THE FORMULATION AND APPLICATION OF A TECHNIQUE, BASED ON PHALANGES, FOR DISCRIMINATING THE SEX OF PLAINS BISON (*Bison bison bison*)

by

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ABSTRACT

This thesis develops a new technique for sexing plains bison (*Bison bison bison*) based on a large collection of front, first phalanges from known sex bison. It includes an evaluation of previous sexing techniques developed on Old World Artiodactyl phalanges and New World bison elements. It remedies the shortcomings of many other techniques which are not based on a large known sex sample. The new sexing technique is developed on the known sex plains bison population from Elk Island National Park, Alberta. The technique is tested on a known sex Museum collection of plains bison from several areas of Central North America. It is applied to bison remains from the Stott Site, an archaeological site near Brandon, Manitoba circa A.D. 800 to A.D. 1400.

The sexing technique utilizes a discriminant function analysis. Three measurements rounded to 0.1 millimeter are required per phalanx. The measurements are as follows: Length (L), Greatest Length (GL), and Distal Height (DH). Complete separation (100%) of male from female bison is demonstrated by the histogram of the discriminant function (GL X 0.52067) + (DH X 0.54678) - (L X 0.29469) with the separation area at slot 29.16 for the EINP and Museum

samples. A value below slot 29.16 indicates a female and above slot 29.16 indicates a male. When the value of the discriminant function is plotted in a bivariate fashion against either the L,GL or DH measurement a clear patterned separation is possible. This patterned separation becomes the important separating tool for prehistoric bison phalanges. The values of separation for the Stott Site are from slots 30.96 to 30.14.

It is concluded that the front first phalanges can be used to establish the sex of plains bison. The phalanges can be used to trace evolutionary changes and to calculate minimum numbers of bison. Sex ratios in turn may be used to determine hunting selection, weight of useable meat and seasonality in special instances at catastrophic kill sites.

The main importance of this thesis lies in the fact that it: a) explores a new area of research in North American studies b) demonstrates the formulation, testing and application of a new sexing technique based on known sex samples c) adds to the interpretation of archaeological sites.

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Chapter I

INTRODUCTION

An interest in North American bison skeletal material prompted a close evaluation of the proposed sexing techniques (Skinner and Kaisen 1947, Reher 1970; Bedord 1974, Shackleton, Hills and Hutton 1975; Miller and Brotherson 1979, Reher and Frison 1980, and Peterson and Hughes 1980). In each above study, except one by Shackleton *et al.* 1975), there has been no attempt to work from a skeletal reference collection of known sex. Because of the difficulty of locating sexed skeletal material in sufficient quantities most researchers have developed techniques based on the premise that for bison the largest animals are male and the smallest are female. These kinds of techniques cannot be relied on to distinguish the larger of the females from the smaller of the males with any assurance. The aim of this thesis is, therefore, to alleviate the problem of working with techniques developed from unsexed samples.

In this thesis, a sexing technique is developed on a large sample of known sex plains bison (*Bison bison bison*) front,first phalanges in order to distinguish male from female bison. The known sex sample is from Elk Island National Park, Alberta and consists of 121 bison. The technique is tested on a known sex bison sample gathered from major museums (N=26), and then applied to an archaeological sample of bison of an unknown sex composition from the Stott Site, Manitoba.

The rationale for choosing the front, first phalanges with closed epiphyses for this study is based on several major reasons: frequent recovery, expectation of workable results, reports of their relative evolutionary stability and an expected emphatic sexual dimorphism in the front limbs due to the weight differences between males and females.

Phalanges from a large animal like the bison are commonly recovered. Phalanges are sometimes broken but frequently large numbers of whole phalanges are reported at kill sites such as the Glenrock Buffalo Jump (Frison 1970:10), the Bonfire Shelter (Lorraine 1968:80-81) and the Gull Lake Site (Kehoe 1973:146,154). The phalanges were also chosen because a sexing technique was needed for the Stott Site. The analysis of the bison material from the Stott Site indicated the most numerous and repeatedly whole bones were the first and second phalanges. From literally thousands of bones, only a few other bones were found whole. Hamilton et al. (1980:109) stated of the part of the site he studied, "virtually every bone recovered from Zone F, with the exception of the phalanges, exhibit a high degree of smashing." Therefore, with the phalanges being the only whole and frequent bone, it was thought that a technique could be developed around them.

Inspiration to develop a technique to sex the phalanges, was gained from other authors who expected workable sexing results from the phalanges. For example, in some of the earliest work on European bison, Bojanus (1825) was "able to differentiate between the phalanges of the manus from those of the pes" (Roskosz and Empel 1965:180). Dottrens (1946) calculated a phalangeal ratio developed from a small sample of domestic cattle. Bosold (1968) attempted to sex several members of the Artiodactyl order based on measurements and indices from metapodials and phalanges. Empel and Roskosz (1963) calculated a front first phalangeal index to distinguish the sexes that was applicable to European bison aged 5+ years. Duffied (1973) proposed that indices on European samples be applied in the sexing of North American bison.

Even though long bones of bison continue to grow throughout the life of the animal, sexual differences can be expected. Work by Lasota and Kossakowski (1972:119) indicated that "processes of bone remodelling persist throughout the bison life". Wilson (1974:143) stated:

> The cross-sectional area of a long bone continues to adjust to the weight of the animal through the external deposition of periosteal bone tissues in thin layers, and the internal remodelling of the bone by osteoclast action.

These statements may at first suggest that the older adult females would become indistinguishable from the young adult males. However, a study by Kobrynczuk (1976:97-98) on the hind limbs of European bison indicated that the postnatal growth of the joints in males from birth to four years of age was more intense than for females of the same age. Because of the initial intense growth by males, even if growth continued for both sexes, it was expected that the sexes would be distinguishable.

As a further rationale for the use of phalanges, pedal elements apparently "change very slightly in bison evolution" (Guthrie 1980:55). According to Guthrie (1980:55), more rapid evolution is demonstrated by "...a complex of traits concerned with social behavior, including horn core shape and size, sinus cavities and frontal bone shape".

The front phalanges rather than the rear phalanges were chosen to increase the likelihood of accentuating the differences between males and females. It was expected that sexual dimorphism would be expressed in both the front and rear phalanges due to the fact that the male adult bison may weigh twice as much as the adult females (Banfield 1974:405). Sexual dimorphic differences were likely to be more greatly accentuated in the front feet than in the rear feet since the greater proportion of that weight in bison is carried in the shoulder area, over the front feet.

Therefore, the front phalanges, as an integral unit of the foot, were expected to demonstrate a clear male/female segregation.

The first phalanges were chosen for study over the second phalanges for two main reasons. Both the first and second phalanges were represented by approximately the same numbers in the Stott Site, so either seemed suitable for study. However in the literature, Empel and Roskosz (1963:293) found that the third phalanx was considered unsexable in European bison. From this information it was assumed that the distal end of the second phalanx which articulates with the proximal end of the third phalanx would less likely express marked sexual differences. Therefore the potential usefulness of the distal end of the second phalanx appeared doubtful. Since sexual dimorphic studies on metacarpals produced positive results (Higham 1969:64, Peterson and Hughes 1980:174) using the measurement of the distal width of the metacarpal which articulates with the proximal end of the first phalanx, there appeared to be a greater chance of finding a marked sexual difference in the first phalanx.

The other reason for choosing first phalanges came from the results of Hamilton's analysis (1977) of an unknown sex bison sample of the first and second phalanges. From his graphs it is apparent that the first phalanges separated into two groups more completely than did the second phalanges. It was expected that known sex groups would similarly separate.

Finally, only the phalanges with fused epiphyses were used in order to obtain precision in the measurements.

The purpose of pursuing a sexing technique for bison is that there is a demand for such techniques. The need for the creation of sexing techniques was pointed out by Johnson in a panel discussion.

> You say that you do not know what paleontologists want you to look at or even whether in fact they have looked at which particular bones need to be measured, and which bones relate to sex determination.... It is those of us who are doing it now, those who are zooarchaeologists, who will be able to tell you eventually which bones will give you the most significant data. But right now the possibility is just very much in the working stage, and we need more people who are interested in this problem (Davis 1978:294).

Knowing the sex of bison can aid in determining seasonality, hunting preference, calculation of minimum numbers of individuals and possibly estimation of meat yields.

