 133.8; 4, 59 df; $P < 0.001$; Table 1). Age classes 1.5, 2.5, 3.5–4.5, and >5.5 differed for number of antler points (F = 169.3; 4, 59 df; $P < 0.001$). Number of antler points for age classes 3.5 and 4.5 were not different from

Table 1. Antler characteristics by age for male white-tailed deer live-captured in Dimmit County, Texas, during 1985–1997.

	Gross BCC[a] score (cm)			Main beam length (cm)			Inside antlerspread (cm)			Basal circumference (cm)			*n* antler points		
Age	*0*	SE	*n*	*0*	SE	*n*	*0*	SE	*n*	*0*	SE	*n*	*0*	SE	*n*
1.5	91.7A[b]	3.74	86	21.9A	0.69	89	18.5A	0.53	86	5.9A	0.13	89	3.8A	0.18	89
2.5	204.9B	3.82	123	38.5B	0.50	123	32.3B	0.42	122	8.3B	0.10	123	7.6B	0.14	122
3.5	261.3C	4.10	123	45.3C	0.50	123	37.9C	0.49	123	9.3C	0.11	123	8.3BC	0.11	123
4.5	301.5D	5.12	102	50.5D	0.53	102	41.2C	0.53	102	10.3D	0.12	102	8.9CD	0.15	102
5.5	330.0E	3.86	119	54.2E	0.46	120	44.9D	0.62	118	11.1E	0.11	120	9.2DE	0.14	119
6.5	338.3E	4.71	90	54.6E	0.53	90	44.2D	0.60	89	11.3E	0.12	90	9.6E	0.22	90
7.5	334.0E	5.20	60	54.3E	0.63	60	44.9D	0.70	60	11.0E	0.17	60	9.4DE	0.20	60
8.5+	322.9E	6.06	53	53.0DE	0.87	53	45.7D	1.07	53	10.9E	0.16	53	9.2DE	0.23	53
Total	268.3	3.25	756	45.9	0.43	760	38.2	0.37	753	9.7	0.08	759	8.2	0.09	758

a. BCC = Boone and Crockett Club.
b. T = Results of Tukey's post hoc tests. Different letters indicate significant differences in means at the $P < 0.05$ level.

Table 2. Body characteristics (cm) for male white-tailed deer live-captured in Dimmit County, Texas, during 1992–1996.

	Chest girth			Stomach girth			Shoulder height			Head length			Interorbital width		
Age	*0*	SE	*n*	*0*	SE	*n*	*0*	SE	*n*	*0*	SE	*n*	*0*	SE	*n*
1.5	80.4A[a]	0.7	46	89.8A	1.0	25	82.6A	0.8	46	23.8A	0.2	25	9.0A	0.1	25
2.5	89.1B	0.6	64	100.6AB	1.1	32	89.8B	0.5	63	25.5B	0.2	41	9.7AB	0.2	41
3.5	92.6BC	0.6	55	102.7B	1.4	21	91.1BC	0.6	55	26.2BC	0.2	34	9.9ABC	0.2	33
4.5	96.2CD	1.0	51	107.9BD	1.3	21	92.8BC	0.5	52	26.5BC	0.2	33	10.2AC	0.1	33
5.5	99.4D	0.6	69	111.4BD	1.9	25	93.5BC	0.6	69	26.9CD	0.2	32	10.5BCD	0.1	32
6.5	100.7D	0.7	45	113.6CD	1.7	25	93.9BC	0.7	45	26.8CD	0.2	30	10.5BCD	0.1	30
7.5	100.9D	0.9	40	115.3CD	1.2	25	93.6C	0.8	40	27.2D	0.2	26	10.9D	0.2	26
8.5+	98.8D	0.8	40	110.6BD	1.5	22	93.5BC	0.9	40	26.5BCD	0.2	25	10.6CD	0.2	25
Total	94.6	0.4	410	106.3	0.8	196	91.4	0.3	410	26.2	0.1	246	10.1	0.1	245

a. Results of Tukey's post hoc tests. Different letters indicate significant difference at the $P < 0.05$ level.

Table 3. Stepwise (highest R^2) multiple regression models ($Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3$) for predicting age of male white-tailed deer at the Faith Ranch, Dimmit County, Texas, 1985–1997.

