Notes

Evaluation of Hunter Antler-Size Selection through an Age-Specific Comparison of Harvested and Naturally Cast Antler Metrics

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Abstract

Deer antler metrics have been used to index the physical condition of deer populations, but those sampled at deer-check stations may not be representative of the population at large if deer hunters select for larger antlered individuals. The objectives of this study were to 1) evaluate whether white-tailed deer *Odocoileus virginianus* hunters exhibit selective behavior through an age-specific comparison of harvested antler metrics to naturally cast antlers; and 2) evaluate the potential value of cast antlers to monitor herd condition via antler seal depth to identify individual health. Antler metrics representing antler mass (main beam basal circumference), length (main beam length), and the number of antler points were taken on yearling (aged 1.5 y) hunter-harvested deer during the 2009, 2010, and 2011 November firearm seasons and compared with freshly cast yearling antlers collected during the corresponding 2010, 2011, and 2012 antler-casting seasons. The antler metric indicative of antler mass was greater in harvested deer than the deer herd at large, providing empirical evidence of size-selective hunter behavior. We suggest that cast antlers be used as a less-biased alternative to measurements taken of antlers of harvested deer to assess herd characteristics.

Keywords: antler morphology; cast antler; hunter selectivity; Nebraska; *Odocoileus virginianus*; pedicle seal depth; white-tailed deer

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Introduction

White-tailed deer *Odocoileus virginianus* are the most pursued big game species in the United States and are ecologically and economically important (USFWS 2006). However, the harvest of wild populations can be selective, with hunters harvesting individuals of a certain size or morphology (Allendorf and Hard 2009); as seen in bighorn sheep *Ovis canadensis* (Coltman et al. 2003); Alaskan moose *Alces alces gigas* (Schmidt et al. 2007); red deer *Cervus elaphus* (Martinez et al. 2005); roe deer *Capreolus capreolus* (Andersen et al. 2007); and white-tailed deer (Ditchkoff et al. 2000; hereafter referred to as deer). Therefore, antler metrics sampled at check stations may not be representative of the deer herd because of hunter selectivity.

Unlike antler metrics of harvested deer, cast antlers may provide an unbiased description of a population's antler characteristics (Ditchkoff et al. 2000). Deer shed (Michael 1965; Behrend and McDowell 1967) or cast their antlers (Ditchkoff et al. 2000) each spring when testosterone levels drop and blood supply is cut off from the antler base (Lincoln 1992; Rolf and Enderle 1999). Currently, baseline cast-antler data exist for Iberian red deer *Cervus elaphus hispanicus* in Spain (Fierro et al. 2002) and deer within a controlled hunting area in Oklahoma (Ditchkoff et al. 2000). However, no known studies have described the baseline cast-antler characteristics of a free-ranging deer herd that is not subjected to intense management.

Antler growth can be related to the quality of forage (Severinghaus et al. 1950); thus, antler metrics can be used to index the physical condition of a deer population (Park 1938; Park and Day 1942). Some studies have observed a correlation between an antler's physical nature at the time of casting and the general health of the individual in deer (Bubenik et al. 1987; Bubenik 1990) and sika deer (*Cirvus nippon*; Kaji et al. 1988). Within experimental populations, Bubenik (1990) found that nutritionally deprived bucks had low blood-testosterone levels, with cast antlers containing concave seal depths. Cast-antler seal depth refers to how the antler pedicle seal detaches from the skull during the process of antler casting, as the osteoclasts absorb calcium from the pedicle. Convex seal depths represented healthier deer with higher concentrations of blood testosterone (Bubenik et al. 1987). Land and wildlife managers may find antler metrics such as seal depth especially useful as an index of an individual deer's antlerogenetic potential, defined by Bubenik (1990) as future antler growth.

The objectives of this study were to 1) evaluate whether deer hunters exhibit a size-selective effect through an age-specific comparison of harvested and cast-antler metrics; and 2) evaluate the potential value of cast antlers as a method to monitor herd condition via antler seal depth to identify individual health and antlerogenetic potential. If hunters selected for larger antlered deer, then hunter-harvested antler metrics will be greater than cast-antler metrics.