Seasonality, as indicated by herd composition, is sometimes inferred at catastrophic kill sites. McHugh (1958:37) in a study of the social organization of bison describes bison as generally being divisable into two groups during the non-breeding season. The bull groups as he describes them are composed of between 1 - 12 male bison, most of which were four years and older. Infrequently they were accompanied by a barren female. Cow groups are described as follows.

> Cow groups contained a majority of females and a smaller number of males, mostly younger bulls. They averaged 23 members during the non-breeding season but increased in size during the rut, when many cow groups coalesced and were joined by bull groups. Cow groups during the non-breeding season were composed of cows, yearlings, calves, 2 year old bulls, some 3 year old bulls and rarely bulls four or more years old (McHugh 1958:37).

McHugh (1958:15,23) presented figures from several populations which suggest the statistical mean of the number of bulls integrating into the cow groups were as follows: 24% during the period from January to March, 17-31% in May and 44% during the rut (June-September). All figures were based on males two years and older. If a statistical mean of approximately 40% males and 60% females were found at a catastrophic kill site, one could infer a kill during the rutting season. Some archaeologists, using information such as herd composition and the ages of the younger bison, infer that the animals were taken in the fall, winter, spring or summer (Frison 1978:51).

The next most prominent application of a sexing technique is as an indication of hunting preference. If the animals were hunted individually, the archaeological sample would reflect a biased sampling by the hunters rather than reflecting the complete bison population as at a catastrophic kill. Knowing the sex of the animals could therefore establish whether or not there was a preference for female or male bison. Some accounts in the historic period suggest the more tender females were preferred to the older bulls (Allen 1876:192, Tanner 1956:63, Hurlburt 1977:30).

As there is a correlation between sex and weight in bison, knowing the sex of an individual could allow for a closer estimation of the total meat yield. Weights for dressed bison from Halloran (1957), could be used as a basis for calculation of the meat yield.

In this thesis the sexing technique has been applied to the Stott Site, Manitoba. The sex, the minimum numbers of bison and the prehistoric hunting patterns of the Native population are presented in the following text.

Chapter II

LITERATURE REVIEW

The literature review is intended to summarize the major work on measurements of Artiodactyl phalanges in Europe since the 19th century and to assess existing sexing techniques used on the North American plains bison. The study of phalanges has a much longer tradition in Europe than in North America. Therefore, it is hoped that a review of their measuring and sexing techniques may be useful in designing a technique applicable to the North American bison. Sexing techniques developed on plains bison skeletal elements such as skulls, mandibles, metapodials and phalanges are also presented. It will be demonstrated that the major shortcoming of much of the North American work is a lack of a known sex data base.

2.1 EUROPEAN SEXING TECHNIQUES APPLIED TO ARTIODACTYL PHALANGES

Research on the measurement of European Bovid first phalanges is included in the work of Bojanus (1825), Duerst (1930), Dottrens (1946), Empel and Roskosz (1963), Bosold (1968) and von den Driesch (1977). The discussion will be confined to measuring and sexing Artiodactyl first phalanges.

Bojanus (1825), in a major scientific paleontological work, attempted to substantiate differences between two undomesticated Bovinae, the European bison and the aurochs, an extinct species of wild ox, (Roskosz and Empel 1965:180). Three measurements were included in his work which applied to the front first phalanges. The descriptions did not include specific diagrams but were outlined as follows:

1. Longitudo ossis primae phalangis (Length of the first phalanx)
2. Crassitudo ciusdem medio corpore,ab anterioribus retrorsum (The anterior posterior width at the middle of the body)
3. Latitudo eirusdem,a medii corporis margine interno ad externum (The transverse width at the middle of the body) (Bojanus 1825:464, trans. mine).

Duerst (1930:492-497), in a handbook on biological methods, describes and illustrates 17 measurements to be taken on first phalanges. The measurements are titled as follows.

1. Laterale Länge (Lateral Length)
2. Innere Länge (Inner Length)
3. Sagittale Länge (Sagittal Length)
4. Grösste Breite des proximalen Endes (Largest Width Proximal End)
5. Breite des medialen Teiles der proximalen Gelenkflache (Width of Medial Portion of the Proximal Articular Facet)
6. Kleinste Breite der Diaphyse (Smallest Width of the Diaphysis)

7. Grösste distale Breite des Knochens (Largest Distal Width)

8. Grösste Breite der distalen Gelenkfläche (Largest Width of the Distal Articular Facet)

9. Breite des medialen Teiles der distalen Gelenkwalze (Width of the Medial Part of the Distal Articular Cylinder)

10. Grösste Durchmesser des proximalen Knochenendes (Largest Diameter of the Proximal End)

11. Grösste Durchmesser der anderen kleineren Halfte (Largest Diameter of the Smaller Half)

12. Durchmesser der Diaphyse an deren schmälster Stelle (Diameter of the Diaphysis at the Narrowest Point)

13. Kleinster Durchmesser der Diaphyse (Smallest Diameter of the Diaphysis)

14. Medialer Durchmesser der distalen Gelenkrolle (Medial Diameter of the Distal Articular Cylinder)

15. Lateraler Durchmesser der distalen Gelenkfläche (Lateral Diameter of the Distal Articular Facet)

16. Torsionswinkel der Phalangen (Torsion Angle of the Phalanges)

17. Fesselgelenkswinkel (Angle of the Fetlock) (Duerst 1930:492-497, trans. Muller).

Dottrens (1947), in his article describing the phalanges of the domestic cow (Bos taurus domesticus), included measurements to aid in distinguishing anterior from posterior phalanges, medial from lateral phalanges and male from female phalanges. His sample included two males and 11 females. For studying the first phalanges, Dottrens chose measurements 2,4,6,10,11,15 and 16 from Duerst (1926). He added four of his own measurements designated C,D,E, and F which are described below. For some reason, measurement C is very similar to E and measurement D is very similar to F.

C La largeur totale de la surface articulaire proximale (The total width of the proximal articular surface)

D Le diamètre antéro-postérieur de la cavité glénoide interne (The antero-posterior diameter of the internal glenoid cavity)

E La largeur de la surface articulaire proximale (The width of the proximal articular surface)

F Diamètre antéro-postérieur de la cavité glénoide interne (Antero-posterior diameter of the internal glenoid cavity) (Dottrens 1946:766-769,trans. mine).

To discern the differences between anterior and posterior first phalanges Dottrens uses two ratios: 4 divided by 2 and D divided by C. In distinguishing medial from lateral phalanges, the ratios of 11 divided by 10 and of F divided by E were chosen. To determine sexual differences between the anterior right lateral elements he employs the ratio of 4 divided by 2, where "2" is described as "hauteur" or "height" (1946:774). This description conflicts with his own description of his interpretation of measurement 2 from Duerst, where a brief translation would more likely be "inner length". Unfortunately, as diagrams are not included and the raw data are averaged in the results, it remains ambiguous whether or not the sexually distinguishing ratio is length divided by the width of the proximal end or the height divided by the width of the proximal end.

In a more recent study, Empel and Roskosz (1963) suggest measurements for the European bison (Bison bonasus) first phalanges as:

1. Grösste Länge (Greatest Length)
2. Grösste Breite des Proximalen Endes (Greatest width of the proximal end)
3. Grösste Breite des distalen Endes (Greatest width of the distal end)
4. Durchmesser des Proximalen Endes (Diameter of the proximal end)
5. Durchmesser des distalen Endes (Diameter of the distal end) (Empel and Roskosz 1963:264, trans. mine)

It is difficult to discern exactly how the measurements were taken. Of the total of 46 measurements for the itemized skeletal parts, only seven measurements are illustrated. Although one illustrated item is a first phalanx, the caption "Kleinster Durchmesser der Diaphyse, d.M." is not used in the tables describing phalanges measurements, but rather is used for the femur, tibia and metapodial measurements.

In a sample of 21 females and 21 males, Empel and Roskosz (1963:275) were able to distinguish only those males and females older than 5 years. They applied the equation: Largest Width of the Proximal End multiplied by 100 and divided by Greatest Length (1963:275). Results for cows aged 5+ years ranged from 47.4 - 50.0 and for the bulls aged 5+ years ranged from 50.7 to 54.7. They believed that the only bones which cannot be sexed are the os carpi intermedium, the calcaneus, the talus and the third front and rear phalanges. They claimed even with these bones, though substantiation is vague, that the larger bones are from the bulls. Although this generally holds true for all bones, the noted exception is the innominate which is larger in cows (Empel and Roskosz 1974:293).

