ON ASSIGNING GENDER TO POST-CRANIAL BISON BONES

by

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ABSTRACT

Gender of prey is increasingly recognized as an important factor in the hunting and processing decision-making of prehistoric hunters (Frison 1978a, Peterson and Hughes 1980, Speth 1983). Speth (1983) particularly stresses this point in reference to prehistoric North American plains bison hunters. Recognition of the possible importance of prey gender to plains bison hunters makes the accurate assignment of gender to archaeologically obtained bison bones vital to the interpretation of plains archaeological sites. In the present study, dissatisfaction is expressed with the implicit theoretical and statistical assumptions underlying gender assigning methods developed in the past (Duffield 1973, Bedord 1974, 1978, Peterson and Hughes 1980). Reservations are particularly expressed about the use of complete single elements and the use of ratio-based indices prevalent in these methodological approaches.

In an effort to improve upon previous methods, a sample of contemporary, known gender bison bone was analayzed using a series of discriminant function analyses. These analyses were carried out on the proximal and distal ends of six major post-cranial elements: the humerus, radius, metacarpal, femur, tibia, and metatarsal. It was found that each end of each element could be assigned gender with an accuracy rate of at least ninety percent in the contemporary known gender bison sample.

The uniformitarian assumption that variables which can be used successfully to assign gender to contemporary bison elements can also be used to assign gender to prehistoric bison elements was made. A series of twenty-nine equations based upon this assumption has been derived from the discriminant function analyses of contemporary bison. Each equation is specific to a given end of a given bone and can be used to assign gender to that element part. At least two equations using different combinations of variables have been produced for most element ends. This avoids the requirement of other methods that a specific set of measurable variables be present on archaeologically recovered material to permit analysis. Users of these equations are warned that changes in bison populations through time limits application to material less than six thousand years old.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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CHAPTER I

INTRODUCTION

The most cursory examination of the North American archaeological literature reveals that people on the northern plains specialized (to a greater or lesser extent) in the communal hunting of bison for about ten thousand years. Indeed, the quantity of bone produced through this specialization was so great that it could be mined economically (Davis 1978). Because bison were an important part of the lives of prehistoric northern plains peoples, detailed study of the relationship between the two is an important part of the development of an understanding of cultural dynamics on the northern plains. This paper will focus upon a single aspect of that relationship -- gender of bison killed and consumed. In particular, the role of method in assigning gender to archaeologically recovered bison bones will be examined and an improved methodology will be suggested.

Gender

Gender is an important demographic feature of any hunted population and can form the basis of hunting and consumption strategies of hunters (Wilkinson 1976). Speth (1983) conducted an extensive search of historical sources and concluded that historic North American plains "hunter-gatherers exercised considerable selectivity in hunting bison of a particular sex" (1983:1). This historic behaviour pattern is held to be similar to prehistoric strategies. Speth and Spielmann (1983) find that in situations where lean meat becomes the principal source of energy, severe nutritional problems can occur. The addition of fat to the diet serves to alleviate these problems. Using Binford's (1978) modified general utility index as a guide to assign nutritional value to various bison elements recovered from an archaeological site in New Mexico, Speth (1983:100) finds that:

> hunters evaluate the utility of an anatomical part not only with respect to other parts in the carcasses of the same sex, but also with respect to the same part in the carcasses of the other sex. (emphasized in the original).

For bison hunters, this evaluation appears to have been based upon seasonal differences in the relative nutritional utility of cows and bulls. For example:

> cows were commonly avoided in the spring when their condition was poorest but became prime targets in the fall and early winter as they built up reserves of fat to carry them through the winter. Males, on the other hand, were preferred in the late spring and early summer, when they were in better condition than the cows, but were avoided during and after the rut when they were often in poorer shape . . . (Speth 1983:2).

Frison (1978a), however, suggests that, for behavioural reasons, cow-calf herds were generally the target of choice of prehistoric northern plains groups. Peterson and Hughes (1980:175) alternatively suggest that aboriginal hunters "were not actively selecting for or against either sex." It is evident that such gender-based interpretations must rest upon strong methods of determining the sex of archaeologically recovered bison remains. This paper explores these methods and concentrates upon the development of statistical techniques for establishing the gender of post-cranial bison bones. This study is frankly exploratory and is an initial step in the development of methods which will permit an objective (Binford 1983:48) and empirically based answer to the question of the importance of prey gender in the decision making of prehistoric northern plains groups.

Scientific Methodology

There has been little or no attempt in the past to answer this question using methods explicitly designed to link an interpretive framework with the archaeological record. The implicit assumption appears to be that if the "facts" of gender are established, they will speak for themselves. Unfortunately, as illustrated below, lack of explicit, consciously held interpretive frameworks has weakened the development of methodology and resulted in the development of questionable "facts".

Binford (1983:21) suggests that the aim of archaeology is the explanation of the order we observe in the archaeological record. In developing explanation of or, perhaps better, in assigning meaning to the archaeological record, Binford further suggests that all meaning comes from the interpreter, that the assignment of meaning to experience by the archaeologist is a cultural process. He notes that to

> point out continuously that data do not speak for themselves and that meanings assigned to archaeological observations may be wrong should not be surprising to anyone. Scientists particularly should appreciate that the scientific

> method was developed to cope with this problem . . . (Binford 1983:23).

This approach to archaeological investigation reflects an increasing recognition among scientists generally (see, for example, Kuhn 1962; Fleck 1979; Gould 1981; Greene 1981; Wagner 1981) that science itself is an ideology and that, as Binford suggests, all meaning comes from the investigator.

Because meaning is now held to be assigned rather than discovered, it is apparent that accounts of the process of developing any scientific methodology must include explicit descriptions of the underlying assumptions or interpretive framework (Binford 1983:184) held by the investigator. As indicated above, previous methodologies have tended to be based upon the notion that "facts" speak for themselves, thereby weakening the development of methodology.

Many attempts to evaluate gender and gender ratios of archaeologically recovered bison bones have, to date, often been based upon impressionistic criteria, whole elements, single elements, or statistical methods of less than maximum power (Duffield 1973; Bedord 1974, 1978; Speth 1983). The following criticisms of these methods should not be viewed as blanket condemnation of past work. These attempts at methodological development serve as a valuable starting point in the refinement of investigatory techniques. It is in this context of technical refinement that the following criticisms occur.

Existing Gender Analysis Methods

(1) Duffield (1973), for example, relies upon an impressionistic division of front and rear medial phalanges based upon the notion that rear medial phalanges are shaped like champagne corks and front ones are not. Clearly more explicit and replicable criteria are necessary. Whole phalanges thus distinguished are then subjected to a ratio form of statistical analysis to establish gender. Ratio analyses involve the use of a ratio between one or more variables as data rather than as products of analysis. The weaknesses in both whole element and ratio analyses are discussed below.

(2) Bedord (1978) also proposes a ratio based analysis of whole elements, in this case metapodials. Bedord's technique involves the bivariate plotting of the transverse width of the distal end of the metapodial against a ratio of the greatest length and the transverse width at the center of the shaft. A regression line is then drawn through the resulting distribution. Following this procedure, a second line is drawn perpendicular to the first at an arbitrarily chosen point between two well-defined clusters. The bones

above the second line represent males and those below represent females (Bedord 1978:43). The major problem associated with the development of gender distinguishing criteria based upon whole element ratios concerns the fact that many bison bones recovered archaeologically were subjected to varying degrees of processing. There are relatively few whole elements available. This factor introduces at least two possible forms of bias. The first involves sample size. Archaeological collections are, *a priori*, limited by problems of differential deposition and preservation and by the extent of excavation of a site. Any effort to overcome these problems must involve an attempt to use as much of the collection as possible. By concentrating upon whole elements, an investigator would be using a very small portion of an already limited sample. A second form of bias involves the possibility of gender-based processing decisions made prehistorically. If, as Speth (1983) suggests, seasonal differences in the fat content in the marrow of the same elements of each gender led to gender-based processing decisions, then, by concentrating upon whole elements, an investigator could unknowingly describe only the gender of material rejected by the prehistoric people. Gender ratios of the hunted animals and the utilized animals would not be recoverable. The "facts" recovered by these methods can potentially be very misleading.