Dependent variable (Y)	Independent variables (X_i)	Coefficients (B_i)	R^2	SE	*P*-value	df
Age	Intercept	1.084	0.943	0.51	0.065	2, 8
	Gross BCC[a] score	0.027		0.00	<0.001	
	n antler points	–0.501		0.20	0.034	
Age	Intercept	–4.442	0.966	2.57	0.128	3, 7
	Gross BCC score	0.022		0.00	0.002	
	n antler points	–0.524		0.16	0.014	
	Stomach girth	0.066		0.03	0.066	
Age	Intercept	–15.590	0.978	6.38	0.050	4, 6
	Gross BCC score	0.019		0.00	0.004	
	n antler points	–0.624		0.15	0.006	
	Stomach girth	0.058		0.03	0.072	
	Head length	0.524		0.28	0.112	

a. BCC = Boone and Crockett Club.

each other, but each differed from 1.5, 2.5, and >5.5 age classes. Age classes 1.5, 2.5, >3.5 differed for chest girth ($F = 57.6$; 4, 24 df; $P < 0.001$; Table 2). Age classes 1.5 and >2.5 differed for head length ($F = 31.3$; 4, 9 df; $P < 0.001$) and shoulder height ($F = 22.2$; 4, 24 df; $P < 0.001$). Age classes 1.5 and >3.5 differed for stomach girth ($F = 14.9$; 4, 6 df; $P = 0.003$), and age classes 1.5 and >4.5 differed for interorbital width ($F = 9.2$; 4, 9 df; $P = 0.003$).

Antler measures with highest correlations with age class were main beam length ($r_s = 0.956$; $P < 0.001$; $n = 64$), gross BCC score ($r_s = 0.949$; $P < 0.001$; $n = 64$), and inside antler spread ($r_s = 0.948$; $P < 0.001$; $n = 64$). Body measures with highest correlations were head length ($r_s = 0.981$; $P < 0.001$; $n = 14$), chest girth ($r_s = 0.932$; $P < 0.001$; $n = 29$), and stomach girth ($r_s = 0.852$; $P < 0.001$; $n = 11$). Live mass was negatively correlated with age for males >4.5 years old ($r_s = -0.366$; $P = 0.017$; $n = 42$). No relationship was found between age and dressed mass.

Stepwise regression analyses indicated the most significant variables for predicting age were gross BCC score and number of antler points for a two-variable model ($R^2 = 0.943$; 2, 8 df; $P < 0.001$); gross BCC score, number of antler points, and stomach girth for a three-variable model ($R^2 = 0.966$; 3, 7 df; $P < 0.001$); and gross BCC score, number of antler points, stomach girth, and head length for a four-variable model ($R^2 = 0.978$; 4, 6 df; $P < 0.001$; Table 3).

Individual criteria that resulted in the highest percentages of specific age classes of males being excluded from harvest included a minimum of eight antler points for 1.5-year-old males (99% of age class protected); an inside spread minimum of 40.6 cm for 2.5-year-old males (97% of age class protected); a main beam length minimum of 53.3 cm for 3.5-year-old males (96% of age class protected); and an inside spread minimum of 48.3 cm for 4.5-year-old males (96% of age class protected; Table 4). These same criteria would also protect varying percentages of mature males (Table 5).

Table 4. Available criteria by age class for protecting young and middle-aged males from harvest during 1985–1997 at the Faith Ranch, Dimmit County, Texas.

Age class	Criteria	% age class protected
1.5	Antler point minimum of 8	99
	Inside antler spread minimum of 25.4 cm	99
	Main beam length minimum of 35.6 cm	97
	Gross BCC[a] score minimum of 177.8 cm	99
2.5	Inside antler spread minimum of 40.6 cm	97
	Main beam length minimum of 45.7 cm	94
	Gross BCC score minimum of 279.4 cm	94
3.5	Inside spread minimum of 45.7 cm	94
	Main beam length minimum of 53.3 cm	96
	Gross BCC score minimum of 330.2	92
4.5	Inside spread minimum of 48.3 cm	96
	Inside spread minimum of 45.7 cm	88
	Main beam length minimum of 58.4 cm	96
	Main beam length minimum of 55.9 cm	90
	Gross BCC score minimum of 381.0 cm	95
	Chest girth minimum of 101.6 cm	93

a. BCC = Boone and Crockett Club.

Table 5. Consequences (i.e., percentage of mature males inadvertently protected) of available criteria for protecting young and middle-aged males from harvest during 1985–1997 at the Faith Ranch, Dimmit County, Texas.

Age class	Criteria	% age class protected
>5.5	Antler point minimum of 10	54
	Antler point minimum of 9	39
	Antler point minimum of 8	8
	Inside spread minimum of 48.3 cm	73
	Inside spread minimum of 45.7 cm	50
	Inside spread minimum of 40.6 cm	25
	Main beam length minimum of 58.4 cm	78
	Main beam length minimum of 53.3 cm	39
	Main beam length minimum of 50.8 cm	23
	Gross BCC[a] score minimum of 381.0 cm	85
	Gross BCC score minimum of 355.6 cm	71
	Gross BCC score minimum of 330.2 cm	48

a. BCC = Boone and Crockett Club.