Study Site

Harvested deer during the 2009, 2010, and 2011 November firearm seasons (corresponding to the 2010, 2011, and 2012 antler-casting seasons) were brought by hunters to the Nebraska Game and Parks Commission Kearney Field Office. Antler metrics were taken by the authors and deer were aged by one of three experienced wildlife biologists using tooth wear and replacement similar to methods described in Severinghaus (1949). Deer were primarily harvested proximal to the Platte River in south-central Nebraska, USA (Schoenebeck et al. 2013). Accordingly, cast deer antlers were also collected along the Platte River, during February through April (2010–2012). The search area consisted of multiple land parcels within the central Nebraska Platte River Lowland within 60 river km of Kearney, primarily consisting of riparian habitat bordered by agricultural fields (Weaver and Bruner 1948). The data set was augmented with freshly cast, yearling antlers collected from our study area by hobbyist cast collectors.

Methods

We selected measurements to represent antler mass (main beam basal circumference [H1]), length (main beam length [MBL]), and the number of antler points to evaluate the study objectives. We counted the number of tines ≥25 millimeters (mm) and measured MBL, and H1 on harvested yearling (aged 1.5 y) deer, using the most accessible antler because antler metrics do not differ between sides (Schoenebeck et al. 2013). We measured MBL and H1 (1 mm) using a measuring tape as specified by the Boone and Crockett Club (Nesbitt and Wright 2009).

All cast antlers collected were identified as either fresh or old (from a previous year). Fresh casts were defined as having a skin ring, which is located around the exterior of the pedicle seal just under the base of the burr (Shead 2011). Only freshly cast deer antlers that were defined as typical by Boone and Crockett Club (Nesbitt and Wright 2009) were considered, and all cast antlers were measured by the authors. For a match set of cast antlers (determined by physical proximity and antler similarity [size, burring, and coloration]), we considered only the first cast antler collected. We used MBL to distinguish cast antlers of yearling bucks from older age groups, as described by Schoenebeck et al. (2013). All tines ≥25 mm were counted toward the point total. To facilitate comparisons, we calculated gross score for each cast antler in accordance with the Boone and Crockett Club standardized measuring system (Nesbitt and Wright 2009). We measured main beam length and tine lengths ≥25 mm (labeled G1–G4) using a flexible measuring tape. We measured circumferences (H1–H4, in mm) using a measuring tape at the smallest diameter between the antler burr and G1 (H1), and the smallest diameter between the G1 and G2 (H2), etc., based on the number of circumferences available (≤4). Main beam diameters (D1–D4, 0.01 mm) were taken using a digital caliper at the same locations as circumference measurements. If a cast antler had <5 points, we took the final circumference and diameter measurement halfway between the last tine and the main beam tip. We measured the mass (0.1 g) of each cast antler using a digital balance. To ensure a standard mass measurement, we placed cast antlers at room temperature (22–23°C) for 2 wk prior to weighing.

We defined the pedicle seal as the proximal surface of the cast antler (i.e., where it would attach to the skull pedicle). Seal depth (0.01 mm) was taken from each cast antler using digital calipers. We did this using the measuring blade of the digital calipers to directly measure from the pedicle seal's base (under side of coronet) to the pedicle seal's most protruding point. Cast antlers exhibiting negative (concave) pedicle seal depths were determined by placing the caliper blade tip within the pedicle seal's deepest point and measured to the flattest portion of pedicle seal (G. A. Bubenik, University of Guelph, personal communication). We took cast-antler seal diameters (0.01 mm) at three bisecting locations using digital calipers and averaged them. We used Pearson correlations to diagnose any predictive relationships between pedicle seal depth and other antler metrics. We used 1-way analysis of variance (or Kruskal–Wallis test if data were nonnormal) to evaluate whether cast-antler metrics varied among study years.

