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Morphological Variation in White-Tailed Deer From Illinois

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ABSTRACT

We examined 361 adult, female white-tailed deer (*Odocoileus virginianus*) skulls to elucidate patterns of morphological variation within Illinois, and to assess the subspecific status of regional Illinois herds with special emphasis on southern Illinois. Deer in Illinois exhibited a latitudinal cline consistent with Bergmann's ecogeographic rule, although a character shift between southern and southcentral Illinois was apparent. Illinois samples were not distinct from specimens representing *O. v. borealis* and larger *O. v. macrourus*. Based upon our findings, continued inclusion of Illinois within the *O. v. borealis* range is warranted.

Key Words: *Odocoileus*, subspecies, morphometry

INTRODUCTION

White-tailed deer from Illinois have been included within the range of the large northern woodland white-tailed deer (*O. v. borealis* [Miller]). Another large form, the Kansas white-tailed deer (*O. v. macrourus* [Rafinesque]), occupies the central plains states west of the Mississippi River, and a smaller race, the Virginia white-tailed deer (*O. v. virginianus* [Zimmerman]), is found southeast of the Ohio River (Kellogg 1956; Halls 1978; Hall 1981) (Fig. 1). White-tailed deer were probably eliminated from Illinois by the early 20th century, the last reported sightings coming from southern Illinois around 1910 (Pietsch 1954; Calhoun and Loomis 1974).

The reintroduction of deer into Illinois began in the 1930s with animals primarily from Michigan and Wisconsin, and others of unknown origin (Pietsch 1954). Reintroductions using animals of differing stock, game farm escapes, natural emigration, and the possibility of surviving remnants of the original herds have obscured the taxonomic picture of deer in Illinois as well as other regions (Kellogg 1956; Halls 1978; Smith et al. 1984).

Ritchie (1970) compared deer from northern and southern Illinois and found that the latter exhibited smaller masses and basal antler beam diameters than the former. He believed these differences resulted from southern deer surviving on a lower nutritional plane. Harder (1980) compared the relationship between body mass and reproductive rates among populations from the northern United States and found that populations with high female

body mass had high reproductive rates. The exception was for deer from Crab Orchard National Wildlife Refuge in southern Illinois which had high fetal rates albeit low body mass. Nelson and Woolf (1985) suggested these differences in size reflect genetic rather than nutritional differences based on the productivity and good physical condition of deer on Crab Orchard Wildlife Refuge (Roseberry and Klimstra 1970; Nelson 1984).

Southern Illinois occupies a unique position with regard to the classification of *O. virginianus*, lying between 2 major river systems which form the boundaries of 3 purported subspecies, with unrestricted gene flow to the north. We studied the morphometric relationships among samples from selected regions of Illinois, and examined the association between these specimens and samples representing the 3 purported subspecies of *O. virginianus*, with special emphasis on southern Illinois.

MATERIALS AND METHODS

Cranial measurements were taken from 361 undamaged adult (≥2 years old), female white-tailed deer skulls. Most skulls were collected from hunter-harvested animals, however museum specimens were also examined (Appendix I). Restricting analyses to adult females reduced the effects of age-related variation, and removed the effects of secondary-sexual variation.

Initial collections from Illinois included northwestern (Carroll, Jo Daviess, and Whiteside counties), westcentral (Adams and Pike counties), and southern (Alexander and Williamson counties) regions of the state (Fig. 1). These areas are characterized by rolling to rugged uplands dissected by forested stream and river corridors, and tracts of contiguous forested habitat. Preliminary sampling also included the prairie region of eastcentral Illinois (Dewitt, Livingston, McLean, and Piatt counties), an area distinctly different with respect to habitat, land use, and physiography. This region is characterized by flat, intensively-farmed terrain with isolated small forests. Subsequent collections included southcentral Illinois (Jefferson and Washington counties) and Effingham county, in order to examine for clinal variation between central and southern Illinois.

Crania from geographically disjunct areas within the accepted range (excluding Illinois) of *O. v. borealis*, *O. v. macrourus*, and *O. v. virginianus* were also examined (Fig. 1). These included: for *O. v. borealis*, northeastern Minnesota, southcentral Michigan, southwestern Pennsylvania, and southern Maine (type locality Bucksport, Hancock Co.); for *O. v. macrourus*, northeastern Kansas (type locality near Wakarusa Creek, Douglas Co.), Arkansas (primarily northcentral), and southeastern Missouri; for *O. v. virginianus*, eastcentral and westcentral Virginia (type locality Virginia), southwestern South Carolina and southwestern Tennessee. More detailed information on sampling localities is provided in Appendix I.