Bosold (1968) studied metapodials and phalanges of a total of 243 known sex members of the Artiodactyl order including: the European red deer (Cervus elaphus), fallow deer (Dama dama), roe deer (Capreolus capreolus), chamois (Rupicapra rupicapra), and the alpine ibex (Capra ibex). In order to determine sex and genus differences, there are six measurements taken from first phalanges:

1. Grösste Länge der peripheren Halfte (Greatest length of the peripheral half)
2. Grösste Breite proximal (Greatest width of proximal end)
3. Grösste Breite distal (Greatest width of distal end)
4. Kleinste Breite der Diaphyse (Smallest width of diaphysis)
5. Tiefe proximal (Proximal depth)
6. Tiefe distal (Distal depth) (Bosold 1968:95-96, trans. Muller).

Each measurement has a brief description and diagrams are included that demonstrate the verbal description. From examining the first phalanx, Bosold created an index:

Kleinste Breite der Diaphyse multiplied by 100 and divided by Grosste Lange (Smallest width of diaphysis multiplied by 100 and divided by the Greatest Length). This index value was then plotted against the measurement Greatest Length. In his summary he claims that sexual differences of the metapodials and phalanges are demonstrated by the males being "longer and stronger" than those of the females (except for Capreolus) (Bosold 1968:114-115). However, only the graphs for the metapodials, in my opinion, give a clear presentation of such a distinction.

Von den Driesch (1963:97) recommends four measurements for the first phalanges of bovids and Sus. They are as follows:

1. GLpe Greatest length of the peripheral (abaxial) half. Most of the anterior first phalanges of Bos are formed in such a manner that the proximodorsal and the proximovolar prominant parts of the peripheral section of the proximal articular surface can serve as fixed points for one of the callipers. If one were to measure the posterior phalanges in the same way, many of them would be oriented obliquely in the measuring instrument. One has to hold these bones in such a way that the (imagined) longitudinal axis of the bone lies parallel to the measuring scale (-).

2. Bp (Greatest) breadth of the proximal end (+).

3. SD Smallest breadth of the diaphysis (-).

4. Bd (Greatest) breadth of the distal end (+) (von den Driesch 1976:97).

The first measurement "Glpe" is thoroughly described and drawn such that the orientation of the specimen is very clear. The other three measurements, "Bp, SD and Bd", were not described in the same detailed manner as was "GLpe". Therefore it is necessary for anyone following these measurements to describe in detail the orientation of their specimens to the calipers for certain measurements so that the results can be duplicated by other researchers.

In von den Driesch's (1976:6,7) evaluation of the relative values of the measureable skeletal parts of large hoofed mammals, phalanges are rated to be of good relative value in terms of size estimation. They are also rated as being moderately frequent in archaeological sites. As for measureability, the first phalanx is given a "+" for the two measurements that are clear and easy to take (Bp and Bd) and a "-" for the two measurements that are difficult to take (GLpe and SD) (von den Driesch 1976:6).

2.2 SEXING TECHNIQUES APPLIED TO NORTH AMERICAN BISON

The following is an evaluation of numerous articles which claim to establish or use sexing techniques for North American bison. It is presented to demonstrate that in most cases the existing sexing techniques for North American Bison are inadequate. The most pronounced shortcoming is that frequently techniques are postulates and have not been tested on known sex samples.

The evaluation is organized into sections based on morphology and titled; skulls, mandibles, metapodials and phalanges. Within each section, the work is presented chronologically so that the reader can easily follow the sequence of the development of sexing techniques on bison in North America . Where an author has worked on more than one morphological area the author is mentioned in each category. The authors who present or use sexing techniques based on bison skulls are Skinner and Kaisen (1947), Wilson (1974b), Shackleton, Hill and Hutton (1975) and Speer (1978). Reher (1970, 1974), Shackleton *et al.* (1975) and Reher and Frison (1980) are mentioned for their work on mandibles. Metapodials are studied by Skinner and Kaisen (1947), Lorrain (1968), Butler, Gildersleeve and Sommers (1971), Bedord (1974, 1978), Miller and Brotherson (1979) and Peterson and Hughes (1980). And finally, phalanges are discussed by Duffield (1973) and Hamilton (1977).

2.2.1 Skulls

Skinner and Kaisen (1947) purported to reorganize the taxonomy of the fossil bison of Alaska by taking twenty-two skull measurements and appling them to male skulls. Male skulls were traditionally used to recognize the North American Bison genus (1947:147). The only mention of sexing techniques based on skull measurements was that the average modern female skull is between 9 and 40% smaller than the average male skull, depending on which measurements are taken (Skinner and Kaisen 1947:148). No further discussion defends the establishment of species types on male skulls alone, and no suggestions are presented as to the sexing of fossil skulls.

A potentially useful technique for sexing mature skulls is suggested by Wilson (1974) in his work on the Casper Site. He used Skinner and Kaisen's measurement number 14, cranial width betwen horn cores and orbits, and in a graph plotted the width against age to demonstrate sexual dimorphism. No argument is presented to defend the reason for choosing this index over any other measurement. Wilson stated there is a problem in establishing the growth line for younger individuals as few were represented in the Casper Site assemblage. However he suggested that the growth line for females "...has at least a limited predictive or comparative value for studies at other sites. The line for males is of little use in these terms at present" (Wilson 1974:159).

Shackleton, Hill and Hutton (1975) discussed cranial variation in a plains bison population of known sex and age from Elk Island National Park, Alberta (N=157). Their data suggests that three skull measurements based on Skinner and Kaisen (1947) can be used to discriminate the sexes aged 5.5 years and older. The measurements used are number 6 (vertical diameter of horn core at right angles to the longitudinal axis), number 12 (transverse diameter of core at right angles to longitudinal axis) and number 14 (width of cranium between horn cores and orbits) (Shackleton *et al.* 1975:873). Shackleton *et al.* (1975:881) noted that the skull measurements would be especially useful for application to archaeological assemblages as these particular portions of the bone preserve well.

Speer (1978:17) advocated the use of "macroscopic examination" of the bison skeletons to determine the sexes of mature individuals in her sample from the Rex Rodgers Site. She seemed satisfied with the "eye-balling" technique and stated "...more refined techniques for sex determination based on measurements of elements such as phalanges served merely to verify the visual determination"(1978:117). Unfortunately, the phalangeal data are not presented to support her conclusion. Skull measurements are presented in tabular form, though no specific explanation is offered as to how the sex was determined from the skull measurements.

2.2.2 Mandibles

To determine the sex of bison from the Glenrock Site by mandibles, Reher (1970:52) decided that "direct observation was unsuitable for accurate sexing results". Reher stated that because he is dealing with archaeological material which had been subjected to butchering practices, the measurement of the length of the mandible was unusable.

After trying several measurements and indices, Reher chose the width below m3 and p4 to sex the mandibles from individuals 5.5 years and older at the site. As no diagrams or descriptions of this measurement are included in the text, it is difficult to repeat or assess his technique.

Reher did little to convince the reader of the validity of his new technique. Because of a separation of mandible widths at p4 in Figure 2a, Reher (1970:53) interpreted the histograms to suggest there were six males. However, in Figure 2b, the mandibles measured at m3 were interpreted to suggest there were 10 males (Reher 1970:53). That Reher overlooks these discrepancies is remarkable. Also, had Reher included the width at m3 from the bison aged 4.5 years, there would have been no apparent separation of the sexes. It is possible that the separation apparent for bison of 5.5 years and older may be the result of sampling error.

In his later work on the Casper Site, Reher applied the same method of sexing bison, but this time, presented only the data from measurements at "the width of the mandible below the center of m3 (between the first and second cusps) on the interior side" (Reher 1974:116-117). Whereas the separation point of males from females for the Glenrock and Wardell populations was approximately 72 mm., the separation point for the Casper Site was set without explanation at 84.5 mm.. According to Reher, the mandible widths below m3 demonstrated that only two individuals were mature males. However, he also stated that skull measurements suggested a presence of at least three males and that two mandibles in the upper end of the female range have marked characteristics of the males (Reher 1974:117). It remains difficult to be convinced of the accuracy of Reher's technique until it is proven on bison mandibles of known sex.