These problems are also evident in evaluations based upon single elements. The fat content of the marrow of the elements and therefore the value of the elements to the hunters can vary between genders (Speth 1983). If, for example, during the spring, male metapodials were of more value than those of females and were preferentially removed from a kill area for processing, a strong and misleading bias toward females would be inherent in any gender ratio based upon analysis of metapodials at a spring kill site.

A final criticism of Bedord's (1974; 1978) technique involves the combination of variables used. Three given variables must, *a priori*, be measurable on the elements in the sample. Cases with damage in the vital areas are excluded from analysis. Bedord's technique lacks the flexibility which is necessary for a more thorough and more accurate analysis of archaeologically recovered bone. Ideally, any improved technique should offer this flexibility.

(3) Speth (1983) recognizes these problems and proposes an analysis of gender ratios based upon analysis of all major limb bones. He also suggests that any techniques developed to evaluate the gender of bison bone should be applicable to bone fragments rather than exclusively to whole elements. This permits a more complete and more

accurate analysis of available data and also reflects a concern with the necessary links between interpretive framework and method. The "facts" of gender are seen to be dependent upon the questions asked of the data and the need to develop techniques of analysis which are explicitly designed for the problems at hand is recognized. These are excellent proposals but, unfortunately, Speth's gender distinguishing techniques involve the simple plotting of one variable measurement against another and assigning gender on the basis of the resulting clusters. This method joins those of Duffield (1973) and Bedord (1974, 1978) in providing for no statistical test of the gender designations and in being relatively helpless when confronted with poorly defined clusters or single gender samples. He does, however, avoid the problems associated with the use of ratio based indices.

A major problem with ratio based statistical discrimination of faunal material is the fact that this procedure does not deal with actual attributes of the bones. The ratios are derived artifacts. Pimental (1978:36) points out that derived variables have several disadvantages including the facts that "since errors of measurement are compounded, indices are less precise than single measurement variables" and "indices obscure relationships between the component variables."

Blackith and Reyment (1971:27) also object to the use of ratios:

> In fact the use of ratios implies certain prior knowledge about the material under examination which, if set out explicitly, would almost certainly be denied by any experienced worker in the field. The weaknesses of ratios include:
>
> (1) The fact that a ratio will not be constant for organisms of the same species unless these are also of the same size by virtue of the almost universal occurrence of allometric growth.
>
> (2) As generally used, ratios contain only two characters and thus afford a poor appreciation of what may turn out to be an involved contrast between two forms.
>
> (3) To compound two characters into a ratio implies that there is only one contrast of form to be studied, and that that unique contrast is well assessed in terms of two characters of equal weights, but opposite in sign.

While derived data cannot be universally condemned, they should not be used in place of available primary data. Existing statistical techniques permit the comparison of primary data. These stronger techniques, which give greater assurance of the validity and accuracy of results should be utilized whenever appropriate. Discriminant function analysis is one such technique.

Discriminant function analysis involves the consideration of similarities and differences between two or more groups using groups of single measurements. In the case under consideration the groups are male and female bison. Pimental (1978) suggests that, unlike other statistical techniques such as multiple regression and multiple correlation, discriminant function analysis does not require that variables be labelled as independent and dependent; all can be considered dependent. This factor allows two or more measurements, each varying among individuals, to be considered as a single set of variables which describes the form of a sample of individuals (Pimental 1978:1). Measurements are compared with each other simultaneously in a single test rather than in multiple tests required by more conventional statistics such as multiple regression and correlation. Thus, despite its more complex methodology, discriminant analysis actually simplifies the interpretation of biological data by greatly reducing the number of calculated statistics (Pimental 1978:1).

Use of discriminant function analysis in the present study rests ultimately upon the uniformitarian assumption that criteria which distinguish gender in contemporary bison bones will also distinguish gender in prehistoric bison. It is also assumed that Speth's (1983) arguments regarding the possibility that hunting and procurement strategies could be partially based upon the differing fat content of bones must be taken into account by any methodology designed to assign gender to archaeologically recovered bison bones. To accomplish this, fragmented bone must be analysed along with whole elements. As indicated above, a methodology which relies solely upon complete elements could well be depending only upon material which was rejected by prehistoric hunters.

Discriminant function analysis has been used successfully in zoological studies to discriminate gender groups within species (Blackith and Reyment 1971, Pimental 1978). This method has also been successfully applied to archaeological material to distinguish canid species (Walker and Frison 1982) and projectile point types (Knight and Keyser 1983).

Walker and Frison (1982) were interested in the status of canid remains recovered from several Wyoming archaeological sites. Discriminant function analyses were carried out to examine the relationships of these remains to a sample of modern wolves and a sample of prehistoric dogs. They conclude that the Wyoming canids were hybrids, related to both wolves and dogs but closer in appearance to dogs.

Knight and Keyser (1983) were interested in the relative dating of projectile points for which temporal information is not available, for example, surface collections. After running a discriminant function analysis on dated material they found they could successfully assign points to either the Archaic or Late Prehistoric periods.

Discriminant function analysis has also been successfully used to predict gender in complete bison metapodials (McCartney 1983). Results from the present study indicate that this form of analysis is also successful in discriminating between male and female fragmented postcranial elements.

CHAPTER II

METHODS AND MATERIALS

In using discriminant function analysis to establish gender distinguishing criteria which could be used to determine the gender of archaeologically recovered bison bones, the first problem to be resolved was the nature of the sample to be employed. The most popular method in use at present (Bedord's) relies upon the definition of variables on archaeological material (Bedord 1974, 1978).

A major problem is associated with such an approach. It involves forcing of analysis results from archaeological material into categories defined *a priori*, in this case, the two genders. If unknown gender material is used, no relationship between the categories and those suggested by the analysis can be objectively established. Causes of the variation in the unknown collection could be quite different from those posited by the preselected classification. Ideally, any attempt to classify unknown materials should rest upon the secure knowledge that the variables used actually do group materials into the desired categories. This assurance can only be established using a collection of known materials.

The problem of the applicability of measurements of variables measured on known materials to fragmentary unknowns is, of course, potentially serious and will be addressed in greater detail later. It was felt initially, however, that variables can be selected, at least in part, on the basis of their anticipated applicability to excavated materials. Experienced archaeologists are familiar with the material they can expect to recover. They can, to a certain extent, develop suitable methods of analysis prior to investigation. A primary requirement of these methods is the demonstration of their validity. For this reason, it was felt that any discriminant function analysis of gender of bison bones must first be conducted on known material to establish the validity of the variables and categories.

It was fortunate that a collection of known material was readily available. Speth (1983) appends lists of all the variables and measurements used to establish gender criteria for bison bones. His raw data are well suited to discriminant function analysis with variables specifically designed for the fragmentary remains expected in archaeological collections. They were used with little modification in the present study. The only changes made were the deletion of several measures which were difficult to reproduce and the elimination from analysis of duplicated cases (i. e., the use of only one element where Speth uses both the left and right elements from a single individual). Speth's variables were used in measuring material used to supplement Speth's sample. See Appendix A for a description of these variables.

