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Methods of Determining Sex and Body Size in Prehistoric Samples of White-tailed Deer (*Odocoileus virginianus*)

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ABSTRACT

Modern samples of *Odocoileus virginianus* are used to determine (1) sex and (2) size of prehistoric conspecifics. A special combination of standardization of measurements and discriminant function analysis is proposed and evaluated. An example, distal ends of tibias from the Brown Site (23VE3), Vernon County, Missouri, is used to illustrate the procedures.

INTRODUCTION

Knowledge of the sex, biological age, and body size represented by bones of white-tailed deer (*Odocoileus virginianus*) recovered from prehistoric sites is important for reconstructions of paleoecology and aboriginal subsistence practices. Many bones from mature individuals can be distinguished from those of immature animals by the extent of epiphyseal fusion (Purdue, 1983). The determination of sex is not as easily evaluated since only the frontal and pelvic bones have qualitative differences (Edwards et al., 1982). White-tailed deer are sexually dimorphic in body size and, thus, the bones also differ in size. However, quantification of bone size is complicated by overlap between males and females and by clinal variation of deer from different geographic and temporal settings (e.g., Richie, 1970). Methods are presented in this paper that determine sex and estimate mean size of individuals in a sample of deer from a particular geographic and temporal setting. The practicability of the methods is demonstrated on a sample of zooarchaeological data.

EXAMPLE DATA

The transverse diameter (width) and anterior-posterior diameter (depth) of the distal ends of tibias were measured for samples of modern deer from Jo Daviess

County, Illinois, 15 counties in central Illinois, and the Savannah River Plant, Aiken and Barnwell counties, South Carolina. The modern samples of tibias were collected from deer either killed by vehicles or brought to hunter check-stations. An enzyme cleaner (Biz) was used to remove the soft tissue. Tibias from an archaeological context, the Brown Site (23VE3), Vernon County, Missouri, were also measured. The Brown Site was occupied by the Great Osage Division of the Osage Tribe from the late 1600's to about 1774 AD (Chapman, 1974). The tibias from all of the deer samples had ossifying or ossified epiphyseal sutures and, consequently, were of adult proportions (Purdue, 1983).

DETERMINATION OF SEX

Three options will be shown for determining sex as indicated by a set of measurements on a bone. All options are variations of two basic statistical techniques, standardization with z-scores and discriminant function analysis (DFA). The z-score (z),

$$z = \frac{x_i - \bar{x}}{s} ,$$

indicates the number of standard deviation units a measurement (x_i) is from the mean ($\bar{x}$) when $\bar{x}$ is set at 0.0 and the standard deviation (s) at 1.0.

The z-scores are entered as variables in DFA, a multivariate procedure which uses the reference specimens, e.g., the modern samples of deer, to develop criteria for determining the sex for individuals in a prehistoric sample (see Cooley and Lohnes, 1971, and Davis, 1973, for general discussions of DFA). DFA is also used to reclassify the individuals in the reference samples so that the degree of morphological overlap between sex classes can be determined.

Option 1. A normal statistical procedure for the determination of sex is to use the mean and standard deviation for the entire sample to standardize and enter the data into DFA. The flaw in this arrangement is that when there are systematic differences in body size between localities, as evidenced by white-tailed deer, then deleterious systematic trends in sex assignment by DFA are introduced (Table 1). Males from small-sized populations, e.g., South Carolina, and large females, e.g., Illinois, are poorly discriminated. Clinal variation is the basis of the problem because males from some localities are the size of females at others and the resulting z-scores are an uncomfortable mix of sex and clinal effects. The classification results are identical to those produced by no standardization.

Option 2. Another method is to independently analyze each sample. This involves computing a mean and standard deviation for each sample before standardizing and then performing DFA on each separate sample. The maximum amount of separation between the sexes is produced for each sample and systematic differences in body size between localities no longer are an issue (Table 1). Unfortunately, the prehistoric samples can no longer be analyzed for sex because there is no appropriate reference group.

Option 3. The final option is a hybrid of the first two. Each sample, using its respective mean and standard deviation, is standardized independently of the others. The males, which in each sample tend to have larger measurements, have positive z-scores and the females, which are smaller, have negative values. The z-scores of all individuals are then analyzed simultaneously with DFA. The results indicate that the systematic problems apparent in Option 1 are resolved and that the sexes can be separated with near the efficiency of Option 2 (Table 1). The critical factor in the procedure is that both sexes are represented in each sample. Ideally, the sex ratio should be 1:1. Various degrees of departure from this ratio were investigated and, fortunately, the ratio can deviate considerably (approximately ± 30%) from the ideal and still produce satisfactory results (Fig. 1). Although not done here, an independent test of the sex ratio is to note the number of each sex represented by the pelvic and frontal bones. Unfortunately both elements tend to be fragmented in archaeological sites and the frontal, in particular, may be biased for males because of the presence of antler which was often used for tools. Overall, Option 3 appears to be the best method for determining sex and it will be utilized in the next section.