We evaluated potential differences between hunter and cast-antler metrics (total points, MBL, and H1) and among the 3 study y using a 2-way analysis of variance if data were normally distributed (evaluated using Shaprio–Wilk normality test) or a Kruskal–Wallis test if data were not normally distributed. Because cast antlers were classified by age group based on MBL (Schoenebeck et al. 2013), we also classified hunter-harvested yearling deer by the same MBL to standardize the comparison between hunter-harvested and cast-antler metrics. To test the assumption that cast antlers were found in

Table 1. Mean ± SE of total points, main beam length (MBL, mm), and basal circumference (H1, mm) representing antler metrics of yearling white-tailed deer *Odocoileus virginianus* from harvested (2009–2011) and cast antlers (2010–2012) from the Platte River Valley, Nebraska, USA. Two-way analysis of variance (H1) or Mann–Whitney (MBL and points) test results describe the comparison between hunter-harvested and cast-antler metrics.

Antler metric	Source	Mean ± SE	Test statistic	*df*	*P*
H1	Harvest	67.6 ± 1.0	$F = 6.193$	1, 223	0.014
	Cast	63.6 ± 1.0			
MBL	Harvest	271.3 ± 4.8	$U = 6233$	1, 228	0.507
	Cast	270.8 ± 4.5			
Points	Harvest	2.9 ± 0.1	$U = 6302$	1, 228	0.701
	Cast	2.8 ± 0.1			

proportion to their availability during this study, we described the skewness and kurtosis for the distributions of the total number of points of harvested deer and cast antlers. Significance was set at $\alpha \leq 0.05$ for all analyses.

Results

Antler metrics did not differ among years but differences between some of the harvested and cast-antler metrics evaluated suggests selective behavior by hunters (Table 1; Data S1). Basal antler circumference (H1) was normally distributed for both harvested ($P = 0.393$) and cast antlers ($P = 0.090$) and was significantly greater for antlers of harvested deer than for cast antlers ($F = 6.193$, $df = 1{,}223$, $P = 0.014$; Figure 1). The interaction between years and antler source was not significant for H1 ($F = 2.756$, $df = 2{,}223$, $P = 0.066$), and H1 did not differ among years ($F = 0.879$, $df = 2{,}223$, $P = 0.417$). Mean beam length (MBL) and the number of antler points were not normally distributed and did not differ between harvested and cast antlers or among years (Table 1).

We measured 48, 27, and 50 antler metrics of harvested yearling deer during November of 2009, 2010, and 2011, respectively. Eight (three during 2009, three during 2010, and two during 2011) of the deer exceeded the MBL cut-off used to separate 1.5- from 2.5-y-old age groups and were therefore excluded from analysis. Similarly, we measured 28, 49, and 36 yearling cast antlers during 2010, 2011, and 2012, respectively. One cast antler during 2010 was characterized as nontypical and was therefore excluded from analysis.

From the harvested yearling antlers ($n = 117$) examined, antler sides contained 1–4 points, with 68.4% of the antlers having 3 or 4 antler points. Points ranged from 1 to 5 for the cast antlers ($n = 112$), with 96.4% having <5 points and 56.3% having 3 or 4 points (Table 2; Data S2). Cast-antler metrics did not vary among years (Table 2). Pedicle seal depth was not correlated to other antler metrics ($r \leq 0.190$). The distribution of both harvested and cast-antler total points were negatively skewed (−0.110, −0.918) with a negative kurtosis (−1.049, −0.879), respectively.