It should be noted that one factor which must be controlled for is the age of the animals represented by the sample. As Bedord (1978:41) indicates, a young male bison can easily be the same size as a mature female. Only the remains of mature animals can be used effectively for purposes of assigning gender. Maturity is defined in the present study as the presence of completely fused epiphyses.

Speth established his criteria using a collection of approximately thirty known gender contemporary bison. The collection of cases is, however, the result of an amalgamation of several museum collections and does not represent a valid sample from a single population. Its representativeness may therefore be challenged. Unfortunately, written inquiries of other, more experienced practitioners in the field did not reveal the existence of better samples. It was decided, therefore, to use Speth's data as the basis for a discriminant function analysis of gender in bison bones. This data base was supplemented by such additional data as the author could collect on an *ad hoc* basis while conducting excavations during the 1984 field season.

In most instances this procedure resulted in the addition of four more cases to Speth's data. However, in a case of extremely good luck, a collection of metapodials from about one hundred and twenty known gender individuals from a single population turned up in the collections of the Archaeological Survey of Alberta. These individuals are from the Elk Island National Park, Alberta herd and were taken during a population reduction program during 1971 (Shackleton et al. 1975). The metapodial sample available for the study, while perhaps not a random sample, is, at least, larger than those available for other elements.

It was decided to proceed with discriminant function analysis of Speth's data and such supplementary material as was available on the grounds that one must work with available data. Such an approach may be criticized for ignoring requirements that a valid discriminant function analysis must, among other requirements, be conducted on a random sample from a well defined population (Pimental 1978:78). However, as Pimental (p. 78) notes, in most cases collections are not likely to be random samples and it is frequently impossible or impractical to define populations in much detail. He concludes that the "abundance of results repeated within an ever-growing framework of detail supports conventional sampling and various degrees of limiting population definitions." In this context, it should be noted that the present study is seen as an initial attempt to strengthen analytical and interpretive techniques of faunal analysis designed to fit eventually into an "ever-growing framework of detail" (Pimental 1978:78).

Discriminant function analysis of the available sample was conducted using the WILKS stepwise method of the SPSSX DISCRIMINANT procedure (SPSS Inc. 1983). This procedure selects the variables which minimize the overall Wilks' lambda and uses these variables to assign cases to groups defined a priori. One statistic which may be obtained using this procedure is a set of classification function coefficients or Fisher's linear discriminant functions. These functions may be used to form classification equations which can be used to classify unknown cases into defined groups. These equations take the general form

$$G_x = C_{x1}V_1 + C_{x2}V_2 + . . . + C_{xn}V_n + K$$

where G_x is the classification score for group x, C is a classification coefficient, K is a constant, and V is a variable. Because each case is classified into the group which produces the highest classification score, one must compute the score of each case in each group (SPSS Inc. 1983:640). In the present study, therefore, two equations must be applied to each case: one for the male group and one for the female. Appendix C contains a worked example of this procedure.

In the present study, stepwise analyses were carried out on each of the proximal and distal ends of six bison post-cranial skeletal elements: the humerus, radius, metacarpal, femur, tibia, and metatarsal. This procedure initially resulted in twelve separate sets of two classification equations which could be used to classify archaeologically obtained material. See Appendix A for a description of the variables used in these analyses.

The next step in the investigation involved examining the applicability of these equations to archaeological material. Reservations have been expressed above about the definition of variables on known material. The possibility that variables measured on known material could be absent on fragmented excavated material was noted. Direct application of the derived equations was therefore conducted on samples of archaeological material from three archaeological sites. It should be noted that severe time and financial constraints restricted the search for appropriate archaeological material. Once again the author was forced to rely upon collections which happened to be easily accessible from an archaeological base camp on the Saskatchewan River. The resulting sample is therefore small (some 170 elements) but does contain sufficient material to provide an initial idea of the presence or absence of the variables necessary to permit the application of the classification equations derived from the discriminant function analysis of known material.

The three sites from which the archaeological material was obtained are Head-Smashed-In in Alberta and Lake Midden and Gilmore in Saskatchewan. The Head-Smashed-In site was used continuously for communal bison killing through almost six thousand years (Reeves 1978, 1983) beginning with a Mummy Cave deposit radiocarbon dated at 3700 ± 100 B. C. and continuing to historic times with use by the Piegan up to almost 1800 A. D. A sample of 47 elements suitable for analysis was used from the Avonlea deposits (ca. A. D. 100 to A. D. 300 -- Reeves 1978:171) of the East Area of the kill site. Thirty-one elements were used from the 1983 collectons from the habitation or processing area below the kill area.

The Lake Midden site represents a Late Prehistoric occupation which has been radiocarbon dated at A. D. 1570 ± 100 (Walde 1983:13). Sixty-two elements were used from the survey samples collected to date. The Gilmore site material is also from a Late Prehistoric occupation which is in the initial stages of archaeological testing. This occupation has yet to be radiocarbon dated but is expected on typological grounds to date at post A. D. 1500. Thirty-three elements were available from this collection. It must be emphasized that the archaeological material used in this study is not considered to be an adequate sample for the study of prehistoric bison populations. The present study of these elements is designed solely to examine the applicability of the variables selected by the stepwise discriminant function analysis of known material and to help in the selection of other useful variables.

When the classification equations were applied to the available archaeological material, it was found that they were useful in the majority of cases. It was, however, often the case that variables selected *a priori* were not measureable on archaeological material. It was these cases which permitted exploitation of the strength and flexibility of discriminant function analysis. Nonconforming cases were grouped according to which variables *were* measureable and the resulting variable groups were measured on the known material. Direct discriminant function analyses (SPSS Inc. 1983:627) were then run on the new variable groups of known material to check their ability to discern gender correctly. These analyses resulted in new classification equations which could be used to classify the previously excluded cases. This procedure was repeated until all cases in the archaeological sample could be classified.

CHAPTER III

RESULTS

The results of the present study are very encouraging. A total of twenty-nine predictor equation sets has been produced, the least successful of which (Equation Two of the distal tibia) has a success rate of ninety per cent in the known sample. In all cases the chi-square probability that the discrimiant functions upon which the equations are based are derived from a single group centroid rather than the two required for successful discrimination is less than 0.01. The chi-square test conducted in the present study is Bartlett's approximation derived from Wilks' lambda.

These equations are listed, along with the appropriate statistical data, in Appendix B. An extended discussion of the derivation of each equation is unnecessary and would probably tax the patience of even the most dedicated statistician. The discussion will therefore be limited to two exemplifying cases, the proximal metacarpal and the proximal radius.

Proximal Metacarpal

The initial step-wise discriminant function analysis on the proximal metacarpal was carried out on a sample of one hundred and forty bones of known gender contemporary bison. The variables maximum width (A), maximum depth (B), and maximum breadth of the magnum articular surface (C) were entered at the beginning of the analysis. All three variables were retained in the analysis which resulted in the successful assignment of gender to 95.71% of the cases or 134 of 140. The single discriminant function used in this classification has an eigenvalue of 2.14140 and a canonical correlation of 0.8256332, both statistically highly significant values. See Appendix B for a discussion of the statistical significance of the discriminant functions derived during the present study.