Discussion

An underlying assumption in our analyses was that estimated ages using TRW were accurate. Few deer were of known age; thus, our results should be interpreted with caution. However, no other technique available for aging live deer is more accurate than TRW (Cook and Hart 1979, Hackett et al. 1979, DeYoung 1989b, Jacobson and Reiner 1989). In addition, harvested deer are aged almost exclusively using this method (Brothers and Ray 1975). Thus our analyses should not be viewed as an evaluation of age estimation techniques *per se*, but rather as an evaluation of alternate criteria for predicting age as estimated by the currently used technique.

Our data suggest that gross BCC score, inside antler spread, basal circumference, and main beam length are the most useful antler characteristics for estimating male age in southern Texas. Gross BCC score may be the best characteristic because all other antler measures are included in this characteristic. However, estimating gross BCC score accurately in the field may be difficult due to lack of experience. Inside antler spread is easier to estimate because tip-to-tip ear spread can be used for comparison. Inside antler spread was also the only measure found by Anderson and Medin (1969) that did not overlap in confidence limits.

Antler characteristics provided the least overlap among age classes, were most correlated with age, and are easier to estimate from a distance than body characteristics because ear length and tip-to-tip ear spread can be used for comparison. Antler characteristics are also fixed within year, whereas most body characteristics change through the breeding season (Knowlton et al. 1979).

Using antler size as the main criterion for harvest has potential pitfalls (DeYoung 1990) and may negatively impact antler size in subsequent years if harvest rates of unprotected males are high (>75%; Strickland et al. 2001). Therefore, the best available option is likely a combination of antler and body characteristics. Our results indicate that chest girth, head length, and stomach girth are the most useful body characteristics for estimating male age. However, head length is difficult to estimate in the field. The best combination of antler and body characteristics for estimating male age likely includes gross BCC score, inside spread, and stomach girth or chest girth.

Unlike most studies involving free-ranging deer, the male age structure of our study herd was well distributed through the age classes with >42% of randomly captured males >5.5 years old. This allowed us to achieve sufficient sample sizes (n = 53–120) among these older age classes and also resulted in a relatively large sample size of mature males in the harvest.

Our results indicate several criteria that may be useful for excluding certain age classes of males from harvest. In our dataset, a simple eight-point minimum would exclude 99% of 1.5-year-old males from harvest. If the management goal also includes protecting the 2.5-year-old age class, our data suggest an inside antler spread minimum of 40.6 cm. This criterion is easy to estimate because this measure is also the typical tip-to-tip ear spread for adult males on this same ranch (M. W. Hellickson, University of Georgia, unpublished data).

Under trophy management guidelines, harvest restrictions are often implemented to also protect 3.5- and 4.5-year-old males from harvest. We recommend a gross BCC score minimum of 330.2 cm for protecting the 3.5-year-old age class, although managers and hunters may prefer an inside spread minimum of 45.7 cm which would exclude a similar percentage of this age class from harvest. A gross BCC score minimum of 381.0 cm is recommended for protecting the 4.5-year-old age class. However, varying percentages of older-aged males would also be protected for each of these criteria. For example, a gross BCC score minimum of 381 cm would also protect 85% of the >5.5-year-old age class from harvest. In areas where unprotected males are subjected to high harvest, we recommend that additional criteria be incorporated to allow for the harvest of older-aged males with small antlers. Body characteristics may be helpful in identifying small-antlered mature males for managers interested in culling these males.

It is unlikely that our results are applicable to regions outside of southern Texas. However, DeYoung (1990) concluded that antler size differences due to genetic or nutritional factors did not appear important in his comparisons of four antler measures among males on two southern Texas ranches and males on the George Reserve in Michigan (McCullough 1982) and the Crab Orchard National Wildlife Refuge in Illinois (Roseberry and Klimstra 1975). However, other studies have reported geographic differences in antler measures (Kline 1965, Richie 1970, Strickland and Demarais 2000). Future research should evaluate the appropriateness, precision, and accuracy of these characteristics in the field.

Acknowledgments

We thank the individuals who assisted with data collection, especially D. A. Draeger and W. Colson. We thank E. L. Marchinton and R. L. Bingham for manuscript review. Research was supported by the Rob and Bessie Welder Wildlife Foundation, Neva and Wesley West Foundation, Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, and the Warnell School of Forestry and Natural Resources, The University of Georgia.

Literature Cited

Anderson, A. E. and D. E. Medin. 1969. Antler morphometry in a Colorado mule deer population. Journal of Wildlife Management 33:520–533.

Beasom, S. L., W. Evans, and L. Temple. 1980. The drive net for capturing western big game. Journal of Wildlife Management 44:478–480.