Shackleton et al. (1975:883) in the same article on skulls previously mentioned, found that for bison mandibles measurement #13 (posterior of m3 to the porterior edge of the articulating process), correctly separated males from females 95.5% of the time. The 4.5% error arose when distinguishing between sub-adult males and adult females.

Reher and Frison (1980:61,70) utilized Reher's technique of measuring the mandible height below the 3rd molar in order to sex 850 mandibles (MNI of 497) from the Vore Site. In order to separate samples of bison which may have been from different populations, the mandibles were treated as groups according to site levels. Any bimodal trends were regarded as indicating male and female groupings. However, the interpretation of bimodal trends by Reher and Frison appears to have little foundation. Of six histograms, only one (level 2), contains a suggestion of a bimodal trend. Reher and Frison give the distinct impression of interpreting the graphs to conform to previous studies which suggested few males and numerous females (Reher 1970, Reher 1974). No diagrams or detailed description of the measurement were included in the report. Only the absolute measurements of mandibles from single levels 1 through 5 and one grouped histogram of all levels 1 through 10 were presented. It is not clear if graphed measurements are of single mandibles or of the minimum numbers of individuals (MNI) count. Only minimum and maximum measurement values were presented from level 6 through 10, which account for 39 of a total of 396 mandibles or approx 10% of the total (Reher and Frison 1980:73). Also it was noted that the site total (N=396) given in Table 6 does not correspond to either of the previous figures given as 850 mandibles or an MNI of 497. When it was attempted to discern exact figures of MNI counts of calves, cows and bulls more discrepancies were noted. Reher and Frison (1980:76) stated, "an estimated minimum of about 200 cows in the entire mandible sample is matched with only 33 calves". An MNI of 200 cows and 33 calves, out of an MNI of 497 does not yield the 80-90% cow ratio Reher and Frison (1980:93) claim in the summary.

Although Reher and Frison (1980) have used measurements to quantify sexual dimorphism, they have not established a clear, or convincing, technique by which to interpret the histograms of those measurements. In most of the cases they present, the bimodal trends are not accentuated by a marked space between males and females. Their interpretation of the histograms is unfortunately accomplished using the intuitive "eye-balling" technique.

Reher and Frison (1980:60-61) stated, "metapodial studies especially have a long established place in morphological analysis, these elements may be more sensitive than mandibles in certain areas (e.g. sex...)". However, they ignore the results of sexing the metacarpals from the same site by Peterson and Hughes (1980) even though their conclusions differ. If Reher and Frison's way of distinguishing sex is incorrect then what they consider to be 80-90% cows could, in part, be bulls. Reher and Frison argue that, because so few calves were present compared to the number of mature cows, there must have been some major cultural activity necessitating the removal of the calves. However, if 60% of the sample is adult cows, as suggested by Peterson and Hughes (1980:171), then 20-30% fewer calves need to be accounted for. As stated previously, until it can be demonstrated on a known sex bison population that the height of the mandible below the 3rd molar indicates sexual dimorphism, the technique as it now stands is not at all convincing.

2.2.3 Metapodials

Skinner and Kaisen, working with a sample of unknown sex (1947:135), stated they could sex metapodials by the "relative heaviness" of the shafts. Then, standard measurements such as greatest length, transverse diameter of the proximal end, transverse diameter of the center of the shaft, transverse diameter of the distal end and the anterior-posterior diameter at the center of the bone were taken on 4,838 random metapodials. An index was created based on the transverse diameter at the center of the shaft divided by the overall length (Skinner and Kaisen 1947:135-137). From a total of 3,050 assumed male and 1,788 assumed female metapodials, index values were presented for only 34 assumed males and 33 assumed females. From the tables of selected metapodials, only a slight overlap of measurements is indicated using the index. There is no index overlap for the metatarsals.

There are obvious problems with these data. The metapodials were not associated with other bones to affiliate them with particular skulls. Since the skulls indicated more than one species, there was likely the same distinction in the metapodials, but it is undetectable (Skinner and Kaisen 1947:135). The sexing of bones was not carried out on a known sex group, so the conclusions cannot be defended. There is no doubt that the technique involves separating the heavy shafted individuals from the lighter shafted individuals, but it remains a very important question whether or not shaft weight can be directly correlated with sex.

Lorrain (1968) described and measured the bison bone from Bonfire Shelter, New Mexico and used the method advocated by Skinner and Kaisen (1947) to distinguish male and female metapodials. First, she visually separated the bones and then, as a check, measured and graphed the index (total length plotted against the center of the shaft diameter). Naively, it was stated that although there was no control sample, an error in judgement occurred only once (Lorrain 1968:84). It is difficult to accept this study for the same reasons it is difficult to accept Skinner and Kaisen's sexing of metapodials. That the method is separating the metapodials into two size groupings is agreed, but whether or not these groups necessarily represent males and females remains unresolved without a group of known sex as a standard.

Butler, Gildersleeve and Sommers (1971) applied Skinner and Kaisen's method of intuitively sexing metapodials based on the massiveness of the shaft. Metapodials were studied from one fossil collection and several archaeological collections which include Skinner and Kaisen's Alaskan sample, Bonfire Shelter Bone Bed 2 and 3, Wasden Site, Duffield Site and Bison Cave (10-CL-10). The data were plotted on a graph using the slope line as calculated for the Alaskan sample separation line. Butler _et al_. (1971:131) found that:

> The line dividing the sexes varies with the mean size of the metapodials in each population, which seems to vary with latitude (an example of Bergmann's rule).

Their concluding remarks specify several recommendations, one of which is that;

> a thorough analysis should be made of a large number of complete modern bison skeletons of known age and sex, with particular attention paid to the maturational and sexual differences. Butler et al. (1971:133)

Bedord (1974) used the measurements described by Lorrain (1968) and Butler et al. (1971) on metapodials from six archaeological sites: Casper, Finley, Hawken, Ruby, Vore and Olsen-Chubbuck. The analysis of the univariate data provided only minor distinctions between male and female groupings, and therefore multi-variate analysis was undertaken. Three measurements, numbers 1,3 and 4 were chosen to be entered into an SPSS program called SCATTERGRAM. Measurement number 4 (the transverse width of the distal end) was plotted on the "y" axis. A ratio called number 6, of measurement number 3 (the transverse width at the center of the shaft) divided by measurement number 1 (the greatest length) was plotted on the "X" axis. To determine the separation, a line "perpendicular to the least squares linear equation and that passes through the break was calculated and plotted on the scattergrams" (Bedord 1974:229). Her technique included the arbitrary placement of the point through which the perpendicular line would pass (1974:230).

Bedord's technique is intended to provide a practical method for aiding the interpretation of a site within the last 10,000 years. She believed that single metapodials could be sexed in the field by taking the previously mentioned three measurements. In summary she stated that:

> Specifically for metacarpals, if measurement no. 4 is greater than (90 - 1/2[Ratio 6]), then the bone is probably a male, and if measurement no. 4 is less than (80 - 1/2[Ratio 6]) then the bone is probably female. For metatarsals, the corresponding division would be as follows: if measurement no. 4 is greater then (76.5 - 1/3[Ratio 6]), then the bone is probably male and if measurement no. 4 is less than (67.5 - 1/3[Ratio 6]), the bone is probably female. For those falling between these two lines, the entire population should be plotted to determine where the break occurs between males and females. (Bedord 1974:239).

In Bedord's work, some of the separation may be due to sexual dimorphism. On the other hand, some separation may be caused by inter-species variation and the size of the site sample. A thorough assessment of Bedord's work could only be achieved by testing a control sample of known sex to determine the validity of the equations.

Bedord (1978) basically summarized her work in 1974, with an additional testing of a known sex and age sample of bison material. The size of this modern sample was not included and only one male and a few females appear to have been tested (Bedord 1978:42).

Miller and Brotherson (1979) presented a summary of measurements of the foot bones from the Rancho La Brea collection which included specimens of *Bison antiquus* and *Bison latifrons*. They included three measurements for a sample of anterior first phalanges as follows:

1. Greatest Length

2. Greatest Anteroposterior Diameter

3. Greatest Transverse Diameter (Miller and Brotherson 1979:7).

The diagrams of measurements 1 and 3 are clear, whereas that of measurement 2 is ambiguous (Miller and Brotherson 1979:18). The authors researched sexual differences only in the metapodials, and referred to the sexing work of Skinner and Kaisen (1947). They did not test the carpals, tarsals or phalanges. Their conclusion from Rancho La Brea, was that sexual dimorphism was present only in the metacarpals.