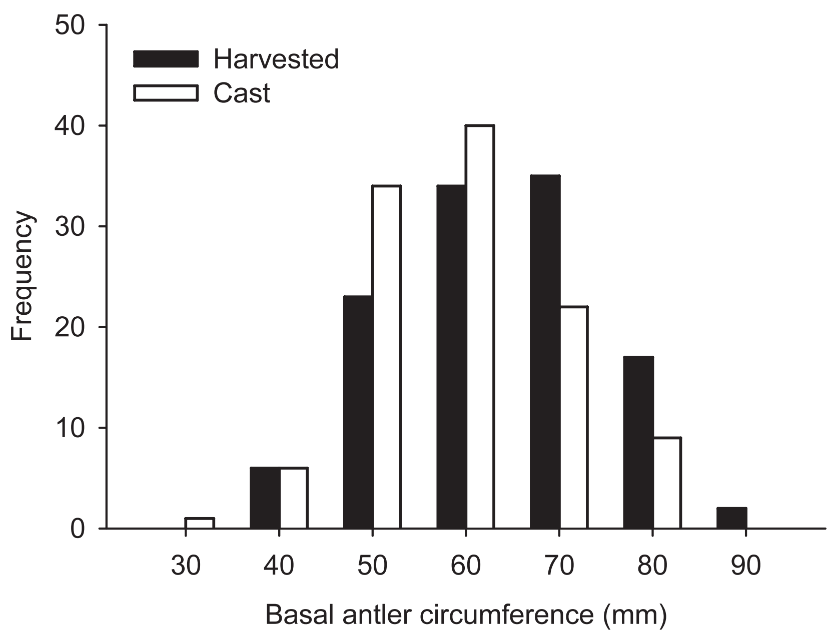

Figure 1. Basal antler circumference (H1) by occurrence of yearling hunter-harvested (solid) and cast- (open) antler white-tailed deer *Odocoileus virginianus* from the Platte River Valley, Nebraska, USA, 2010–2012.

Table 2. Three-year mean ± SE, sample size (*n*), minimum (min.) and maximum (max.) values and test statistics representing cast-antler metrics (points, gross score, main beam length [MBL], tine length [G1–G4], circumference [H1–H4], diameter [D1–D4], pedicle seal diameter [Seal Dia.], and depth and antler mass) of yearling white-tailed deer *Odocoileus virginianus* from the Platte River Valley, Nebraska, USA, 2010–2012. One-way analysis of variance or Kruskal–Wallis (MBL, G1, H2, seal depth, and mass) test results describe the lack of variability among years for each antler metric. Reported metrics are in mm, except for points (number of points), gross score (as determined following Nesbitt and Wright 2009), and mass (g).

Antler metric	*n*	Mean ± SE	Min.–Max.	*F* or *K*	*df*	*P*
Points	112	2.8 ± 0.1	1–5	1.012	2, 111	0.367
Score	112	544.0 ± 17.2	110–945	0.882	2, 111	0.417
MBL	111	270.8 ± 4.5	72–348	0.495	2, 110	0.781
G1	91	56.4 ± 2.6	25–131	3.056	2, 90	0.217
G2	61	89.2 ± 4.2	26–165	1.126	2, 60	0.331
G3	29	71.3 ± 5.8	27–130	0.610	2, 28	0.511
G4	3	44.0 ± 4.9	35–52			
H1	112	63.6 ± 1.0	38–89	0.476	2, 111	0.623
H2	100	56.3 ± 1.0	35–75	1.692	2, 99	0.429
H3	70	53.1 ± 1.3	30–84	0.255	2, 69	0.776
H4	37	43.5 ± 1.7	20–65	0.233	2, 36	0.802
D1	112	20.97 ± 0.31	12.00–28.65	0.857	2, 111	0.427
D2	101	19.23 ± 0.35	9.67–26.44	1.631	2, 100	0.201
D3	71	18.68 ± 0.53	10.45–33.44	0.467	2, 70	0.629
D4	38	14.80 ± 0.64	7.72–23.78	0.441	2, 37	0.647
Seal Dia.	112	23.44 ± 0.23	18.26–30.66	1.119	2, 111	0.330
Seal Depth	112	4.08 ± 0.19	−3.50–8.69	3.048	2, 111	0.218
Mass	101	116.7 ± 4.3	39.3–233.7	1.204	2, 100	0.548

Discussion

The antler metric indicative of antler mass (i.e., H1) was greater in harvested yearling deer than the yearling herd at large, providing limited empirical evidence that hunters selected deer with larger antlers—a possible causal mechanism for the selective harvest hypothesis (Monteith et al. 2013). A previous study found that hunters harvested smaller-than-average antlered bucks than were present in the herd as indexed by cast antlers (age groups not separated), likely due to the increased movement and naiveté of younger, smaller antlered bucks (Ditchkoff et al. 2000). Unlike Ditchkoff et al. (2000), our study limited the question of hunter selectivity to a single age group (yearlings) to standardize the comparison and eliminate the among age-group variability that can possibly confound results. Regardless of the cause, (age-specific movement and naiveté or hunter antler selection) caution should be exercised when using harvested deer antlers to describe the antler characteristics of the herd. We concur with Ditchkoff et al. (2000) and suggest that cast antlers could be used as a less-biased alternative to assess antler characteristics of the deer herd. Although yearling buck harvest was not high in the unit and during the years of this study (yearling buck harvest averaged 25% of the total buck harvest; Taylor 2010, 2011, 2012), the use of cast-antler metrics may become biased in regions with high yearling buck harvest because larger yearlings may be disproportionally harvested prior to antler casting.

