Deer Antler Characteristics in Relation to Land Use and Spatio-temporal Factors in Missouri

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Abstract: Deer antler growth is influenced by the environment, population density, genetics, and nutrition. As land use and densities change over time, antler characteristics are hypothesized to also change. We examined how geography, land use, and the number of deer harvested per unit area (i.e., harvest density) related to white-tailed deer *(Odocoileus virginianus)* antler characteristics of harvested yearling bucks in Missouri during 2 time periods (1951–1970 and 1997–2001). Latitude related positively to antler characteristics in the early time period. Amount of cropland harvested was positively associated with antler characteristics, while amount of pastureland, and amount of grazed woodland were negatively related during the recent time period. Deer from the Glaciated Plains physiographic region exhibited a significant decline in number of points ($\bar{x}$ = 6.3 to 5.4) and beam circumference ($\bar{x}$ = 72.5 to 68.6 mm) across time. Physiographic regions differed in relation to antler characteristics during the early time period ($P < 0.0001$), but became similar with time. Harvest differed with physiographic region within each time period. Changing antler characteristics through time may reflect lower densities during the 1950s and 1960s in relation to the nutritional plane available across the state. Effects of land use practices, along with effects of physiographic-specific harvest, should be considered when setting population management goals.

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Recent interest by hunters in taking larger antlered deer has led researchers to investigate effects of habitat components on antler growth of deer, especially white-tailed deer *(Odocoileus virginianus).* Habitat and density may have the greatest impact on yearling bucks because these animals have not yet matured. Body size in-

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creases with age and is positively correlated with antler size in adult cervids, with larger bodied deer typically producing larger antlers (Servinghaus and Moen 1983, Stewart et al. 2000). Interest in yearling bucks has focused on antler characteristics because of heritability of future antler characteristics (Schultz and Johnson 1992, Ditchkoff et al. 1997, Lukefahr and Jacobson 1998) and the pressure applied to the yearling age class through harvest. Environmental factors affecting antler characteristics include latitude, physiographic region, land use, and density (Baker 1984, McCullough 1984, Strickland and Demarais 2000). Kissell et al. (in press) found latitude accounted for >70% of the variation in the number of points and beam circumference in yearling deer taken by hunters in Missouri from 1951–1970. However, they found during recent years (1997–2001) latitude accounted for just over 40% of the variation. They hypothesized changing land use patterns may explain the reduced north-south association in antler characteristics. Others have suggested that land use, especially agricultural practices, may affect antler characteristics (Richie 1970, Strickland and Demarais 2000) and deer density (Roseberry and Woolf 1998).

Deer densities may affect antler growth by limiting food resources or increasing stress through social interactions (Bartos 1990, Shea et al. 1992). Additionally, population density and antler characteristics both have been tied to the occurrence of agriculture (Vanderhoof 1995, Roseberry and Woolf 1998). Agricultural practices and land devoted to agriculture in the southeastern United States, as well as other parts of the United States, have changed over the past 50 years. A 16.9% decrease of agricultural land has occurred in Missouri since 1950, but individual farms have increased in size (U.S. Dep. Agric. 1962, 2001, 2002). The effect of land use patterns on antler development has received limited attention (Strickland and Demarais 2000) and has not been examined in relation to changing landscapes.

Our objectives were to determine how changes over time in agricultural land use were related to antler characteristics. Specifically, we hypothesized that 1) agricultural land use would be positively related to antler development, 2) livestock grazing land use would be negatively related to antler development, 3) antler characteristics within or among physiographic regions have not changed over time, and 4) harvest densities within physiographic regions would be inversely related with antler characteristics.

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Methods

Missouri Department of Conservation (MDC) personnel and volunteers collected antler characteristics (beam circumference (mm) measured ~2.5 cm above the pedicel and number of points) and age (Servinghaus 1949) data at established county check-stations during 2 time periods: 1951 to 1970 (Early Time Period [ETP]) and 1997 to 2001 (Recent Time Period [RTP]). Because management units have changed over time, we used counties as observational units and years as replicates. We as-