Several other investigators became interested in the project at this stage. The equations derived for the metapodials were supplied to these investigators for application to archaeological material. A problem with the variables used surfaced as one result of this collaboration. Both Jack Brink (of the Archaeological Survey of Alberta) and Neil McKinnon (a graduate student with the Department of Archaeology, University of Calgary) found that replication of the C variable measurement on both the metacarpal and the metatarsal was uncertain at best. This variable has been defined above for the metacarpal and is defined as the maximum breadth of the cuneiform facet for the metatarsal. These variables were therefore dropped from the next analysis of known metapodials. Variables A and B (see Appendix A) were then subjected to a direct discriminant function analysis of both elements in the known sample. For the proximal metacarpal, this procedure resulted in the successful assignment of gender to 95.71% of 140 cases; the same result as the earlier step-wise analysis using three variables. The single discriminant function used in this classification has an eigenvalue of 2.09714 and a canonical correlation of 0.8228739. Both values are once again highly significant.

The equations resulting from this second analysis were sufficient to classify all but one of the archaeological test cases. Only the maximum width was measurable on this bone. A direct analysis of the known sample was therefore carried out using this variable alone. This analysis resulted once again in the successful assignment of gender to 95.71% of 140 cases. The discriminant function used in this classification has an eigenvalue of 1.94028 and a canonical correlation of 0.8123400 and again these values are highly significant.

A second problem noted as a result of collaboration with another investigator (Neil McKinnon) involves disagreement between the gender designated by the proximal and distal equations applied to the same archaeologically obtained element. This occurred in three of the ten cases where such a comparison was possible. Such a rate of disagreement is, of course, unacceptable and renders the use of the equations potentially unreliable. The source of this disagreement had to be found.

To find the source of disagreements between the gender designations of proximal and distal ends of the same bone in the available archaeological sample, a study of such disagreements in the known contemporary sample was undertaken. Only two of 138 possible comparisons showed disagreement. In both cases the bones involved are the remains of exceptionally small three year old males in which the proximal gender designations were incorrect and the distal assignments were correct. A sample of two is, of course, too small to form the basis of any firm conclusions.

Neil McKinnon noted a similar problem when he applied the equations derived from the present study to his own material and suggested that a relationship might exist between the absolute value of the difference between the results of the two gender-classifying equations and the probability of correct gender designation. To check this suggestion, the matrix materials derived from the analysis of the known contemporary proximal and distal metacarpals were used to classify the relevant archaeological material. This SPSSX Discriminant procedure established the probabilities of correct gender designation in the archaeological material. Use of this procedure allows the investigator to establish the probability of correct gender designation for each case in a sample. The investigator can then make a decision as to what level of probability is acceptable. Unfortunately, this procedure requires access to a computer and to the matrix materials generated by the present study. This factor may tend to render the methods proposed inaccessible to many practising archaeologists, particularly contract archaeologists.

In an effort to overcome this shortcoming, the probabilities obtained through the use of the known matrix materials were compared to the absolute values of the differences between the results of the gender-designating equations. It immediately became apparent that absolute values of differences in discriminant scores of less than 1.2 were associated with probabilities of 65% and less. This is an unacceptably low probability of success. Unfortunately, the number of incorrect designations is too low to allow a suggestion with any degree of statistical confidence of an absolute difference value at which gender designations should be automatically rejected. An obvious beginning is the 1.2 value. The next highest available absolute score difference is, however, 2.18. This value is associated with the strong probability of success of 0.8987. Obviously the probabilities rise rapidly after the 1.2 difference value but exactly how rapidly remains a question unanswerable given the available sample. Pending the results of more research a rejection value of 1.6 is arbitrarily suggested. This value may, perhaps, allow a relatively low probability of success but a higher rejection value would cause the rejection of too many correctly designated cases. For work in which the gender designation of individual cases is of vital importance the rejection value could be raised. In the more common population studies, however, raising the rejection value would result in an unnecessary and inaccurate loss of data.

Use of the equations given in Appendix B in conjunction with the suggested rejection value offers a high probability of correct gender designation. This procedure also puts a valid and reliable method of gender designation for bison within the reach of any archaeologist with a microcomputer, a hand calculator, or even just paper and pencil.

Proximal Radius

The procedures used to derive gender-designating equations for the proximal radius are the same as those used for the proximal metacarpal. The use of this element as an example is designed to illustrate the power and versatility of discriminant function analysis when applied to the problem of assigning gender to archaeologically recovered bison bones.

Following the initial step-wise analysis of the known sample, an examination of the usefulness of the derived pair of gender-designating equations was carried out on the available archaeological sample. These equations could be used on only nine of the twenty-six available cases. The variables which were available were then measured on the remaining cases. Cases which could not be assigned gender using the first equation set were assigned to shared variable groups. Direct discriminant function analyses were then run on the known sample using the variable groups required by the archaeological sample. This resulted in a total of six different equations which were needed to classify the archaeological sample completely. The least successful of these correctly classified 96.77% of the thirty-one available known cases. The discriminant function on which this gender-designating equation pair is based has an eigenvalue of 3.47957 and a canonical correlation of 0.881342. The other five equations all correctly classified 100% of the available known cases.

CHAPTER IV

DISCUSSION AND SUMMARY

Discussion

The equations developed in this paper are dependent upon the uniformitarian assumption that criteria which can be used to distinguish gender in contemporary bison can also be used to distinguish gender in archaeologically recovered bison bones. It is, however, well known that the *Bison* genus shows evidence of species change through time (see, for example, Guthrie 1970, Shackleton and Hills 1977, Wilson 1978). Because the equations derived during the present study use criteria developed from a *Bison bison bison* sample, it is not possible to justify automatic application of the equations to other species. Indeed, because the variables used in the present study were picked to reflect sexual dimorphism (i.e., size differences) between bison genders and because general body size decreased through time (Peterson and Hughes 1980), it is recognized that at some point females of the larger *Bison* species will enter the size range of contemporary male *Bison*, rendering any equations derived during the present study useless after some time level. The challenge, then, is to find that time level.

Peterson and Hughes (1980) investigate the phenomenon of bison size diminution using data derived from metapodials. They find that diminution ceased by about 4,500 B.P. (contra Wilson 1978) and that the greatest reduction in length and proximal and distal width occurred between 10,000 and 6,500 years ago. In the present study, data used by Peterson and Hughes (1980) supplemented by other data (see Appendix D) were used in an attempt to set a time level beyond which the gender-distinguishing equations should not be used. Analysis of these data largely confirms the conclusions of Peterson and Hughes. An examination of Figure One reveals a general decline through time of both maximum and minimum lengths of bison metacarpals. This decrease becomes abrupt at about 8,000 years B.P. and levels off at about 6,000 B.P. It appears likely that the equations derived during the present study can be applied with confidence to bison material less than six thousand years old.