Ages of specimens were determined according to tooth eruption and wear (Severinghaus 1949). Cleaned and dried crania and rami were measured with a Helios dial micrometer (0.05 mm calibration) and a Dunlap measuring board (1.0 mm calibration). Twenty cranial measurements taken are described by Levengood (1991). Evaluations of univariate and multivariate normality, outliers, and homogeneity of variance-covariance matrices were satisfactory. Specimens were grouped by geographic region. An alpha level of 0.01

was selected for univariate and multivariate analyses of skeletal characters. Testing for differences between means was accomplished using the GLM procedure of SAS (SAS Institute Inc. 1985); multiple comparisons were performed using the Tukey/Kramer method.

Stepwise discriminant function and canonical-variate analyses were used to identify and separate groups using the DISCRIMINANT procedure of SPSSX (SPSSX Inc. 1983). Stepping was accomplished using the MAHAL specification of the METHOD subcommand. This procedure selected a subset of the original variables which maximizes Mahalonabis' distance between the two closest groups. F-to-enter and F-to-remove were the default value of 1.0. Prior probabilities were set equal to sample sizes to account for disparity in group size. A distance phenogram was constructed based on a UPGMA analysis of standardized character means using CLUSTER and TREE of SAS (SAS Institute, Inc 1985).

RESULTS

Univariate comparisons of 272 *O. virginianus* skulls from Illinois revealed 15 characters with significant levels of geographic variability (Table 1). Deer from southern Illinois averaged smaller than specimens from the westcentral, northwestern, eastcentral, and southcentral portions of the state for 12, 11, 9, and 5 cranial measurements, respectively. Specimens from Effingham County, Illinois, were significantly larger for 10 characters, when compared to skulls from the southern region. Comparisons between more northerly (southern Illinois excepted) regions of the state were less conclusive.

Six characters increased in size from southern Illinois northward through southcentral, Effingham County, and eastcentral Illinois (Table 1). Specimens from eastcentral Illinois, however, averaged larger or equal to those from northwestern Illinois for 15 measurements, and were larger than all Illinois regions for 11 characters. These patterns were apparent for palatal length (PALATLEN), the most geographically variable of 20 characters examined (Fig. 2). Correlations between PALATLEN and the remaining 19 characters ($r = 0.32 - 0.42$, $\underline{P} < 0.001$) suggested similar trends for all craniodental measurements. A character shift or step was apparent between southcentral and southern Illinois.

In order to examine the status of regional Illinois deer herds relative to specimens representing *O. v. borealis*, *O. v. macrourus*, and *O. v. virginianus*, a stepwise discriminant function analysis was performed using 20 cranial measurements from 361 specimens as predictors of membership in 9 groups (Fig. 3a); southern Illinois specimens were considered unknowns. Seven functions were derived, but only the first 3 functions were significant ($X^2_{42} = 66.6$, $\underline{P} = 0.01$). The first, second, and third functions accounted for 58, 16, and 10 percent of the between-group variability, respectively.

Eighteen characters in combination were useful in distinguishing groups. Length of the lower molariform tooth row (0.7), length of the upper molariform tooth row (-0.5), and palatal length (0.5) were among the most important discriminators on the first function; condylobasal length (-1.9), palatal length (1.3), and length of the upper molariform tooth row (1.1) were the primary distinguishing variables on the second function.

In a bivariate plot of canonical-variate scores samples from northwestern, westcentral, eastcentral, Effingham County, and southcentral Illinois overlapped considerably and are enclosed within a single polygon (Fig. 3a). The southern Illinois and combined Illinois polygons were not distinctive. The *O. v. borealis* sample coincided with 61, 58, and 41 percent of the combined Illinois, *O. v. macrourus*, and southern Illinois polygons, respectively. The 2 Illinois polygons in combination overlapped 81 percent of the *O. v. borealis* sample; of the Illinois samples, the southcentral Illinois centroid (C) was farthest from the *borealis* centroid (B), while the westcentral Illinois centroid (W) was in closest proximity to the latter. The *O. v. virginianus* and *O. v. macrourus* samples exhibited 31 and 74 percent congruence, respectively, with the *O. v. borealis*, combined Illinois, and southern Illinois samples. The *O. v. macrourus* specimens overlapped 66 percent of the *O. v. virginianus* sample.