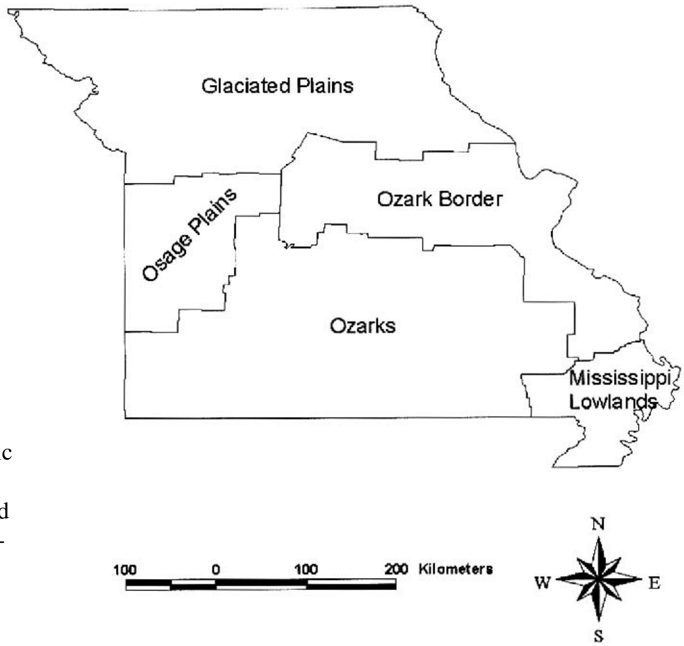

Figure 1. Physiographic regions delineated by counties in Missouri used to study relationships between antler characteristics and landuse factors, 1951–2001.

sumed the animal was checked in the county of harvest. Yearlings comprised most of the harvest and provided the greatest potential for variation. Therefore, we used only 1.5-year-old males in analyses.

Counties also were grouped according to physiographic region (Fig. 1) to represent a second scale. Physiographic regions included were Glaciated Plains (GP), Ozark Border (OB), and Ozarks (OZ) (Thom and Wilson 1980). The Osage Plains and Mississippi Lowlands regions were omitted due to insufficient data. Soils of the GP are deep, loamy, and clayey, originating from loess and glaciated till. Native vegetation indicative of the GP includes tall grasses intersected by hardwood drainages. Loam, chert, and clay soils are associated with the OB. Oak (*Quercus* spp.)—hickory (*Carya* spp.) forests interspersed with glades is typical of the OB region. Chert and loamy soils from limestone and dolomite are typical of the OZ and habitat is an oak-hickory forest (Allgood and Persinger 1979). Agricultural land use has been different among the physiographic regions. During the past 50 years approximately 40%, 20%, and 7% of the areas have been in croplands in the GP, OB, and OZ, respectively (U.S. Dep. Agric. 1962, 1999).

We determined mean deer antler circumference and number of points by county and physiographic region for each county for each time period. We used stepwise regression (PROC REG, SAS Inst. 2001) to model each time period using antler characteristics as dependent variables, and latitude, longitude, and percent of county area in harvested cropland, woodland grazed by livestock (grazed woodland), pastured cropland, other cropland (failed crops, Conservation Reserve Program (CRP) land,

and fallow acreage), and pastureland as independent variables. Independent variables were considered significant and allowed to enter and remain in the model when $P \leq 0.1$. Land use data were acquired from the Missouri Agricultural Statistical Service (U.S. Dep.Agric. 1999). We assessed differences in antler characteristics by time periods and physiographic regions using an analysis of variance (PROC GLM, SAS Inst. 2001). We tested the assumption of equal variance with Levene's test for homogeneity (Snedecor and Cochran 1980). Variance was homogeneous and no transformations were used. We used number of deer harvested/mi^2 in each county (harvest density) as an index to population density. We acknowledge the limitations of using harvest density as an index to population density, and used the assumed relationship in the absence of any other measured population density parameter. We assessed the relationship between harvest density and antler characteristics using Pearson correlations (PROC CORR, SAS Inst. 2001) by physiographic region. All statistical analyses were conducted using SAS (SAS Inst. 2001) and alpha was set at 0.05 unless otherwise noted.

Results

Statewide

Latitude played the main role in the distribution of number of points during the ETP (Table 1) and was the most important factor associated with beam circumference. Percentage of county area in pasturelands also explained a small proportion of variation (negative association) of beam circumference during the ETP (Table 1).

During the RTP, the percentage county area in grazed woodland, pastureland, and longitude were negatively associated with number of points; other cropland was positively correlated. Beam circumference was directly related to the percentage of county area in cropland harvested and inversely, but weakly related to the percentage of county area in grazed woodland (Table 1).

Table 1. Partition of variation of factors associated with number of points and beam circumference from deer harvested in Missouri from the periods 1951–1970 (early) and 1997–2001 (recent).