Skinner and Kaisen used the indices of the transverse diameter at the center of the shaft plotted against the greatest overall length to demonstrate relative heaviness of shafts and assess a separation. It appears Miller and Brotherson intended to copy Skinner and Kaisen, though none of their combinations duplicated the older study. They used the following combinations of measurements in their work.

1. Greatest length (against) Greatest distal transverse diameter

2. Greatest tranverse width proximal end (against) Greatest transverse width distal end

3. Greatest anteroposterior width proximal end (against) Greatest transverse width proximal end

4. Greatest anteroposterior width proximal end (against) Greatest transverse width distal end (Miller and Brotherson 1979:9).

Miller and Brotherson did use a measurement similar to Skinner and Kaisen's transverse diameter at the centre of the shaft. Miller and Brotherson's similar measurement is number 5, the least transverse width of the shaft, but it is not presented in the analysis. The diagrams of the measurements only add to the reader's confusion. Measurements labelled 4,5,6 and 7 disagree with the verbal description on pages 6-8. (Miller and Brotherson 1979 6-8,16,18)

Peterson and Hughes (1980) studied a sample of 629 complete and mature metacarpals from 11 archaeological sites in and near Wyoming and one small modern sample. They used four measurements to determine if any bimodal trends suggesting sexual dimorphism were present within each site. Two of the measurements were taken using an osteometric board and the others were read from an x-ray plate. Results using a combination of variables and indices indicated "distinct bimodal clusterings were evident in nearly 70% of the samples" (Peterson and Hughes 1980:174). The best results were found when the X axis was plotted as cortex thickness and the Y axis was a statistic adding the width of the distal epiphysis to the width divided by length ratio (Peterson and Hughes 1980:174). The slope line was standardized to -0.59 and used to separate the cases into males above and females below the slope. The results of these graphs suggest that in over 70% of the samples males and females were killed in a ratio of approximately 40% male and 60% female (Peterson and Hughes 1980:175).

The ratios of the remaining 30% of the sample are not summarized, nor is it clear which sites demonstrated which ratios. The authors did not discuss the problem of an archaeological bison sample extending over a 10,000 year range. For example, there is no explanation of differences or similarities in the results from sites with fossil forms compared to sites without fossil forms. Peterson and Hughes did not state the percentage of animals that can be sexed by their technique, nor is their modern sample large enough (N=8) to give the study added credibility.

2.2.4 Phalanges

Duffield (1973) proposed a bivariate plotting of measurements and indices for North American bison following those established by Empel and Roskosz (1963) to discriminate the sexes of the European bison (*Bison bonasus*). Using Empel and Roskosz's known sex and age data, Duffield demonstrated a clustering by sex for the metatarsals and rear second phalanges with a graph of an index (width of proximal end divided by length) plotted against the width of the distal end (1973:136,138). Unfortunately in the translation from the German, Duffield ignored the fact that Empel and Roskosz used only individuals aged 5+ years in their demonstration. This age factor cannot be controlled in an archaeological sample unless the bison were well articulated or skeletally complete. Therefore, the application of Empel and Roskosz's technique for European bison to North American bison, as suggested by Duffield, is less certain. Later, it will be shown that the index developed on European bison is unsuccessful in sexing North American bison aged 3 years and older.

Hamilton (1977), in his analysis of a sample (excavation unit 9) of the faunal material from the Stott Site, used Duffield's suggestion of the bivariate plotting of measurements and indices to distinguish the sex of the front and rear, first and second phalanges. He used one sub-adult female wood bison (Bison bison athabascae) as a control group. However, the archaeological sample of 32 first phalanges and 35 second phalanges "proved too small to produce distinct clusters with known class limits" (Hamilton 1977:38). From the graphs, it is apparent that the results based on the front, first and second phalanges separated distinctly, although the first phalanges separated even more completely than did the second phalanges. The results for the rear first and second phalanges overlapped and therefore did not distinguish each set. The separation of the front first phalanges appeared to be very distinct with two male phalanges much larger than the other phalanges. However, it still cannot be proven that the lower cluster was all females without an adequate control group of known sex bison.

It is apparent from this literature review that work done on the sexing of European Artiodactyl phalanges can stimulate research on known sex North American bison. North American studies, though plentiful, are represented in only one case by work on a population of known sex (Shackleton *et al.* 1975). None of the other studies base their sexing techniques on a large known sex population and they thereby loose their credibility. The one known sex study depends on measurements that require portions of the skull to be intact. Skulls are not frequently intact at sites, and were not intact at the Stott Site, so it became apparent that a different sexing technique was required. Many of the front first phalanges are whole at the Stott Site, and at other sites. Therefore, it became obvious that a sexing technique developed on front first phalanges of a known sex bison sample could be effective in interpreting archaeological bison remains.

Chapter III

METHODS OF MEASUREMENT, SOURCES OF DATA AND PRELIMINARY TESTS

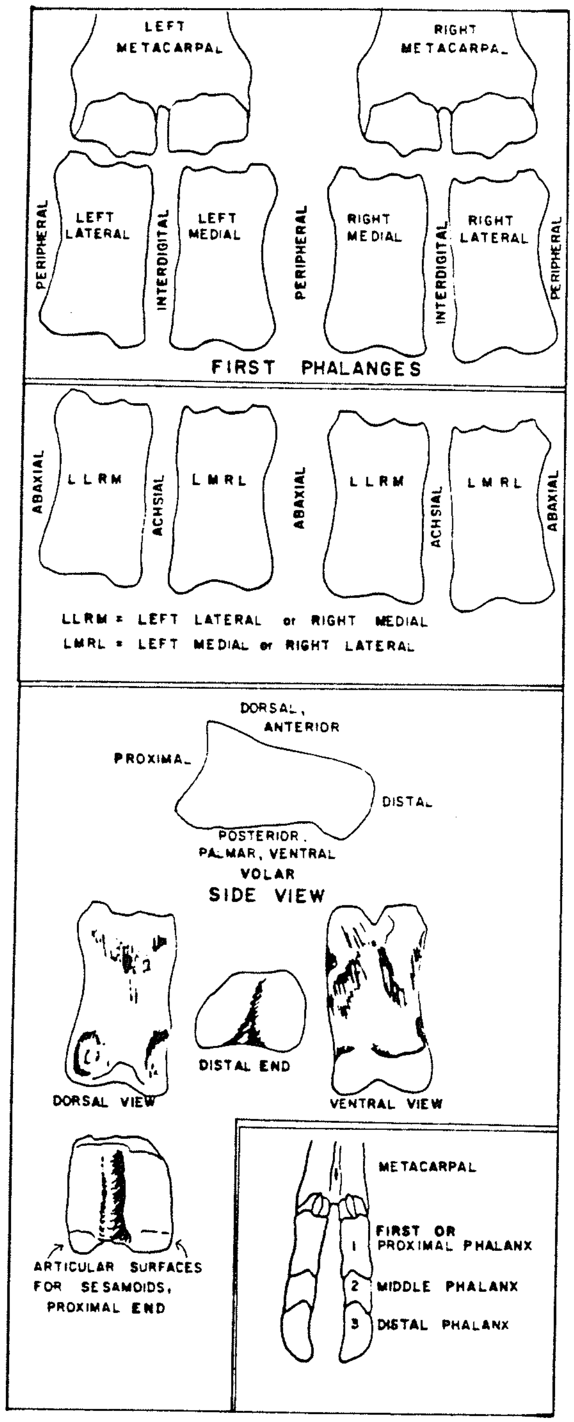
This chapter contains a description of this study's eight metric measurements. Full verbal descriptions, line illustrations and photographs are included for clarity.

The major source of data, a known sex population of plains bison from Elk Island National Park, Alberta is described. Also described are the known sex test group from Central North America known as the Museum sample and the unknown sex sample from the Stott Site, Manitoba.

The preliminary tests include a defence of the replicability of metric measurements. Characteristics used to distinguish front from rear phalanges are also presented. Finally, a phalangeal index developed by Empel and Roskosz (1963:275) and suggested for application on North American bison by Duffield (1973:136) is applied to the Elk Island sample and the results are given.