Correct classifications ranged from 31.6 (Effingham Co. IL) to 74.4 percent (*O. v. virginianus*). Twenty (62.0%), 14 (40.0%), and 1 (10.0%) specimen(s) of misclassified *O. v. borealis*, *O. v. macrourus*, and *O. v. virginianus*, respectively, were categorized as Illinois specimens. Sixteen (80.0%) misclassified *O. v. borealis* were grouped with northwestern or westcentral Illinois. Overall, 83% of *O. v. borealis* were classified as *O. v. borealis* (including Illinois). Of 45 Illinois specimens misclassified as *O. v. borealis*, *O. v. macrourus*, or *O. v. virginianus*, 30 grouped with *borealis*; the remainder were classed as *O. v. macrourus*.

Thirty-two (54.2%) southern Illinois specimens (classed *a priori* as unknowns) grouped with Illinois skulls, primarily those from northwestern and westcentral Illinois. A large proportion were categorized as *O. v. borealis* (25.4%) or *O. v. macrourus* (18.6%); only 1 specimen grouped with *O. v. virginianus*.

A phenogram based upon standardized character means produced two primary groups, 1 including smaller specimens representing *O. v. virginianus*, as well as *O. v. macrourus* from Arkansas, the other containing the larger *O. v. borealis*, Illinois, and *O. v. macrourus* (Kansas and Missouri) specimens (Fig. 3b). Within the latter group, 2 secondary groups were distinguished, 1 comprised of samples from Missouri, Pennsylvania, and southern Illinois, the other consisting of the remaining regions. Samples from Missouri, Pennsylvania, and southern Illinois were intermediate in size between the 2 morphotypes for most characters (Levengood 1991).

DISCUSSION

According to Bergmann's Rule, homeotherms at higher latitudes should be larger than their counterparts at lower latitudes. The surface-to-volume law is most often invoked to explain this phenomenon. Larger animals have a smaller surface-to-volume ratio, and should therefore be more efficient at conserving heat. White-tailed deer are thought to exhibit clinal variation consistent with this biogeographic rule (Baker 1984). Based upon analysis of cranial characters, deer in Illinois displayed a general pattern of variation consistent with Bergmann's Rule, although a step between southcentral and southern portions of the state was apparent. According to Endler's (1972) ecotone model, abrupt environmental changes need not be large to produce steep clines in character gradients.

The degree of geographic differentiation would be increased by stronger selection pressures and decreased by stronger gene flow. Thus, deer could be subject to strongly divergent selection pressures in the face of apparent gene flow (e.g. across the Southern Till Plain - Shawnee Hills Divisions in southern Illinois).

The large degree of overlap and misclassification among *O. v. borealis* and the Illinois samples agrees with the original classification of *O. v. borealis*, which included all of Illinois (Hall 1981). Our results suggest that *O. v. borealis* and *O. v. virginianus* are morphologically distinct forms, and that deer from Illinois (including southern Illinois) are assignable to *O. v. borealis*. The large degree of overlap between *O. v. macrourus* and *O. v. borealis* was primarily due to the misclassification of a relatively large number (79% of misclassifications) of *O. v. macrourus* specimens as *O. v. borealis*. Further discussion of relationships among subspecies is beyond the scope of this paper.

In our phenetic analysis, Illinois specimens grouped with the larger *O. v. borealis* and *O. v. macrourus* (Kansas and Missouri) specimens, further substantiating our conclusions. Missouri, Pennsylvania, and southern Illinois formed a secondary cluster within that cluster comprised of the large morphotypes. The southern Illinois and southeastern Missouri sampling localities were geographically close. The Illinois and Missouri herds are separated by the Mississippi River, which provides a partial barrier to gene flow. While it is likely that some genetic interchange is occurring, these herds are also constrained by similar environmental conditions. This argument (parapatry) does not explain the relationship between deer from southern Illinois and southeastern Missouri and the Pennsylvania sample. Deer from these regions may to some extent share a common genetic background, because deer from Michigan were used in restocking programs in Illinois, Missouri, and Pennsylvania (Robb 1959; Pietsch 1954; W. Shope pers. commun.). The degree to which these introduced genes were swamped or lost through competition with better-adapted native stock remains unknown.