Period/Character	Variable	Estimate	Partial R^2	*F*	*P*
Early/Points	Latitude	0.76667	0.75	104.85	<0.001
Recent/Points	Grazed woodland	-0.11363	0.71	50.90	<0.001
	Longitude	-0.14437	0.09	8.47	0.009
	Other cropland	0.07271	0.04	4.34	0.051
	Pastureland	-0.03528	0.03	4.34	0.052
Early/Beam	Latitude	5.48810	0.72	94.18	<0.001
	Pastureland	-0.19102	0.02	3.17	0.084
Recent/Beam	Cropland harvested	0.19293	0.74	57.78	<0.001
	Grazed woodland	-0.76978	0.11	14.48	0.001

Table 2. Results of analysis of variance tests examining number of points and beam circumference (mm) by time period (1951–1970: early and 1997–2001: recent) within 3 physiographic regions of Missouri.

	Time period				
Character/Region	Early	Recent	*N*	*F*	*P*
Number of points					
Glaciated Plains	6.3	5.4	17	24.54	0.001
Ozark Border	5.1	4.6	12	1.52	0.243
Ozarks	4.3	4.4	27	0.20	0.659
Beam circumference					
Glaciated Plains	72.5	68.6	17	5.57	0.031
Ozark Border	61.5	65.0	13	3.27	0.096
Ozarks	58.7	60.7	26	1.60	0.218

Table 3. Pearson correlation coefficients of harvest density and number of points, and harvest density and beam circumference by time period within 3 physiographic regions of Missouri. Significance (*P*-value) is provided in parentheses.

	Time period			
Character/Region	1951–1970	*N*	1997 – 2001	*N*
Number of points				
Glaciated Plains	-0.58435 (0.076)	10	-0.64508 (0.084)	8
Ozark Border	-0.58296 (0.170)	7	-0.06110 (0.909)	6
Ozarks	-0.17261 (0.480)	19	0.07618 (0.846)	9
Beam circumference				
Glaciated Plains	-0.33904 (0.338)	10	-0.40252 (0.323)	8
Ozark Border	-0.23162 (0.581)	8	-0.25970 (0.619)	6
Ozarks	-0.12468 (0.622)	18	0.02134 (0.957)	9

Physiographic Regions

We found number of points in deer from the GP significantly less in the RTP compared to the ETP. A similar comparison within the OB and OZ produced no differences between time periods. During the ETP, number of points was different among regions. During the RTP, the OB and OZ were not different for number of points, but both differed from the GP (Table 2).

Only the GP had a significant change in beam circumference between time periods (Table 2). The GP differed in beam circumference from the OB and OZ during the ETP. However, there was no difference between the OB and OZ. In the RTP, the GP was different from the OZ; there was no significant difference between the OZ and OB or between the GP and the OB (Table 2). We found number of points to be weakly correlated with harvest density in the GP during both time periods (Table 3). Fewer deer were harvested from the GP compared to the OZ and OB during the ETP, and fewer were harvested from the OZ than the GP or OB during the RTP (Table 4).

Table 4. Mean harvest density (deer harvested/mi^2) by physiographic region and time period. Differences determined using Tukey range test. Similar letters indicate no difference; different letters indicate a significant ($\alpha = 0.05$) difference.

	1951–1970		1997–2001	
Region	Mean	*N*	Mean	*N*
Glaciated Plains	0.20 A	40	4.1 A	40
Ozark Border	0.37 B	21	4.3 A	21
Ozarks	0.32 B	37	2.8 B	37

Discussion

Factors generally considered affecting antler characteristics of deer are age, nutrition, population density, and genetics (Brothers et al. 1995). Habitat, altered by humans and by deer themselves, must also be considered. Our results suggest an interaction between density and nutrition could play a role in antler characteristics at the landscape scale. Changing antler characteristics through time may reflect lower densities during the 1950s and 1960s in relation to the nutritional plane available across the state. Removal of the most nutritious, highly palatable browse plants over time may have occurred as deer populations increased (DeCalesta 1997, Healy 1997).

Locally, body size and antler development is tied to nutritional quality of available forage (Wentworth et al. 1992). Livestock that graze in woodlands remove understory forage and cover such that available forage or suitable habitat is removed (Gladfelter 1984). Energy lost to low quality forages cannot be devoted to body size and antlerogenesis, and smaller antlers likely result. Occurrences of farming practices, including the amount of cropland harvested and the amount in CRP, fallow fields, or failed crops, likely provided greater forage quantity and/or quality for antlerogenesis compared to areas without access to crops. Nutrition as related to land use, due to density increases, may have influenced a change in antler characteristics.