To examine the usefulness of the equations with bison material over six thousand years old, an equation pair using maximum proximal width and maximum length of the metacarpal was created in a discriminant function analysis of the known

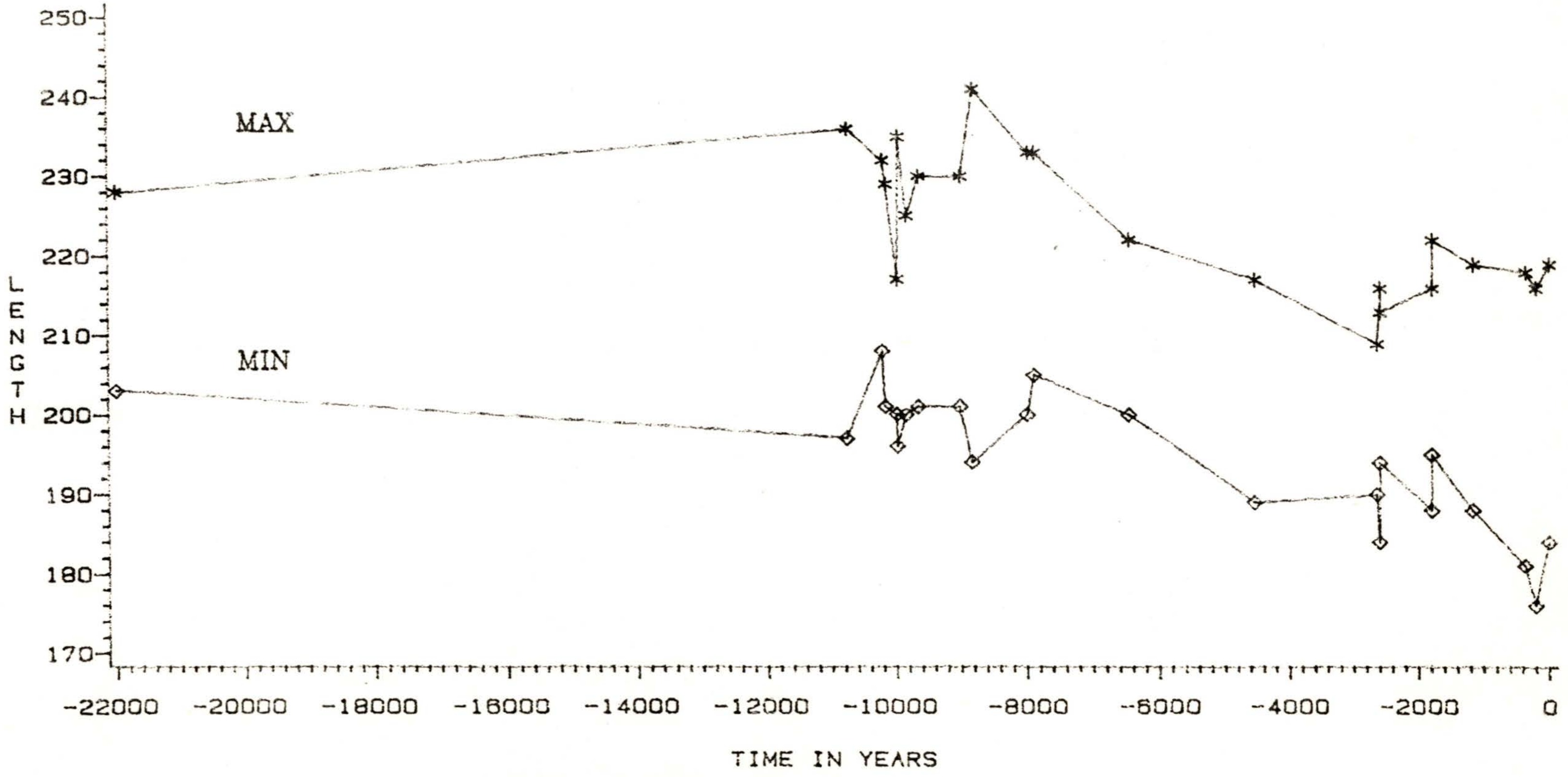

FIGURE 1. BISON METACARPAL DIMINUTION (AFTER PETERSON AND HUGHES 1980).

gender contemporary sample. These variables were chosen to allow comparison with other published data. This analysis assigned 94.74% of 114 cases to the correct gender group. The resulting discriminant function has an eigenvalue of 1.62047 and a canonical correlation of 0.7863768. The equation pair was applied to material from several archaeological and palaeontological sites ranging in age from about 2,600 to about 22,000 radiocarbon years B.P. (Lorrain 1968, Butler *et al*. 1971, Harington and Clulow 1973, Shackleton and Hills 1977, McCartney 1983). All material over 8,000 years old (n=101) was assigned to the male category. This is an unreasonable result simply on intuitive grounds. On a more analytic level, Harington and Clulow (1983:740-741) and Shackleton and Hills (1977:997) provide strong evidence in the form of bivariate scatterplots for the presence of female bison in the older bison samples.

It is clear that the formulae derived during the present study can not be applied to material over eight thousand years old with any reliability. Unfortunately, the author was unable to gain access to any material between six and eight thousand years old. Potential users of the present formulae are therefore urged to err on the side of caution and apply the equation sets only to material less than six thousand years old. The development of methods to sex the fragmented post-cranial remains of the older *Bison* (sub-?)species must await the collection of larger, reliably dated samples.

In an overview article Horton (1984) notes that estimating the number of animals represented by the bones recovered from archaeological sites continues to be a matter of some controversy. He concludes that no single method can be judged to be the overall best and suggests that the utility of a given methodology can be determined only within the context of the material to which it is applied. Minimum number, exact number, and original number of individual estimates are all seen as useful in different contexts. The latter two approaches require methods of pairing or rather demonstrating lack of pairing (Horton 1984:260) of skeletal elements to derive the data required for the various estimating formulae.

Although not designed explicitly for this purpose, the equations derived during the present study can be used as an additional method in the pairing operation with bison remains. The separation of male and female elements is an initial step in demonstrating lack of pairing.

It is noted in Chapter One that explicit description of the interpretive framework underlying any study is an integral part of the development of methodology. The theoretical approaches of Binford (1978, 1981) and Speth

(1983) have been cited previously as providing the interpretive framework for the development of the methodology proposed in the present study. One other aspect of the underlying interpretive framework remains to be discussed.

Dunnell and Dancey (1983:271) note that:

> Most sites in a traditional sense represent domestic or activity loci from which the exploitation of the surrounding environment took place. Using site to structure recovery limits data collection to a small fraction of the total area occupied by any past cultural system and systematically excludes nearly all direct evidence of the actual articulation between people and their environment.

In the context of the present study, it should be noted that a study of the faunal material in one site type may not necessarily reflect the decision making processes of prehistoric people. The faunal contents of a site may be said to reflect the final disposition of faunal resources within a given site area but they do not necessarily reflect the nature of the resources originally exploited. For example, the information that the majority of bison parts present in a fall residence site are female is important but does not imply a preference (seasonal or otherwise) for female bison. It could simply reflect an accumulation from a hunt or series of hunts which happened to encounter nursery herds. Wilkinson (1976) notes that the results of "random" hunting can often produce assemblages which give the appearance of the operation of gender influenced hunting strategies.

Site-specific gender analyses are almost certain to exclude at least some evidence of the "actual" articulation between people and their prey species. As with other archaeological methods, the site should no longer be considered to be the basic unit of investigation for analyses of the hunting and consumption strategies of past cultures. Instead the region must become the unit of investigation within which archaeological studies are pursued.

Summary

This paper explores the relationship between theory and the development of methods of assigning gender to archaeologically recovered post-cranial bison bones. Dissatisfaction is expressed with the implicit theoretical and statistical assumptions underlying methods developed in the past. It is suggested that these assumptions can no longer be justified and that additions to the body of theoretical and statistical knowledge must be considered.

Ideas presented by Binford (1978, 1981) and Speth (1983) are considered and form the theoretical base of an improved method of bison gender analysis. This improved method involves the use of discriminant function analysis of contemporary bison skeletal elements of known gender to produce equations which can be used to assign gender to fragmented bison bones. This form of analysis is shown to be very accurate and, because many different combinations of variables can be used, very versatile.