Brothers, A. and M. E. Ray, Jr. 1975. Producing quality whitetails. Fiesta Publishing Company, Laredo, Texas.

Cook, R. L. and R. V. Hart. 1979. Ages assigned known age Texas white-tailed deer: tooth wear versus cementum annuli analysis. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 33:195–201.

Dapson, R. W. 1980. Guidelines for statistical usage in age-estimation technics. Journal of Wildlife Management 44:541–548.

DeYoung, C. A. 1988. Comparison of net-gun and drive-net capture for white-tailed deer. Wildlife Society Bulletin 16:318–320.

———. 1989a. Evaluation of bias in antler measurements of harvested white-tailed deer on a south Texas ranch. Texas Journal of Agriculture and Natural Resources 3:24–25.

———. 1989b. Aging live white-tailed deer on southern ranges. Journal of Wildlife Management 53:519–523.

———. 1990. Inefficiency in trophy white-tailed deer harvest. Wildlife Society Bulletin 18:7–12.

———. 1998. How good are our aging techniques? (On the hoof). Pages 87–89 *in* D. Rollins, editor. The role of genetics in white-tailed deer management. Proceedings of the 1998 Symposium of the Texas Chapter of the Wildlife Society. College Station.

———, J. R. Heffelfinger, S. L. Beasom, and S. P. Coughlin. 1989. Classifying male white-tailed deer from a helicopter. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 43:292–296.

Gilbert, J. R. 1978. Estimating population characteristics. Pages 297–304 *in* J. L. Schmidt and D. L. Gilbert, editors. Big game of North America: ecology and management. Stackpole Books, Harrisburg, Pennsylvania.

Hackett, E. J., D. C. Guynn, and H. A. Jacobson. 1979. Differences in age structure produced by two aging techniques. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 33:25–29.

Jacobson, H. A. and R. J. Reiner. 1989. Estimating age of white-tailed deer: tooth wear versus cementum annuli. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 43:286–291.

Kline, P. D. 1965. Status and management of the white-tailed deer in Iowa, 1954–1962. Iowa Academy of Science 72:207–217.

Knowlton, F. F., M. White, and J. G. Kie. 1979. Weight patterns of wild white-tailed deer in southern Texas. Pages 55–64 *in* D. L. Drawe, editor. Proceedings of the First Welder Wildlife Foundation Symposium, Corpus Christi, Texas.

Kroll, J. C. and H. A. Jacobson. 1995. Starting out. Pages 19–46 *in* K. V. Miller and R. L. Marchinton, editors. Quality whitetails: the why and how of quality deer management. Stackpole Books, Mechanicsburg, Pennsylvania.

Leon, F. G., III, C. A. DeYoung, and S. L. Beasom. 1987. Bias in sex and age composition of white-tailed deer observed from helicopters. Wildlife Society Bulletin 15:426–429.

McCullough, D. R. 1982. Antler characteristics of George Reserve white-tailed deer. Journal of Wildlife Management 46:821–826.

———. 1994. What do herd composition counts tell us? Wildlife Society Bulletin 22:295–300.

Miller, K. V. and R. L. Marchinton, editors. 1995. Quality whitetails: the why and how of quality deer management. Stackpole Books, Mechanicsburg, Pennsylvania.

Nesbitt, W. H. and P. L. Wright. 1997. Measuring and scoring North American big game trophies. Second edition. Boone and Crockett Club, Missoula, Montana.

Richie, W. F. 1970. Regional differences in weight and antler measurements of Illinois deer. Transactions of the Illinois State Academy of Science 63:189–197.

Roseberry, J. L. and W. D. Klimstra. 1975. Some morphological characteristics of the Crab Orchard deer herd. Journal of Wildlife Management 39:48–58.

SAS Institute, Inc. 1996. SAS/STAT software: changes and enhancements through release 6.11. SAS Institute, Inc., Cary, North Carolina.

Severinghaus, C. W. 1949. Tooth development and wear as criteria of age in white-tailed deer. Journal of Wildlife Management 13:195–216.

Strickland, B. K. and S. Demarais. 2000. Age and regional differences in antlers and mass of white-tailed deer. Journal of Wildlife Management 64:903–911.

———, S. Demarais, L. E. Castle, J. W. Lipe, W. H. Lunceford, H. A. Jacobson, D. Frels, and K. V. Miller. 2001. Effects of selective-harvest strategies on white-tailed deer antler size. Wildlife Society Bulletin 29:509–520.

Weishuhn, L. L. 1983. Management of white-tailed deer on south Texas ranges. Pages 349–353 *in* R. D. Brown, editor. Antler development in Cervidae. Caesar Kleberg Wildlife Research Institute, Texas A&I University, Kingsville.