3.1 DESCRIPTION OF MEASUREMENTS

The phalangeal linear measurements were selected from and based on descriptions of measurements by authors included in Chapter 2. These metric measurements are the most commonly used measurements of the last 50 years. Volumetric measurements were considered for use in this study. Sellards (1955:338-339) and Zeimens and Zeimens (1974:245) attempted to use the volume of bison astragali "as an indicator of relative animal size". Lorrain (1968:127) used volumetric measurements of several bones including first and second phalanges to assess speciation at the Bonfire Shelter Site. Upon close inspection of the archaeological specimens to which the sexing techniques were to apply in this study, it was apparent that volume measurements could not be executed without reconstructing many surfaces which were not entirely perfect. Certain bones, though relatively whole, were in places either chewed by carnivores, gnawed by rodents, fragmented or affected by trowel "trauma". As reconstruction would involve estimation it was decided to pursue a technique based on linear measurements and indices rather than volumetric measurements. Unfortunately, inadequate documentation and diagrams in many of the previously cited reports left some measurements open to interpretation. Explicit descriptions of the measurements used in this study are presented here. Figure 1 provides a review of the anatomical terminology applicable to phalanges



A. Metacarpals and first phalanges in articular position.

B. First phalanges as if from an archaeological context.

C. Anatomical features of bison first phalanges.

D. Planview of pedal elements.

Figure 1: Review of the Anatomical Terminology Applicable to Phalanges

and Figures 2 - 5 augment the verbal description of the measurements.

1. LENGTH (Figures 2 and 3) The length is taken on the abaxial portion of the phalanx. The bone is placed with the more central portion of the proximal articular surface of the abaxial half against the immovable arm of the caliper. The moveable arm of the caliper is slid to touch the corresponding most distal articular surface.
2. GREATEST LENGTH (Figures 2 and 3) Greatest length is the diagonal length of the interdigitating side of the phalanx. The interdigitating side is opposite that taken in the Length measurement. The measurement is taken from the most volar and medial portion of the proximal articulation to the most dorsal portion of the distal articulation. The volar proximal portion is against the rigid arm and the distal anterior portion is moved in a slow arc to achieve the greatest length (after Lorrain's Length Measurement 1968:126).
3. PROXIMAL DEPTH (Figures 2 and 3) This measurement is the antero-posterior depth of the proximal end. The middle of the proximal dorsal surface is placed against the immovable arm. The phalanx is placed so that the depression is lined up perpendicularly to the arm. The sliding arm is then moved to touch the

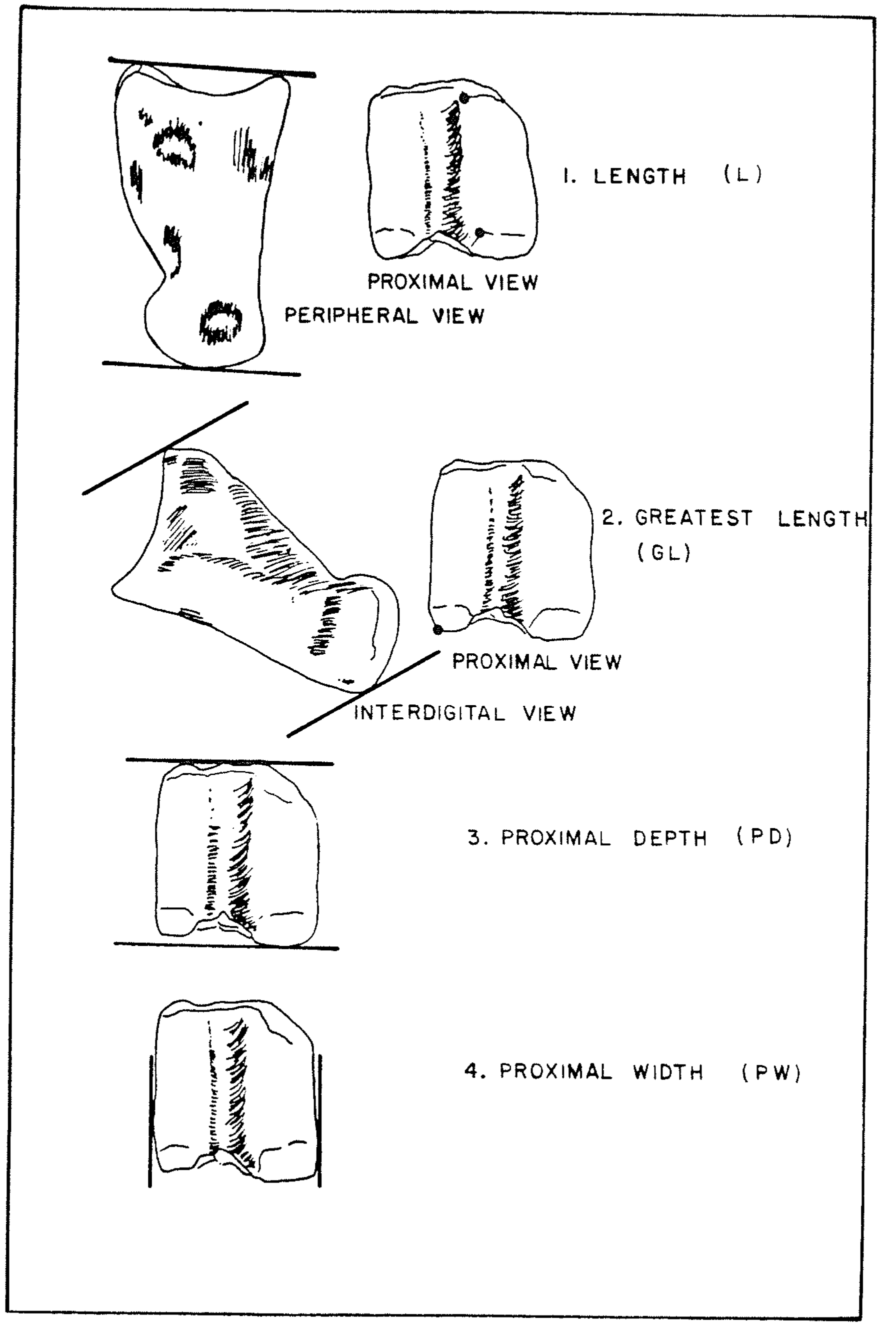
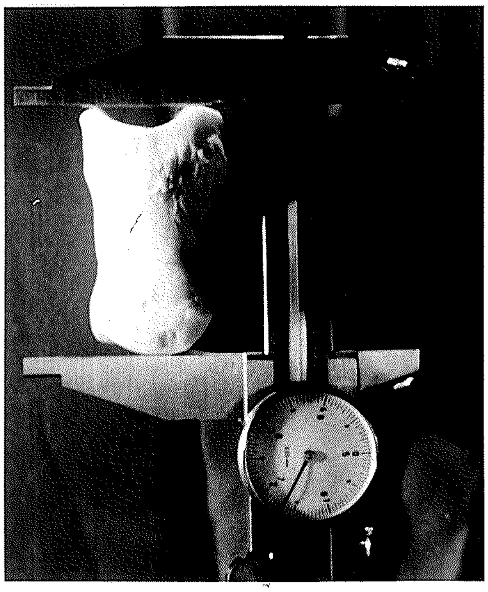
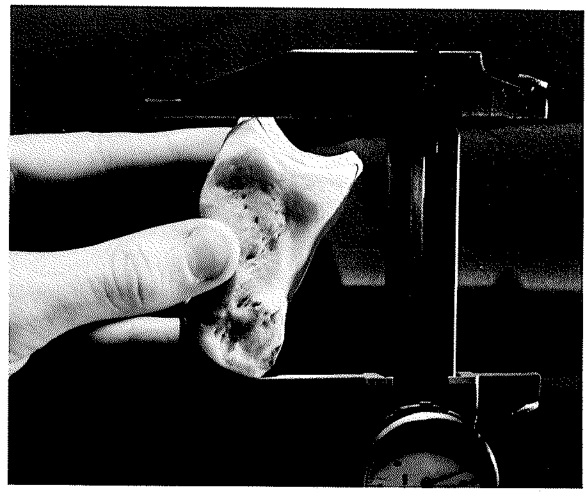


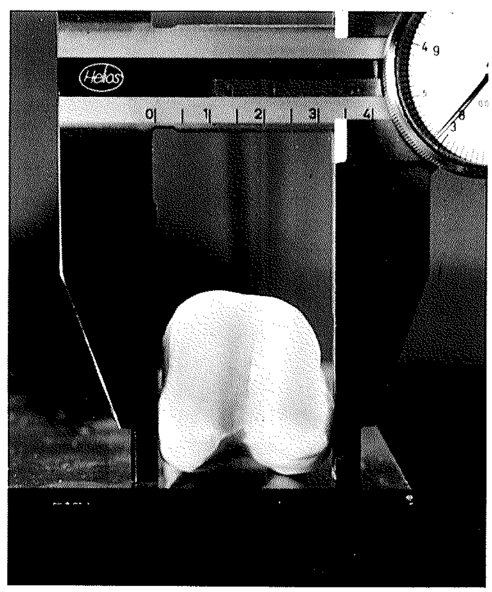
Figure 2: Measurements 1 Through 4



1 LENGTH



2 GREATEST LENGTH



4 PROXIMAL WIDTH

Figure 3: Photographs of Measurements 1,2 and 4

most projecting volar portion of the proximal articulation at the articulation with the sesamoids.