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Table 1. Univariate comparisons of adult female *Odocoileus virginianus* skulls from Illinois. Measurements are mean ± S.D. in millimeters. Like superscripts denote means not different by Rukey/Kramer multiple comparisons test ($\underline{P} < 0.01$).

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Fig. 1. Maps depicting currently accepted ranges of *Odocoileus virginianus borealis*, *O. v. macrourus*, and *O. v. virginianus* (TOP; dots represent collection localities) and collection localities within Illinois (BOTTOM).

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Fig. 2. Latitudinal variation in palatal length (Paletlen) of *Odocoileus virginianus* skulls from 6 regions of Illinois.

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Fig. 3. Morphometric relationships among samples of *Odocoileus virginianus* from 16 localities within the eastern and midwestern United States: a (TOP) plot of canonical-variate scores based upon a series of 20 cranial measurements, and b (BOTTOM) phenogram of morphometric relationships based upon a cluster analysis (UPGMA) of standardized character means of 20 cranial characters.

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APPENDIX I
Specimens Examined

Collection localities, number of specimens, and acronyms of museums housing specimens.

ARKANSAS: Drew Co., 1 (CWRL); Pope Co., Holla Bend NWR, 12 (CWRL); Prairie Co., 3 (CWRL); Van Buren Co., 1 (CWRL); unknown (previous counties or Franklin Co.), 2 (CWRL). ILLINOIS: Adams Co., 16 (CWRL); Adams or Pike Co., 30 (CWRL); Alexander Co., Horseshoe Lake Conservation Area, 14 (CWRL), Horseshoe Lake Conservation Area or Crab Orchard National Wildlife Refuge (Williamson Co.), 4 (CWRL); Carroll Co., 11 (CWRL), Carroll or JoDaviess Co., 4 (CWRL); Carroll, Jo Daviess, or Whiteside Co., 37 (CWRL); Dewitt Co., 3 (CWRL); Effingham Co., 19 (CWRL); Jefferson Co., 8 (CWRL); Jo Daviess Co., 10 (CWRL); Livingston Co., 4 (CWRL); Livingston, McLean, or Piatt Co., 11 (CWRL); McLean Co., 6 (CWRL); Piatt Co., 2 (CWRL); Pike Co., 25 (CWRL); Washington Co., 12 (CWRL); Williamson Co., Crab Orchard NWR, 56 (CWRL). KANSAS: Douglas Co., 1 (KU); Douglas, Jefferson, or Leavenworth Co., 24 (CWRL); Johnson Co., 1 (KU); Leavenworth Co., 3 (KU). MAINE: Androscoggin Co., 1 (CWRL); Kennebec Co., 2 (CWRL), Oaklawn, 1 (CWRL); Knox Co., Appleton, 1 (CWRL); Penobscot Co., Orono, 1 (CWRL); Somerset Co., 1 (CWRL); Waldo Co., 2 (CWRL), Belfast, 1 (CWRL), Brooks, 1; York Co., 3 (CWRL); southern Maine, 3 (CWRL). MICHIGAN: Clinton, Ingham, or Shawassee Co., 24 (CWRL); Livingston Co., George Reserve, 6 (UMMZ). MINNESOTA: Cook, Itasca, Lake, St. Louis C., 34 (CWRL). MISSOURI: Cape Girardeau Co., 27 (CWRL). PENNSYLVANIA: Westmorland Co., 9 (CMNH), Rachelwood Wildlife Research Preserve, 17 (CWRL). SOUTH CAROLINA: Aiken/Barnwell Cos., Savannah River Plant, 17 (CWRL). TENNESSEE: Carroll/Henderson Cos., Natchez Trace WMA, 1 (MSUMZ); Fayette/Hardeman Cos., Ames Plantation, 2 (MSUMZ); Hardeman Co., 3 (MSUMZ); Haywood Co., 1 (MSUMZ), Hatchie NWR, 11 (MSUMZ); Henderson Co., 1 (MSUMZ); Shelby Co., Shelby Forest WMA, 4 (MSUMZ). VIRGINIA: Allegheny Co., 1 (USNM); Bath Co., 1 (USNM); New Kent Co., 1 (USNM); Richmond Co., 1 (USNM); Shenandoah National Park, 1 (USNM).