The demonstrated versatility of discriminant function analysis frees the investigator from methods which require the presence of a single, predetermined combination of measureable variables on archaeological materials. Any combination which has been verified on known material can be used. This versatility also allows investigators to define their own interpetive frameworks and problems. Methods such as those of Duffield (1973) and Bedord (1974, 1978) rely implicitly upon the assumption that the bison hunting and consumption strategies of prehistoric northern plains groups can be accurately reflected by the complete single elements which serve as the basic units of analysis. Use of these methods does not permit questions such as Speth's (1983) regarding seasonal differences in hunting and consumption strategies of communal bison hunters or those resulting from Binford's (1978) more general thoughts on possible differences in the general utility of various skeletal elements. These methods predetermine the investigator's interpretive framework and define the kinds of questions which can be asked. Such use of methodology has been referred to as the "Law of the Hammer" which states that "given a hammer, a young child will find that the world is poundable" (Moore and Keene 1983:4).

Moore and Keene (1983:4) go on to suggest that the

> image of the hammer provides a robust metaphor for much of contemporary archaeology. Methods are tools. They are developed for specific tasks to produce specific kinds of observations. But methods, like tools, can be abused. The most obvious form of abuse involves using methods not because they fit the task at hand, but because they are methods we know and can easily apply. The Law of the Hammer suggests that, although the methods we use are often appropriate to the task, too frequently a given method is used simply because it is the tool currently in hand. In these cases the pounding has produced more than a little noise, yet little anthropological

> understanding of prehistory has been constructed . . .

This type of use of methodology can no longer be justified. Method must be seen to be dependent upon and relevant to problems defined by theory (Leaf 1979:328) or "interpretive framework" (Binford 1983:320 and passim).

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APPENDIX A

DESCRIPTION OF VARIABLES

The following descriptions of the variables used in the equations derived during the present study are summarized from Speth (1983:172-180). They are included solely for the convenience of the reader. Investigators wishing to duplicate the measurements are urged to consult Speth's more complete descriptions.

Proximal Humerus

A - Depth of lateral tuberosity. (Depth is anterior to posterior).

B - Depth of caudal eminence of lateral tuberosity.

C - Greatest depth of proximal end.

D - Greatest breadth of proximal end.

E - Depth of head from cranial edge of articular surface.

F - Depth of head from anterior edge of medial tuberosity.

G - Length of cranial eminence of lateral tuberosity from distal edge of infraspinatus tendon.

H - Diagonal breadth of proximal end from cranial edge of medial tuberosity to prominent notch between head and caudal eminence of lateral tuberosity.

Distal Humerus

I - Greatest breadth of distal condyle.

J - Medial length of trochlea from bottom of shallow depression immediately caudal to proximal edge of articular surface of trochlea to bottom of shallow depression immediately caudal to distal edge of articular surface.

K - Greatest diagonal depth of medial epicondyle from bottom of shallow depression immediately caudal to proximal edge of articular surface of trochlea.

M - Breadth of distal condyle at proximal edge of articular surface.

N - Length of capitulum.

O - Length of lateral epicondyle from (and perpindicular to) distal edge of lateral epicondyle to proximal eminence of lateral epicondyloid crest.

Proximal Radius

A - Greatest breadth of proximal end.

B - Greatest depth of proximal end.

C - Depth of capitular articular surface.

D - Breadth between lateral and medial ulnar facets.

Distal Radius

G - Greatest breadth of distal end between points of lateral and medial epiphyseal fusion.

H - Medial length of distal epiphysis from distal extremity of carpal articular surface to proximal edge of prominant tuberosity for attachment of medial carpal ligament.

I - Greatest breadth of articular surfaces of intermediate and radial carpals.

J - Minimum breadth of radial carpal facet.

K - Greatest breadth of radial carpal facet.

Proximal Femur

A - Greatest breadth of proximal end.

B - Breadth of head and neck from lateral margin of fovea capitis to most lateral point of articular surface on proximal side of neck (edge of fusion line).

C - Greatest craniocaudal diameter of head.

D - Greatest craniocaudal depth of greater trochanter.

E - Minimum craniocaudal depth of neck.

Distal Femur

H - Greatest breadth of medial condyle.

I - Greatest breadth of distal end.

J - Greatest length of lateral condyle from bottom of shallow depression immediately cranial to proximal edge of articular surface to distal edge of articular surface.

K - Greatest medial depth of distal end from cranial surface of medial ridge of trochlea to caudal surface of medial condyle.

L - Greatest length of medial condyle from bottom of shallow depression immediately cranial to proximal edge of articular surface to distal edge of articular surface.

M - Greatest breadth of lateral condyle.

N - Greatest breadth of trochlea.

O - Minimum depth from cranial surface of medial ridge of trochlea to nearest point on caudal surface of the shaft.

Proximal Tibia

A - Greatest breadth of proximal end.

E - Breadth of medial condyle.

F - Breadth of lateral condyle.

Distal Tibia

H - Greatest breadth of distal end.

I - Greatest depth of distal end.

J - Greatest breadth of lateral and medial articular grooves.

Proximal Metapodial

A - Greatest breadth of proximal end.

B - Greatest depth of proximal end.

Distal Metapodial

D - Greatest breadth of distal end. Measured at line of epiphyseal fusion.

E - Breadth of medial condyle.

F - Breadth of lateral condyle.

I - Depth of medial sagittal ridge.

J - Depth of lateral sagittal ridge.

APPENDIX B

EQUATIONS DERIVED

Before proceeding to the list of equations derived during the present study a brief summary of the accompanying statistics is appropriate. It should be noted that the statistics which accompany each equation pair summarize the statistical significance of the discriminant functions from which the equations were derived. The first statistic listed is the eigenvalue. The size of the eigenvalue is related to the discriminating power of the function. It has been suggested (Christenson 1979; Walker and Frison 1982) that eigenvalues less than or equal to 1.0 possess little significant discriminating power. The reader will note that all the discriminant functions from which the gender predicting equations are derived possess eigenvalues greater than 1.0.

The canonical correlation coefficient is

> a measure of association which summarizes the degree of relatedness between the groups and the discriminant function. A value of zero denotes no

> relationship at all, while large numbers (always positive) represent increasing degrees of association with 1.0 being the maximum (Klecka 1980:36).

The canonical correlation coefficients derived during the present study all indicate a high degree of association.

Wilks' lambda determines the probability level for the null hypothesis of no group differences (Cooley and Lohnes 1971:12). Lambda is an inverse measure; therefore values of lambda near zero indicate high discrimination. Lambda scores near the maximum of 1.0 denote no group differences (Klecka 1980:39). All lambda scores listed below indicate high discrimination.

Lambda can more usefully be converted into a test of significance (Klecka 1980:40). In the present study, the significance of lambda is tested by converting it into an approximation of the chi-square distribution. A significance level of less than or equal to 0.05 is taken to suggest that it may be safely assumed that the results come from a population which did have differences between the gender groups. In all cases below, the gender group differences are significant before the derivation of the discriminant function.

Note that the equation label M denotes the equation for the male group and F denotes the female group equation.

Proximal Humerus

Equation One -- 100% of 31 known cases grouped correctly.

$$M = -9.677982(C) + 31.61367(D) + 35.38570(E) - 3.157891(F) + 30.15858(G) - 417.0617$$

$$F = -5.408166(C) + 22.42634(D) + 26.54183(E) + 1.530750(F) + 21.17843(G) - 272.9888$$

Eigenvalue = 8.16884 Canonical correlation = 0.9438935
After Function 0, Wilks' Lambda = 0.1090651, Chi-square = 56.503 with 5 degrees of freedom. Significance = 0.0000.