4. PROXIMAL WIDTH (Figures 2 and 3) The phalanx is placed on a glass platform at eye level, with both mid-body volar muscle attachments touching the glass and the full width of the proximal end between the caliper arms. The proximal width is taken at the proximal end from the medial or interdigitating surface to the lateral or abaxial surface. Special care is taken to align the main axis of the bone perpendicularly to the caliper and to have the flat ends of the calipers on the flat surface of the glass.

5. GREATEST PROXIMAL HEIGHT (Figures 4 and 5) This measurement is taken to include the prominent tendon attachment areas of the mid body volar surface of the phalanx. Keeping the proximal end toward the measurer, the bone is placed volar surface down, the whole bone toward the edge of a glass platform. At least the proximal end of the bone should be steady. Typically, the left medial and right medial bones will only have one distal surface resting on the glass when the proximal end is steady. The measurement is taken to include the lower edge of the glass to the highest portion of the dorsal proximal surface. No pressure should be applied to the bone.

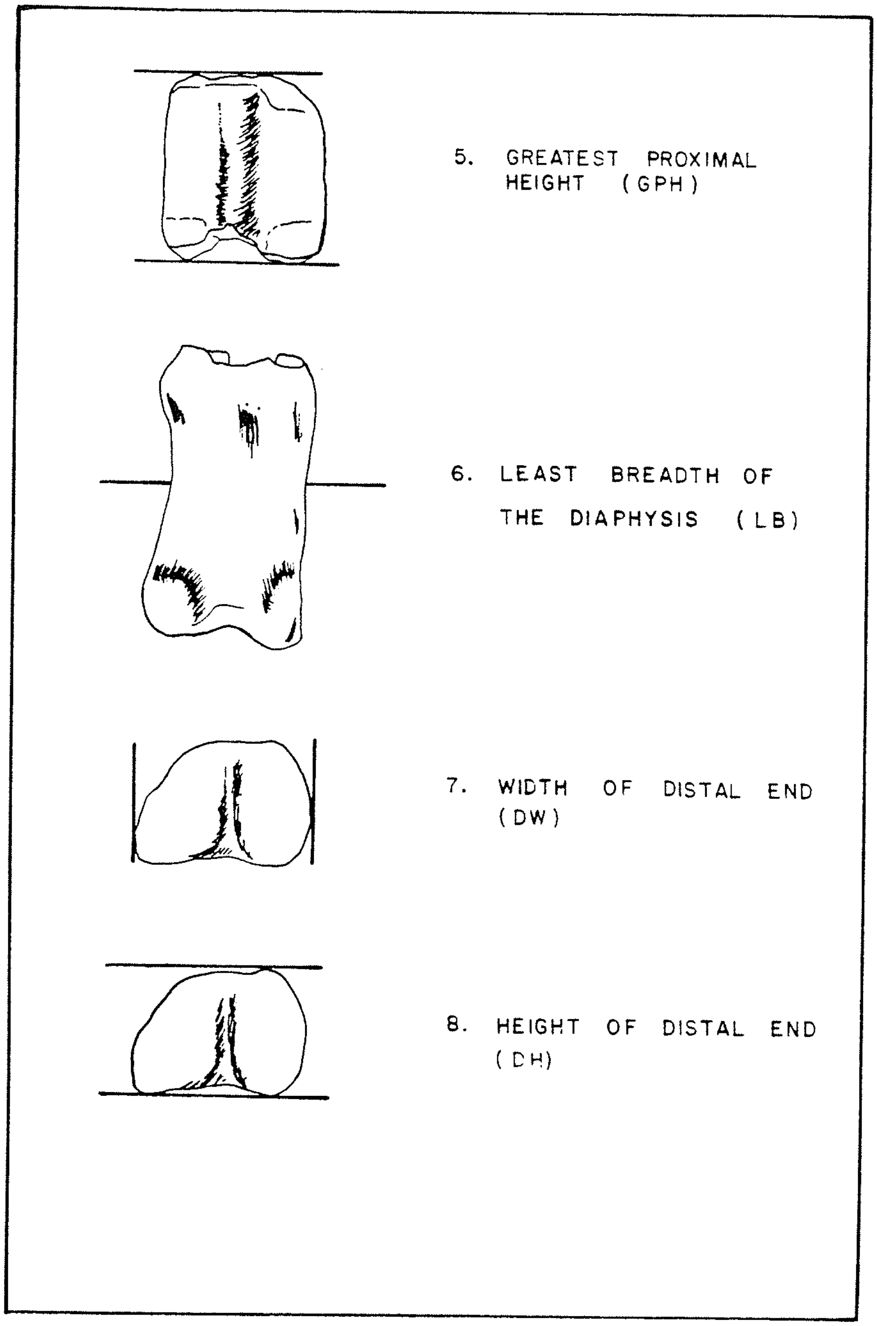
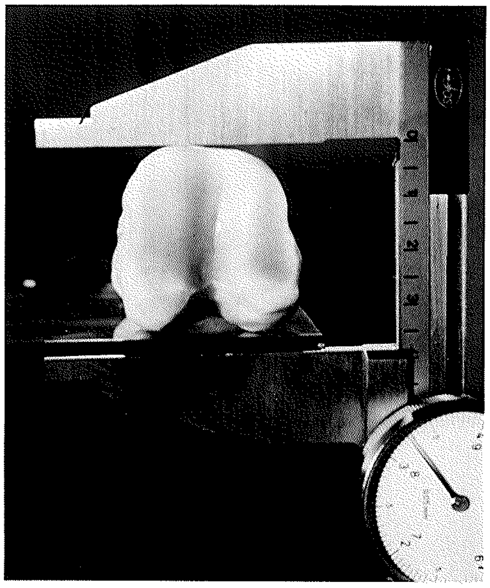
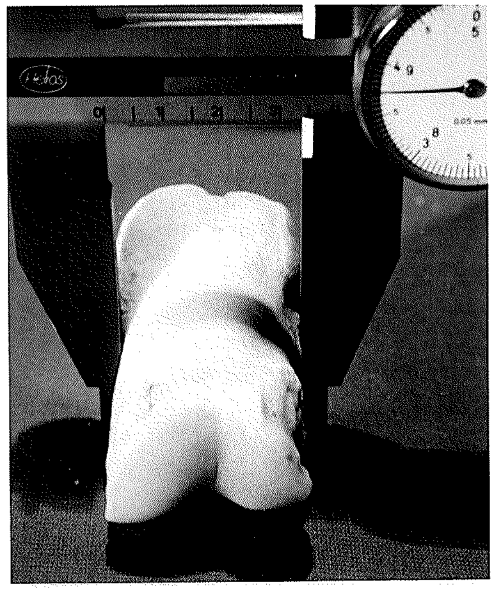