Ditchkoff et al. (2000) suggests that antler size may affect visibility when conducting searches for cast antlers. During this study the distribution of harvested antler points had a negative skewness because three- and four-point antlers were the most common. Similarly, yearling cast antlers had a negative skewness because three- and four-point antlers were the most common, supporting the assumption that cast antlers were found in proportion to their availability during this study. The distribution of cast-antler points was also negatively skewed in Oklahoma (Ditchkoff et al. 2000). The appropriateness of search technique may vary regionally depending upon vegetation characteristics and deer densities, so search patterns specifically designed for local conditions may be required to ensure that a representative sample of cast antlers are obtained (Ditchkoff et al. 2000).

We agree with others who found that cast antlers can provide useful information regarding herd management, posthunting-season age structure, overwintering habitat, as well as comparisons between different study areas or among time periods (Anderson and Medin 1969; Kaji et al. 1988, 2004; Ditchkoff et al. 2000; Fierro et al. 2002). Similarly, cast-antler metrics of yearling deer during this study were developed as a means for less-biased comparisons among years, regions, and individual antlerogenetic potential. We agree with Anderson and Medin (1969), who stated that yearling deer antlers provide the most sensitive metrics available, because yearlings 1) respond to environmental stressors, 2) can be accurately identified as yearlings, and 3) are available in large sample sizes. However, individual variability may have been too high during this study to detect temporal variation in cast-antler metrics during the 3 y of this study. Alternatively, annual changes in environmental conditions may not have varied enough over the course of this study to affect antler metrics because forage, water, and shelter were likely not limiting during this study. Similarly, antler metrics of roe deer were found to be more influenced by age and body condition than environmental changes (Vanpe et al. 2007). This brings into question the use of cast-antler metrics to describe changes among years within the Platte River Valley; although, annual consistency would favor the use of cast antlers for regional comparisons.

Hunter-harvested yearling antler metrics such as MBL, H1, and total points were greater in central Nebraska (271.3 mm, 67.6 mm, and 2.9) than reported in harvested yearlings within a controlled hunting area in Oklahoma (174 mm, 51 mm, and 1.7; Ditchkoff et al. 2000). Unfortunately, there are currently no regional comparisons to make among cast antlers because this is the first report of cast yearling deer antlers. Ditchkoff et al. (2000) provided baseline data describing cast antlers of deer within a controlled hunting area; however, age groups were not separated.

The wide range of cast-antler seal depths of yearling deer highlights the variable levels of individual deer health within the herd. For example, cast-antler pedicle seal depths of yearling deer ranged from −3.50 to 8.69 mm during this study, which was similar to the range of −3.0 to 9.0 mm in 1–10-y-old pen-raised deer (Bubenik 1990). This range of cast-antler seal depths correlated to a range of poor (approx. 4 ng/mL) to high (10 ng/mL) testosterone levels and consequently deer health (Bubenik 1990). Two animals that exhibited −3.0-mm cast-antler seals were yearlings (G. A. Bubenik, personal communication) because testosterone levels are typically lower in yearlings than in older bucks (Bubenik and Schams 1986). Additional experiments by Bubenik (1990) found concave seal depths of −6.0 mm in castrated deer and extreme seal depths of 10.0–15.5 mm in highly aggressive mature bucks. Individual variability in cast-antler seal depth observed during this study and by Bubenik (1990) suggests that this metric is sensitive to the health of individual deer. Considering the prevalence of agriculture in the study area, variability among individual seal depths was unexpected because we hypothesized that yearling deer health within the study area would be average to healthy. We recommend the causal explanations for the observed wide range of individual variability in the depth of the antler seal be investigated further.