Equation Two -- 100% of 31 known cases grouped correctly.

$$M = -3.791409(C) + 24.01631(D) + 20.10080(E) + 21.24372(F) - 356.3185$$

$$F = -1.270970(C) + 17.18883(D) + 15.91181(E) + 18.76003(F) - 245.6565$$

Eigenvalue = 5.12904 Canonical correlation = 0.9147909
After Function 0, Wilks' Lambda = 0.1631577, Chi-square = 48.952 with 4 degrees of freedom. Significance = 0.0000

Distal Humerus

Equation One -- 96.55% of 29 known cases grouped correctly.

$$M = 31.25167(I) + 36.78960(K) - 7.269762(O) - 295.3420$$

$$F = 33.05248(I) + 33.05248(K) - 10.76356(O) - 215.2202$$

Eigenvalue = 3.66983 Canonical correlation = 0.8864872
After Function 0, Wilks' Lambda = 0.2141404, Chi-square = 39.299 with 3 degrees of freedom. Significance = 0.0000

Equation Two -- 96.55% of 29 known cases grouped correctly.

M = 28.79399(I) + 21.80006(M) + 42.90262(N) - 7.706758(O) - 295.3420

F = 25.00129(I) + 20.61446(M) + 37.35205(N) - 11.36661(O) - 214.8981

Eigenvalue = 3.63851 Canonical correlation = 0.8856711
After Function 0, Wilks' Lambda = 0.2155867, Chi-square = 38.360 with 4 degrees of freedom. Significance = 0.0000

Equation Three -- 96.88% of 32 known cases grouped correctly.

M = 13.94022(I) + 11.56050(J) + 28.73515(K) - 234.9319

F = 11.76021(I) + 10.37910(J) + 23.51349(K) - 164.7614

Eigenvalue = 2.86346 Canonical correlation = 0.8609091
After Function 0, Wilks' Lambda = 0.2588355, Chi-square = 38.520 with 3 degrees of freedom. Significance = 0.0000

Proximal Radius

Equation One -- 100% of 28 known cases grouped correctly.

M = 91.34896(B) + 31.32640(C) + 51.03718(D) - 442.1715

F = 83.74868(B) + 15.13232(C) + 44.06654(D) - 316.6830

Eigenvalue = 5.44795 Canonical correlation = 0.9191909
After Function 0, Wilks' Lambda = 0.1550880, Chi-square = 45.662 with 3 degrees of freedom. Significance = 0.0000

Equation Two -- 100% of 29 known cases grouped correctly.

M = 19.96907(A) + 93.12315(B) + 21.62989(C) - 386.8776

F = 18.55453(A) + 84.72096(B) + 4.506548(C) - 277.6151

Eigenvalue = 4.77143 Canonical correlation = 0.9092485
After Function 0, Wilks' Lambda = 0.1732672, Chi-square = 44.699 with 3 degrees of freedom. Significance = 0.0000

Equation Three -- 100% of 30 known cases grouped correctly.

M = 9.120694(A) + 69.06372(B) + 53.21497(D) - 378.5183

F = 6.684358(A) + 59.59075(B) + 46.14385(D) - 272.8552

Eigenvalue = 4.14892 Canonical correlation = 0.8976550
After Function 0, Wilks' Lambda = 0.1942154, Chi-square = 43.428 with 3 degrees of freedom. Significance = 0.0000

Equation Four -- 100% of 29 known cases grouped correctly.

M = 35.27990(A) + 69.74736(C) - 303.6013

F = 32.48393(A) + 48.28254(C) - 208.6884

Eigenvalue = 4.45974 Canonical correlation = 0.9037925
After Function 0, Wilks' Lambda = 0.1831590, Chi-square = 44.132 with 2 degrees of freedom. Significance = 0.0000

Equation Five -- 100% of 29 known cases grouped correctly.

M = 107.8611(B) + 47.06050(C) - 369.6882

F = 98.41492(B) + 28.13575(C) - 262.7748

Eigenvalue = 4.73178 Canonical correlation = 0.9085890
After Function 0, Wilks' Lambda = 0.1744660, Chi-square = 45.397 with 2 degrees of freedom. Significance = 0.0000

Equation Six -- 96.77% of 31 known cases grouped correctly.

M = 22.83487(A) + 75.22286(B) - 314.3558

F = 18.58567(A) + 65.07088(B) - 225.3341

Eigenvalue = 3.47957 Canonical correlation = 0.8813422
After Function 0, Wilks' Lambda = 0.2232359, Chi-square = 41.987 with 2 degrees of freedom. Significance = 0.0000

<u>Distal Radius</u>

Equation One -- 96.67% of 30 known cases grouped correctly.

M = 43.72442(G) - 1.527155(H) + 37.84848(K) - 270.2225

F = 37.02789(G) - 2.536615(H) + 21.42282(K) - 177.9612

Eigenvalue = 5.10137 Canonical correlation = 0.9143864
After Function 0, Wilks' Lambda = 0.1638975, Chi-square = 47.926 with 3 degrees of freedom. Significance = 0.0000

Equation Two -- 96.67% of 30 known cases grouped correctly.

M = 4.070459(H) + 79.21357(I) - 2.910456(J) - 0.4518446(K) - 216.1221

F = 7.571212(H) + 72.96668(I) - 7.635025(J) - 15.05775(K) - 145.2314

Eigenvalue = 4.25408 Canonical correlation = 0.8998176
After Function 0, Wilks' Lambda = 0.1903282, Chi-square = 43.134 with 4 degrees of freedom. Significance = 0.0000

Equation Three -- 100% of 30 known cases grouped correctly.

M = 37.11544(G) + 38.64219(I) + 3.414983(K) - 280.9385

F = 30.93407(G) + 38.48713(I) - 8.487367(K) - 188.4601

Eigenvalue = 4.85007 Canonical correlation = 0.9105413
After Function 0, Wilks' Lambda = 0.1709146, Chi-square = 46.815 with 3 degrees of freedom. Significance = 0.0000

Proximal Metacarpal

Equation One -- 95.71% of 140 known cases grouped correctly.

M = 51.83050(A) + 60.76415(B) - 325.1766

F = 44.31637(A) - 53.96473(B) - 245.4911

Eigenvalue = 2.09714 Canonical correlation = 0.8228739
After Function 0, Wilks' Lambda = 0.3228785, Chi-square = 154.88 with 2 degrees of freedom. Significance = 0.0

Equation Two -- 95.71% of 140 known cases grouped correctly.

M = 78.61195(A) - 291.5982

F = 68.10102(A) - 219.0070

Eigenvalue = 1.94028 Canoncial correlation = 0.8123400
After Function 0, Wilks' Lambda = 0.3401038, Chi-square = 148.29 with 1 degree of freedom. Significance = 0.0000.

Distal Metacarpal

Equation One -- 97.10% of 138 known cases grouped correctly.

$M = -43.29477(E) + 123.2426(F) + 155.6651(J) - 423.1247$

$F = -40.21917(E) + 101.9401(F) + 147.5251(J) - 337.0919$

Eigenvalue = 2.18197 Canonical correlation = 0.8280878
After Function 0, Wilks' Lambda = 0.3142706, Chi-square = 155.68 with 3 degrees of freedom. Significance = 0.0.

Equation Two -- 96.28% of 138 known cases grouped correctly.

$M = 37.03167(D) - 20.69326(E) + 112.5793(F) - 286.2210$

$F = 36.68809(D) - 18.99443(E) + 89.55291(F) - 216.8286$

Eigenvalue = 2.01211 Canonical correlation = 0.8173170
After Function 0, Wilks' Lambda = 0.331929, Chi-square = 148.31 with 3 degrees of freedom. Significance = 0.0000.

Equation Three -- 97.10% of 138 known cases grouped correctly.