ESTIMATING MEAN SIZE OF AN UNKNOWN SAMPLE

Even using the optimal technique there is overlap in the size of the sexes of deer and DFA is unable to distinguish sex correctly all the time (Table 1). Results of DFA on the modern samples can be used to "correct" for the effects of the misclassifications in the unknown or zooarchaeological sample. Descriptive statistics, i.e., mean and standard deviation, are calculated for the known or modern samples, thus producing a set of actual values, i.e., values that estimate the parameters of the population with morphological overlap of the sexes. A set of apparent descriptive statistics is also calculated for the known samples by reassigning those individuals that DFA placed in the wrong sex. The apparent set of values is directly comparable with the descriptive statistics for the unknown sample sexed by DFA. Further, the means of the unknown sample can be altered for comparison with the actual means of known deer by the following correction:

$$\bar{x}_u = \bar{x}_a \left(\frac{1}{g} \sum_{1}^{g} \frac{\bar{r}_i}{\bar{a}_i} \right)$$

where $\bar{x}_u$ = the corrected mean of one sex for the unknown sample, $\bar{x}_a$ = the apparent mean of the same sex for the unknown sample, $\bar{r}_i$ = the actual mean of the same sex for the i'th known sample, $\bar{a}_i$ = the apparent mean of the same sex for the i'th known sample, and g = the number of known samples. The correction factor is the proportion of actual to apparent values averaged over the number of known samples.

There are several characteristics worthy of note in the example of the application of the method (Table 2). The differences between the actual and apparent values are slight, ranging from near 0 to approximately 2%. The apparent means for the males are slightly larger relative to the actual values and the reverse is true for the females. The apparent standard deviations for both sexes are smaller then the actual values. These effects are the result of the small males being classified by DFA as females and large females as males. Therefore, apparent sex groups are more homogeneous resulting in lower variance measures. In general, the individuals that are reclassified by DFA are the small males and the large females that are close to the same size and the descriptive statistics generated from actual and apparent data approximate each other.

DISCUSSION

The special application of data standardization described here yields an estimate of the sex ratio of a sample of prehistoric deer. Under normal circumstances, the larger the unknown sample size, the greater is the probability that the critical factor, i.e., both sexes are present, is satisfied. However, because of the possible vagarities of the actual prehistoric sex ratio as well as the inherent overlap in size of the sexes, the sex ratio produced by these statistical procedures for a sample should be considered tentative. In contrast, the estimate of mean size is more robust since individuals misassigned by sex approximate each other in bone measurements and produce a compensating effect when descriptive statistics are calculated. The estimates of mean size can be used for further statistical procedures, such as projection of body weight by regression analysis and comparison to other samples by principal component analysis. While the methods presented here are specifically designed for application to white-tailed deer, they could obviously be applied to other species where sexual dimorphism is present.

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Table 1. Classification by sex of white-tailed deer (*Odocoileus virginianus*) from three localities using Discriminant Function Analysis (SPSS; MAHAL option; prior probabilities set equal to the proportions of males and females in the sample; Klecka, 1975) on 2 measurements on the distal end of the tibia.

		Percent Classified					
		Male			Female		
Location[a]	Option[b]	n	MasM[c]	MasF	n	FasF	FasM
JD	1	23	91.3	8.7	39	71.8	28.2
	2	23	78.3	21.7	39	89.7	10.3
	3	23	78.3	21.7	39	89.7	10.3
CI	1	14	85.7	14.3	20	70.0	30.0
	2	14	71.4	28.6	20	80.0	20.0
	3	14	57.1	42.7	20	90.0	10.0
SC	1	26	19.2	80.8	31	100.0	0.0
	2	26	65.4	34.6	31	93.5	6.5
	3	26	73.1	26.9	31	87.1	12.9

[a]JD = Jo Daviess Co., Illinois; CI = central Illinois; SC = South Carolina.
[b]1 = pooled standardization and Discriminant Function Analysis (DFA), 2 = independent standardization and DFA, and 3 = independent standardization and pooled DFA (see text).
[c]MasM = % males as males, MasF = % males as females, FasF = % females as females, FasM = % females as males.