Density has been posed as a factor affecting antler characteristics (Roseberry and Klimstra 1975, Shea et al. 1992, Ditchkoff et al. 1997, McCullough 2001), but few experiments testing density effects have been conducted (Connolly 1981). Density reduction should increase the nutritional plane of survivors, thereby allowing increases in body size and antler characteristics. However, results are conflicting (Shea et al. 1992, Ditchkoff et al. 1997, McCullough 2001). We expected negative correlation coefficients to increase in magnitude, but observed coefficients in the GP were weak. This relationship, however, may have been demonstrated by a reduced rate of fecundity during similar time periods (Hansen et al. 1996). Deer densities likely increased at a faster rate in the GP through time. Changing agricultural practices, such as CRP and row crops harvested, likely supported more deer through time in the GP.

Other influences of antler size include genetics through selective harvest (Ott et al. 1997, McCullough 2001, Strickland et al. 2001). Lukefahr and Jacobson (1998) indicated yearling antler size should not be used as a criterion to improve antler characteristics, as physiological maturity and age are needed to realize the full potential of an individual. In contrast, Strickland et al. (2001) indicated removal of larger antlered, young deer resulted in smaller antler characteristics in the same cohort under circumstances that appear to be nutritionally related. Each year it is estimated Missouri deer hunters collectively harvest more than 100,000 yearling bucks (Hansen, unpubl. data.). With such effort, it is selective pressure from hunting that could affect antler characteristics over a long period of time (Thelen 1991). While Missouri has not had a mandatory selective harvest criterion, hunters may select larger antlered deer. Firearms season in Missouri is held during the rut. Most bucks are harvested early each season, and if hunters actively select larger deer, deer with smaller antlers are left to breed. However, we did not find the same decreases in antler size in each physiographic region. This may indicate that environment plays a stronger role in some physiographic regions than in others (Strickland and Demarais 2000).

Management Implications

Our results indicate expectations of antler size decrease with decreased occurrence of agriculture, increased densities, and poorer soils. At the state-wide level, manipulation of harvest may be used to influence antler characteristics in some areas. Reduced population densities may provide increased nutrition relative to available vegetation, thereby yielding larger antlers. At a smaller scale, food plots are a tool promoted to enhance the nutritional plane, even on good sites (Kammermeyer and Thackston 1995). Future research should be directed at examining the density-nutrition association across other physiographic regions, and the influence of harvest-altered genetics. Also, comparisons of antler development for deer in areas within physiographic regions could help understanding of the influence of resource availability on a local scale.

Literature Cited

Allgood, F.P. and I.D. Persinger. 1979. Missouri general soil map and soil association descriptions. U.S. Dep. Agric., Columbia, Mo. 74pp.

Baker, R.H. 1984. Origin, classification and distribution. Pages 1–18 *in* L.K. Halls, ed. White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pa.

Bartos, L. 1990. Social status and antler development in red deer. Pages 442–459 *in* G.A. Bubenik and A.B. Bubenik, eds. Horns, pronghorns, and antlers. Springer-Verlag, New York, N.Y.

Brothers, A., D.C. Guynn, Jr., J. Hamilton, and R.L. Marchinton. 1995. The spike question. Pages 112–117 *in* K.V. Miller and R.L. Marchinton, eds. Quality whitetails: the why and how of quality deer management. Stackpole Books, Mechanicsburg, Pa.

Connolly, G.E. 1981. Limiting factors and population regulation. Pages 245–285 *in* O.C. Wallmo, ed. Mule and black-tailed deer of North America. Univ. Neb. Press, Lincoln.

DeCalesta, D.S. 1997. Deer and ecosystem management. Pages 267–279 *in* W.J. McShea, H.B. Underwood, and J.H. Rappole, eds. The science of overabundance: deer ecology and population management. Smithsonian Inst. Washington, D.C.

Ditchkoff, S.S., E.R. Welch, W.R. Starry, W.C. Dinkines, R.E. Masters, and R.L. Lochmiller. 1997. Quality deer management at the McAlester Army Ammunition Plant: A unique approach. Proc. Annu. Conf. Southeast. Fish and Wildl. Agencies 51:389–399.

Gladfelter, H.L. 1984. Midwest agricultural region. Pages 427–440 *in* L.K. Halls, ed. White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pa.

Hansen, L.P., J. Beringer, and J.H. Schulz. 1996. Reproductive characteristics of female white-tailed deer in Missouri. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 50: 357–366.