$M = 25.59875(D) + 40.20182(F) + 141.2704(J) - 424.3431$

$F = 25.89654(D) + 21.71680(F) + 133.6313(J) - 340.5890$

Eigenvalue = 2.15660 Canonical correlation = 0.8265610
After Function 0, Wilks' Lambda = 0.3167969, Chi-square = 154.61 with 3 degrees of freedom. Significance = 0.0.

Proximal Femur

Equation One -- 100% of 31 known cases grouped correctly.

$M = 57.13058(A) + 12.61203(D) - 467.7439$

$F = 49.48881(A) + 9.070869(D) - 337.4001$

Eigenvalue = 5.13257 Canonical correlation = 0.9148422
After Function 0, Wilks' Lambda = 0.1630637, Chi-square = 50.781 with 2 degrees of freedom. Significance = 0.0000

Equation Two -- 100% of 32 known cases grouped correctly.

M = 52.14836(A) - 34.78090(B) + 42.02317(C) + 12.90860(E) - 393.7014

F = 42.41465(A) - 31.26783(B) + 44.91676(C) + 9.841088(E) - 294.0988

Eigenvalue = 4.00931 Canonical correlation = 0.8946351
After Function 0, Wilks' Lambda = 0.1996281, Chi-square = 45.116 with 4 degrees of freedom. Significance = 0.0000.

Distal Femur

Equation One -- 100% of 32 known cases grouped correctly.

M = 72.30969(I) - 43.24349(J) + 48.14870(N) - 432.2655

F = 62.35619(I) - 37.63656(J) + 40.37718(N) - 313.5030

Eigenvalue = 4.22738 Canonical correlation = 0.8992773
After Function 0, Wilks' Lambda = 0.1913003, Chi-square = 45.483 with 3 degrees of freedom. Significance = 0.0000

Equation Two -- 96.88% of 32 known cases grouped correctly.

M = 57.34540(K) + 24.32931(L) - 496.6706

F = 51.89116(K) + 17.80598(L) - 385.1042

Eignevalue = 3.23764 Canonical correlation = 0.8740821
After Function 0, Wilks' Lambda = 0.2359805, Chi-square = 41.876 with 2 degrees of freedom. Significance = 0.0000

Proximal Tibia

Equation One -- 100% of 31 known cases grouped correctly.

M = 98.57972(A) - 597.6180

F = 85.06322(A) - 445.1485

Eigenvalue = 4.93278 Canonical correlation = 0.9118361
After Function 0, Wilks' Lambda = 0.1685550, Chi-square = 45.403 with 1 degree of freedom. Significance = 0.0000

Distal Tibia

Equation One -- 96.67% of 30 knwon cases grouped correctly.

M = 51.72701(H) + 123.9436(J) - 524.9618

F = 44.89744(H) + 111.2860(J) - 412.9482

Eigenvalue = 3.03990 Canonical correlation = 0.8674498
After Function 0, Wilks' Lambda = 0.2475309, Chi-square = 37.698 with 2 degrees of freedom. Significance = 0.0000

Equation Two -- 90% of 30 known cases grouped correctly.

M = 70.46407(H) + 45.28692(I) - 393.1222

F = 60.77891(H) + 42.31711(I) - 308.5945

Eigenvalue = 2.34154 Canoncial correlation = 0.8371002
After Function 0, Wilks' Lambda = 0.2992632, Chi-square = 32.574 with 2 degrees of freedom. Significance = 0.0000

Proximal Metatarsal

Equation One -- 96.27% of 134 known cases grouped correctly.

M = 36.00557(A) + 75.22826(B) - 310.2521

F = 26.97551(A) + 71.58561(B) - 242.6477

Eigenvalue = 1.76447 Canonical correlation = 0.7989160
After Function 0 , Wilks' Lambda = 0.3617332, Chi-square = 133.21 with 2 degrees of freedom. Significance = 0.0000

Distal Metatarsal

Equation One -- 93.98% of 134 known cases grouped correctly.

M = 73.04380(D) + 28.15834(E) + 64.65266(F) - 378.4802

F = 68.80700(D) + 23.77840(E) + 50.50987(F) - 299.9102

Eigenvalue = 1.78366 Canonical correlation = 0.8004751
After Function 0, Wilks' Lambda = 0.3592396, Chi-square = 132.58 with 3 degrees of freedom. Significance = 0.0000.

Equation Two -- 93.98% of 134 known cases grouped correctly.

M = 5.082149(E) + 80.04562(F) + 123.0008(I) + 27.75796(J) - 415.5844

F = 2.819047(E) + 55.04459(F) + 108.9200(I) + 43.67631(J) - 342.7880

Eigenvalue = 1.81080 Canonical correlation = 0.8026389
After Function 0, Wilks' Lambda = 0.3557708, Chi-square = 133.32 with 4 degrees of freedom. Significance = 0.0000.

Equation Three -- 93.23% of 133 known cases grouped correctly.

M = 59.37705(D) + 112.7494(I) + 24.28190(J) - 455.5155

F = 50.10468(D) + 98.37936(I) + 33.25444(J) - 376.6443

Eigenvalue = 1.54117 Canoncial correlation = 0.7787685
After Function 0, Wilks' Lambda = 0.3935196, Chi-square = 120.77 with 3 degrees of freedom. Significance = 0.0000.

APPENDIX C

ANALYSIS OF GENDER: A WORKED EXAMPLE

The following example is provided to clarify the procedures to be used in applying the equations derived during the present study to archaeological material.

In a hypothetical excavation a number of distal metacarpals have been recovered. These bones are measured in centimetres and the results tabulated (see Table 1). An examination of the results indicates that Equation One for the distal metacarpal can be applied (see Appendix A). Application of the equation pair to each case results in each case being assigned a score for the male equation (GRP1) and the female equation (GRP2). These scores are listed in Table 2. In each case, the highest score results in the assignment of the bone to its gender. It will be noted that two cases (31741146 and 31751293) have differences in their scores of less that 1.6. These cases would be ignored in any further analysis of gender ratios in this sample.

TABLE 1

Original Data

CATNO	E	F	J
1.00	3.14	2.99	3.42
2.00	3.53	3.22	3.79
3.00	3.76	3.69	3.96
4.00	3.66	3.58	3.78
3205.00	3.74	3.46	3.86
3432.00	3.74	3.52	3.60
4405.00	3.33	3.02	3.44
10009.00	3.23	2.98	3.64
723738.0	3.16	2.83	3.41
3025229	3.06	2.93	3.38
3025534	3.66	3.55	3.72
3025626	3.07	2.90	3.35
3026834	3.31	2.99	3.68
31741146	3.13	3.10	3.50
31741164	3.72	3.41	3.71
31751293	3.63	3.23	3.58

TABLE 2

Results of Analysis

CATNO	GRP1	GRP2	GENDER *	DIF
1.00	341.80	345.96	2.00	-4.16
2.00	410.86	408.30	1.00	2.55
3.00	485.29	472.04	1.00	13.24
4.00	448.04	438.30	1.00	9.74
3205.00	442.24	434.65	1.00	7.59
3432.00	409.16	402.41	1.00	6.75
4405.00	340.38	344.32	2.00	-3.94
10009.00	370.92	373.77	2.00	-2.86
723738.0	319.66	327.37	2.00	-7.71
3025229	331.64	337.16	2.00	-5.51
3025534	435.00	426.39	1.00	8.62
3025626	322.84	329.27	2.00	-6.43
3026834	374.91	377.48	2.00	-2.56
31741146	368.24	369.37	2.00	-1.13
31741164	413.59	408.23	1.00	5.37
31751293	375.07	374.32	1.00	.75

* 1 = Male
2 = Female

APPENDIX D

FIGURE ONE REFERENCES

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04 April, 1985