Table 2. Size in mm of the distal end of the tibia of *Odocoileus virginianus* from Jo Daviess County (JD), Illinois, central Illinois (CI), Savannah River Plant, South Carolina (SC), and Brown Site (23VE3) (BR), Missouri. Standard deviations and sample sizes are enclosed in parenthesis. See text for definitions of actual and apparent measurements.

		Actual		Apparent	
Locality	Sex	Width	Depth	Width	Depth
JD	M	39.67 (1.20,23)	28.68 (1.23,23)	39.96 (0.92,22)	28.84 (1.07,22)
	F	36.74 (1.18,39)	26.43 (1.00,39)	36.65 (0.96,40)	26.40 (0.96,40)
CI	M	38.97 (1.99,14)	28.44 (1.75,14)	39.42 (1.43,14)	28.71 (1.46,14)
	F	36.42 (1.24,20)	26.14 (1.09,20)	36.11 (0.96,20)	25.96 (0.91,20)
SC	M	35.18 (1.56,26)	25.78 (1.21,26)	36.03 (0.97,19)	26.28 (0.95,19)
	F	32.95 (1.11,31)	24.01 (0.96,31)	32.94 (0.90,38)	24.09 (0.92,38)
BR	M	37.66[a]	27.63	38.20 (1.18,51)	27.95 (0.92,51)
	F	35.62	25.91	35.49 (1.07,72)	25.87 (0.88,72)

[a]Corrected values (see text).

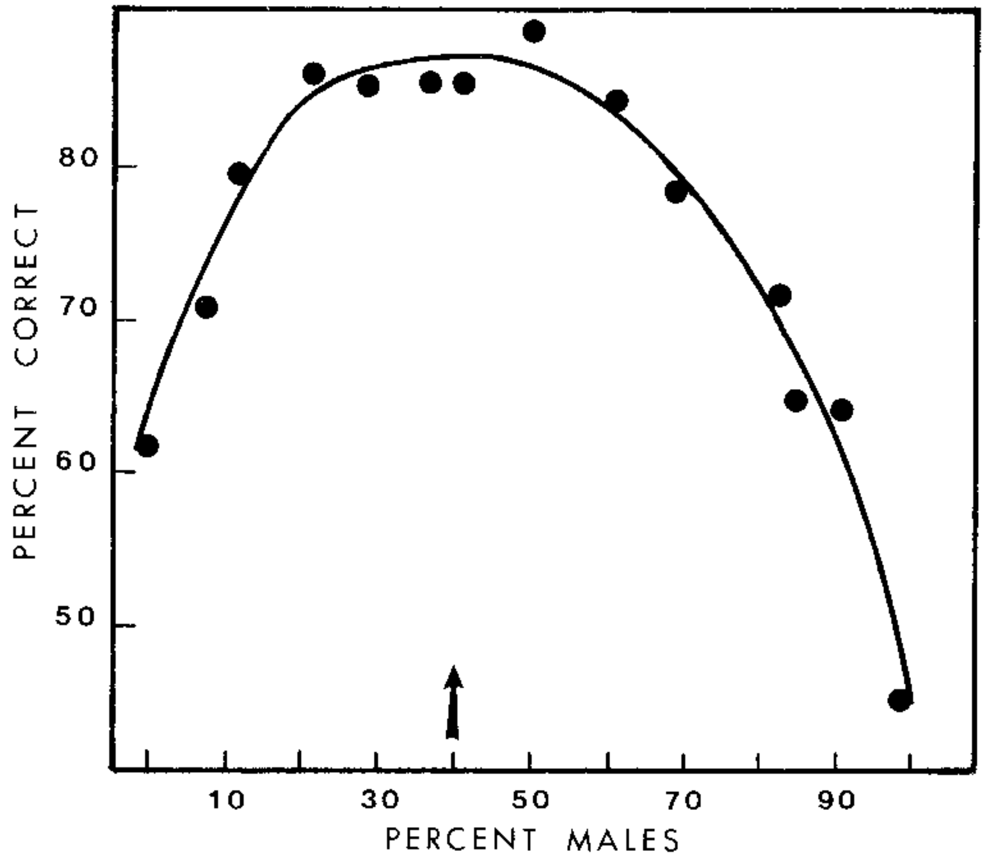

Fig. 1. Effect of the sex ratio on classification using Option 3 statistical procedures (see text). Measurements of distal ends of tibias of deer from Jo Daviess County, Illinois, were treated as if they were from an archaeological site. The sex ratio was varied by random deletion and addition of specimens for 14 trial runs. Z-scores were recalculated for each run. The reference sample was comprised of deer from three localities: Jo Daviess County, central Illinois, and South Carolina. The curve is drawn by hand.