Healy, W.M. 1997. Influence of deer on the structure and composition of oak forests in central Massachusetts. Pages 249–266 *in* W.J. McShea, H.B. Underwood, and J.H. Rappole, eds. The science of overabundance: deer ecology and population management. Smithsonian Inst. Washington, D.C.

Kammermeyer, K.E. and R. Thackston. 1995. Habitat management and supplemental feeding. Pages 129–154 *in* K.V. Miller and R.L. Marchinton, eds. Quality whitetails: the why and how of quality deer management. Stackpole Books, Mechanicsburg, Pa.

Kissell, Jr., R.E., C.G. Wieberg, L. Hansen, and J. Beringer. in press. Changes in antler characteristics from harvested white-tailed deer across 50 years. Trans. Mo. Acad. Sci.

Lukefahr, S.D. and H.A. Jacobson. 1998. Variance component analysis and heritability of antler traits in white-tailed deer. J. Wildl. Manage. 62:262–268.

McCullough, D.R. 1984. Lessons from the George Reserve, Michigan. Pages 211–242 *in* L.K. Halls, ed. White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pa.

———. 2001. Male harvest in relation to female removals in a black-tailed deer population. J. Wildl. Manage. 65:46–58.

Ott, J.R., S.A. Roberts, J.T. Baccus, D.E. Harmel, W.E. Armstrong, and E. Fuchs. 1997. Antler characteristics and body mass of spike- and fork-antlered yearling white-tailed deer at maturity. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 51:400–413.

Richie, W.F. 1970. Regional differences in weight and antler measurements of Illinois deer. Trans. Ill. Acad. Sci. 63:189–197.

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

——— and A. Woolf. 1998. Habitat-population density relationships for white-tailed deer in Illinois. Wildl. Soc. Bull. 26:252–258.

SAS Institute, Inc. 2001. The SAS system for windows software. Release 8.2. Cary, N.C.

Schultz, S.R. and M.K. Johnson. 1992. Antler development of captive Louisiana white-tailed bucks. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 46:67–74.

Servinghaus, C.A. 1949. Tooth development and wear as criteria of age in white-tailed deer. J. Wildl. Manage. 13:195–216.

——— and A. N. Moen. 1983. Prediction of weight and reproductive rates of a white-tailed deer population from records of antler beam diameter among yearling males. N.Y. Fish and Game J. 30:30–38.

Shea, S.M., T.A. Breault, and M.L. Richardson. 1992. Herd density and physical condition of white-tailed deer in Florida flatwoods. J. Wildl. Manage. 56:262–267.

Snedecor, G.W. and W.G. Cochran. 1980. Statistical methods, 7th ed. Iowa St. Univ. Press, Ames. 507pp.

Stewart, K.M., R.T. Bowyer, J.G. Kie, and W.C. Gasaway. 2000. Antler size relative to body mass in moose: tradeoffs associated with reproduction. Alces 36:77–83.

Strickland, B.K. and S. Demarais. 2000. Age and regional differences in antlers and body mass of white-tailed deer in Mississippi. J. Wildl. Manage. 64: 903–911.
———, ———, 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. Wildl. Soc. Bull. 29:509–520.
Thelen, T.H. 1991. Effects of harvest on antlers of simulated populations of elk. J. Wildl. Manage. 55:243–249.
Thom, R.H. and J.H. Wilson. 1980. The natural divisions of Missouri. Trans. Mo. Acad. Sci. 14:9–23.
U.S. Department of Agriculture. 1962. Number of farms 1910–1959, land in farms 1950–1959 by states. Stat. Rep. Serv. Stat. Bull. 316:1–14.
———. 1999. 1997 Census of agriculture: Missouri state and county data. Natl. Agric. Stat. Serv. Geogr. Area Ser. Rep. AC97-A-25 Vol. 1. Washington, D.C. 605pp. + append.
———. 2001. 2001 Missouri farm facts. Stat. Rep. Serv., Columbia, Mo. 80pp.
———. 2002. Farms and land in farms. Natl. Agric. Stat. Serv. Rep. Washington, D.C. 15pp.
Vanderhoof, R.E. 1995. Agronomic forage plantings and deer management: a modeling approach. Ph.D. Diss., Miss. St. Univ., Mississippi State. 140pp.
Wentworth, J.M., A.S. Johnson, P.E. Hale, and K.E. Kammermeyer. 1992. Relationships of acorn abundance and deer herd characteristics in the southern Appalachians. South. J. Appl. For. 16:5–8.