Although antler metrics of yearling deer such as MBL, gross score, and total points have not been found to accurately predict future antler size (Koerth and Kroll 2008), cast-antler seal depth may be indicative of future antler potential (Bubenik 1990). Convex cast-antler seals are representative of antlerogenetically promising deer because of the correlation among cast-antler seal depth, testosterone levels, and deer health (Bubenik 1990). Therefore, cast-antler seal depth can possibly be used to manage for antlerogenetically superior deer by identifying and allowing these individuals to remain in the herd. In addition, because concave cast-antler seals represent antlerogenetically poor deer (Bubenik 1990), wildlife biologists and lands managers can use cast-antler seal depth to identify potential cull bucks. Management based on harvested antler metrics may not allow for the same diagnoses of antlerogenetic potential because pedicle seal depth was not correlated to other antler metrics. Although the practicality of management based on cast-antler seal depth may be more useful to land managers because of the difficulty of linking a cast antler to the individual, it nonetheless highlights the usefulness of cast-antler metrics. The baseline cast-antler metrics and methods provided herein should serve as a building block for future comparisons among deer populations.

Supplemental Material

Please note: The *Journal of Fish and Wildlife Management* is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

Reference S1. Park BC, Day BB. 1942. A simplified method of determining the condition of white-tailed deer herds in relation to available forage. U.S. Department of Agriculture Technical Bulletin No. 840.

Found at DOI: 10.3996/032013-JFWM-022.S1; also available at http://naldc.nal.usda.gov/download/CAT86200833/PDF (2154 KB PDF).

Data S1. Total points, main beam length (MBL, mm), and basal circumference (H1, mm) representing antler metrics of yearling white-tailed deer *Odocoileus virginianus* from harvested (2009–2011) and cast antlers (2010–2012) from the Platte River Valley, Nebraska, USA.

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Data S2. Cast-antler metrics (points, gross score, main beam length [MBL], tine length [G1–G4], circumference [H1–H4], diameter [D1–D4], pedicle seal diameter [Seal Dia.], and depth and antler mass) of yearling white-tailed deer *Odocoileus virginianus* from the Platte River Valley, Nebraska, USA, 2010–2012.

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References

Allendorf FW, Hard JJ. 2009. Human-induced evolution caused by unnatural selection through harvest of wild animals. Proceedings of the National Academy of Sciences of the United States of America 106:9971–9978.

Andersen R, Karlsen J, Austmo LB, Odden J, Linnell JDC, Gaillard J. 2007. Selectivity of Eurasian lynx *Lynx lynx* and recreational hunters for age, sex and body condition in roe deer *Capreolus capreolus*. Wildlife Biology 13:467–474.

Anderson AE, Medin E. 1969. Antler morphomerty in a Colorado mule deer population. Journal of Wildlife Management 33:520–533.

Behrend DF, McDowell RD. 1967. Antler shedding among white-tailed deer in Connecticut. Journal of Wildlife Management 31:588–590.

Bubenik GA. 1990. The antler as a model in biomedical research. Pages 474–487 in Bubenik GA, Bubenik AB, editors. Horns, pronghorns and antlers: evolution, morphology, physiology and social significance. New York: Springer-Verlag.

Bubenik GA, Schams D. 1986. Relationship of age to seasonal levels of LH, FDH, prolactin and testosterone in male, white-tailed deer. Comparative Biochemistry and Physiology 83:179–183.

Bubenik GA, Schams D, Coenen G. 1987. The effect of artificial photoperiodicity and antiandrogen treatment on the antler growth and plasma levels of LH, FSH, testosterone, prolactin and alkaline phosphatase in the male white-tailed deer. Comparative Biochemistry and Physiology 87:551–559.

Coltman DW, O'Donoghue P, Jorgenson JT, Hogg JT, Strobeck C, Festa-Bianchet M. 2003. Undesirable evolutionary consequences of trophy hunting. Nature 426:655–658.

Ditchkoff SS, Welch ER, Lochmiller RL. 2000. Using cast antler characteristics to profile quality of white-tailed deer *Odocoileus virginianus* populations. Wildlife Biology 6:53–58.

Fierro Y, Gortazar C, Landete-Castillejos T, Vicente J, Garcia A, Gallego L. 2002. Baseline values for cast antlers of Iberian red deer (*Cervus elaphus hispanicus*). Zietschrift Fur Jagdwissenschaft 48:244–251.

Kaji K, Koizumi T, Ohtaishi N. 1988. Effects of resource limitation on the physical and reproductive condition of sika deer on Nakanoshima Island, Hokkaido. Acta Theriologica 33:187–208.

Kaji K, Okada H, Yamanaka M, Matsuda H, Yabe T. 2004. Irruption of a colonizing sika deer population. Journal of Wildlife Management 68:889–899.

Koerth BH, Kroll JC. 2008. Juvenile-to-adult antler development in white-tailed deer in South Texas. Journal of Wildlife Management 72:1109–1113.

Lincoln GA. 1992. Biology of antlers. Journal of Zoology 226:517–528.

Martinez M, Rodriguez-Vigal C, Jones OR, Coulson T, Miguel AS. 2005. Different hunting strategies select for different weights in red deer. Biology Letters 1:353–356.

MichaelED. 1965. Characteristics of shed antlers from white-tailed deer in South Texas. Journal of Wildlife Management 29:376–380.

Monteith KL, Long RA, Bleich VC, Heffelfinger JR, Krausman PR, Bowyer RT. 2013. Effect of harvest, culture, and climate on trends in size of horn-like structures in trophy ungulates. Wildlife Monographs 183:1–26.

Nesbitt WH, Wright PL. 2009. Measuring and scoring North American big game trophies. 3rd edition. Missoula, Montana: The Boone and Crockett Club.

Park BC. 1938. Deer weights and measurements on the Allegheny National Forest. Transactions of the North American Wildlife Conference 3:261–278.

Park BC, Day BB. 1942. A simplified method of determining the condition of white-tailed deer herds in relation to available forage. U.S. Department of Agriculture Technical Bulletin No. 840 (see *Supplemental Material,* Reference S1, http://dx.doi.org/10.3996/032013-JFWM-022.S1); also available: http://naldc.nal.usda.gov/download/CAT86200833/PDF (November 2013).

Rolf HJ, Enderle A. 1999. Hard fallow deer antler: a living bone till antler casting? The Anatomical Record 255: 69–77.

Schmidt JI, Ver Hoef JM, Bowyer RT. 2007. Antler size of Alaskan moose *Alces alces gigas*: effects of population density, hunter harvest and use of guides. Wildlife Biology 13:53–65.

Schoenebeck CW, Peterson BC, Obermiller JA. 2013. Accuracy of antler metrics in predicting age of white-tailed deer and mule deer. Great Plains Research 23:33–37.

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

Severinghaus CW, Maguire HF, Cookingham RA, Tanck JE. 1950. Variations by age class in the antler beam diameters of white-tailed deer related to range conditions. Transactions North American Wildlife Conference 15:551–570.

Shead J. 2011. Shed hunting: a guide to finding white-tailed deer antlers. Berlin, Wisconsin: Deer Antler Press.

Taylor JS. 2010. Annual performance report: 2009–10. Lincoln: Nebraska Game and Parks Commission, Wildlife Division. W-15-R, Segment 66. Available: http://nlc1.nlc.state.ne.us/epubs/G1800/A001-200910.pdf (November 2013).

Taylor JS. 2011. Annual performance report: 2010–11. Lincoln: Nebraska Game and Parks Commission, Wildlife Division. W-15-R, Segment 67.

Taylor JS. 2012. Annual performance report: 2011–12. Lincoln: Nebraska Game and Parks Commission, Wildlife Division,. W-15-R, Segment 68.

United States Fish and Wildlife Service [USFWS]. 2006. National survey of fishing, hunting, and wildlife-associated recreation. Available: http://digitalmedia.fws.gov/cdm/singleitem/collection/document/id/1248/rec/20 (January 2013).

Vanpe D, Gaillard J, Kjellander P, Mysterud A, Magnien P, Delorme D, Van Laere G, Klein F, Liberg O, Hewison AJ. 2007. Antler size provides honest signal of male phenotypic quality in roe deer. The American Naturalist 169:481–493.

Weaver JE, Bruner WE. 1948. Prairies and pastures of the dissected Loess Plains of Central Nebraska. Ecological Monographs 18:507–549.