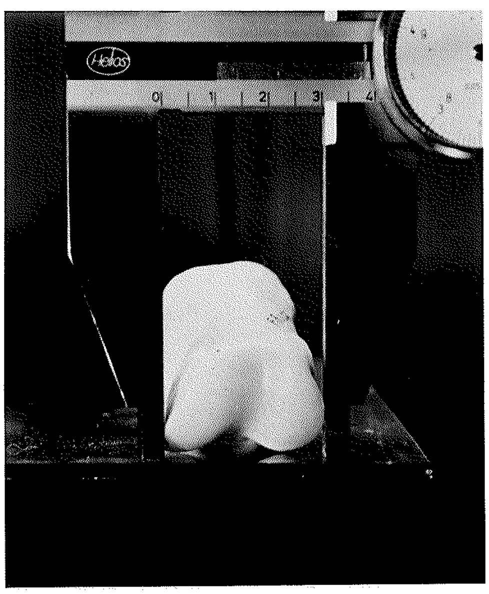
Figure 4: Measurements 5 Through 8



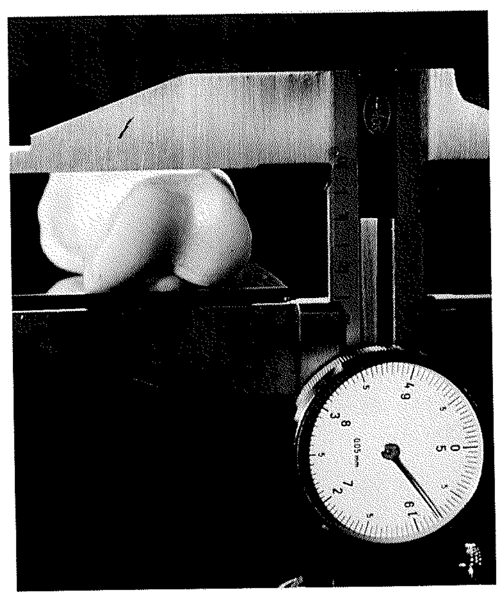
5 GREATEST PROXIMAL HEIGHT



6 LEAST BREADTH



7 DISTAL WIDTH



8 DISTAL HEIGHT

Figure 5: Photographs of Measurements 5 Through 8

The depth of the glass is subtracted and the bone height recorded.

6. LEAST BREADTH OF THE DIAPHYSIS (Figures 4 and 5) This is the least medial-lateral or transverse width of the shaft when the volar surface is placed on a surface. The bone is allowed to rest "naturally". The calipers are placed over the specimen, the arms on each side of the specimen and the arms touching the table. Care is taken to align the main axis of the bone perpendicularly to the caliper and to hold the bone during measurement in its "natural" position. Sometimes it is necessary to check a few areas along the body of the shaft to obtain the least measurement. Typically, the least breadth is found more toward the proximal than the distal portion of the body.

7. WIDTH OF DISTAL END (Figures 4 and 5) This measurement is the maximum medial-lateral distance between the edges of the distal articulation taken to touch the slight peripheral projection. The volar surface of the phalanx is placed on the table with the distal end toward the measurer and the calipers perpendicular to the axis of the specimen. Both the medial and lateral edges of the distal end must be touching the table.

8. HEIGHT OF DISTAL END (Figures 4 and 5) This is the antero-posterior height of the articulation of the distal end. The bone is placed volar surface down on a glass platform with the distal end toward the measurer. The distal end must be steady as in measurement 7. The caliper is moved to measure from under the glass platform to the highest or most dorsal portion of the distal articular surface. The thickness of the glass is then subtracted and the bone measurement recorded.

The instrument used to measure the specimens was a Helios sliding dial caliper, with long, wide and squared off projecting arms. Measurements were read to the nearest 0.01 millimeter and rounded to the nearest 0.1 millimeter (0.1 mm.). Digits were rounded following the method advocated by Sokal and Rolf (1969:16) which is generally accepted as a way to lessen inadvertent skewing of the data. Digits ending from 0.00 to 0.04 were rounded downward. Digits ending from 0.06 to 0.09 were rounded upward. When the digit to be rounded ended at 0.05 it was unchanged if it was even and increased by one if it was odd (Sokal and Rolf 1969:16). For example, 7.65 became 7.6 and 7.75 became 7.8. Pathological or anatomically abnormal bones were measured only where the bone appeared unaffected. Only bone which was not calcined and not carbonized was measured because of the shrinkage factor in burnt bone (von den Driesch 1976:4).

Each front first phalanx from the Elk Island sample was measured and rounded. Then the sample was measured again. If the second measurement was the same, the figure remained unchanged. If the second rounded measurement was taken and was different, then a third measurement was taken and all three measurements were averaged. The same procedure was followed for the Museum and Stott samples except that measurement 3, Proximal Height, was excluded. A total of approximately 13,000 measurements were taken. The final measurements are presented in Appendix A.

3.2 SOURCES OF DATA

3.2.1 Elk Island National Park, Alberta

A sample from Elk Island National Park (abbreviated as the EINP sample) was used as a data base to establish the sexing techniques (Figure 6). The use of the word sample in the following descriptions is always meant as a sample from all bisons and does not mean a sample from the collections (EINP, Museum or the Stott Site). The EINP sample consisted of 121 plains bison (*Bison bison bison*) of which there are 25 females and 96 are males. These bison were aged between three and 12 years with some individuals assessed an average age of either 3+, 4+ or 5+ years (Figure 7). To my knowledge this is by far the largest collection of bison pedal elements of known sex and age in North America. There was a complete set of four front phalanges for each of the

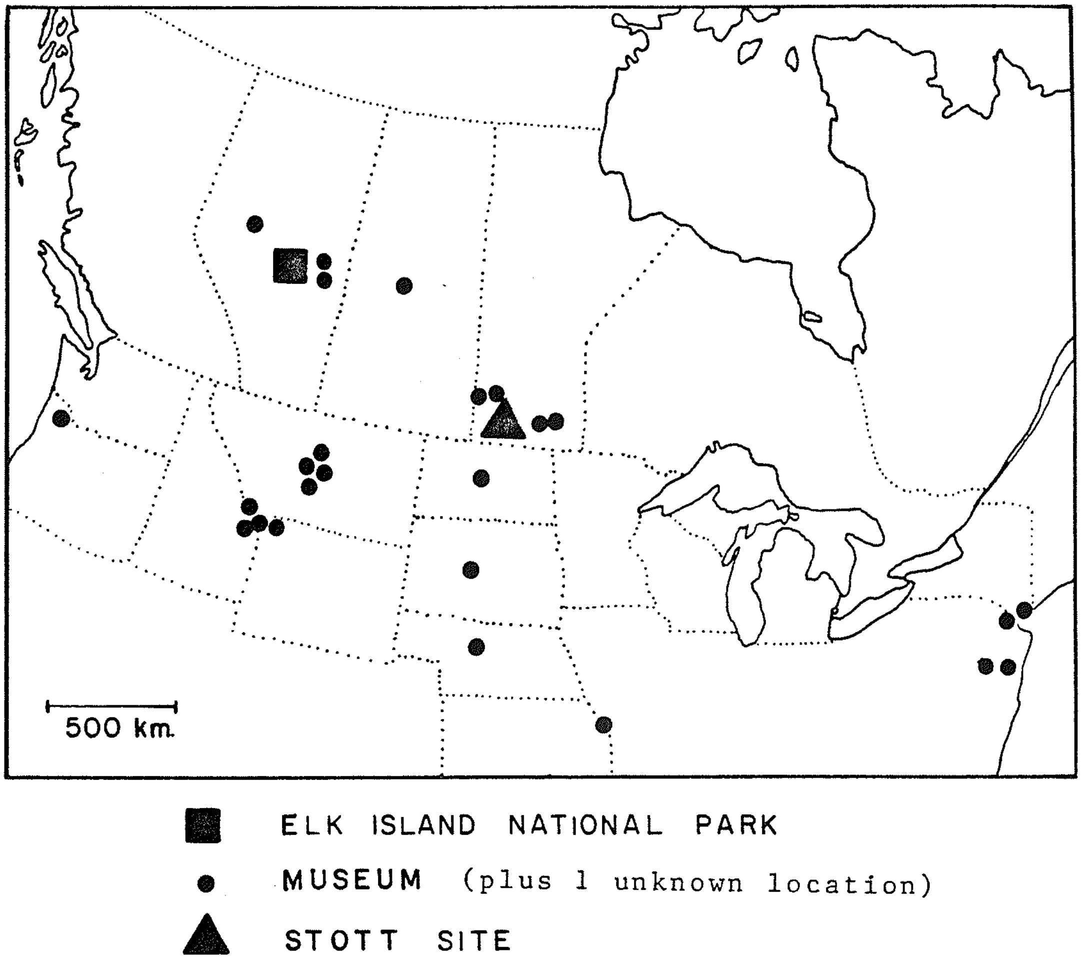


Figure 6 Map with Locations of the Three Samples: EINP Museum and the Stott Site

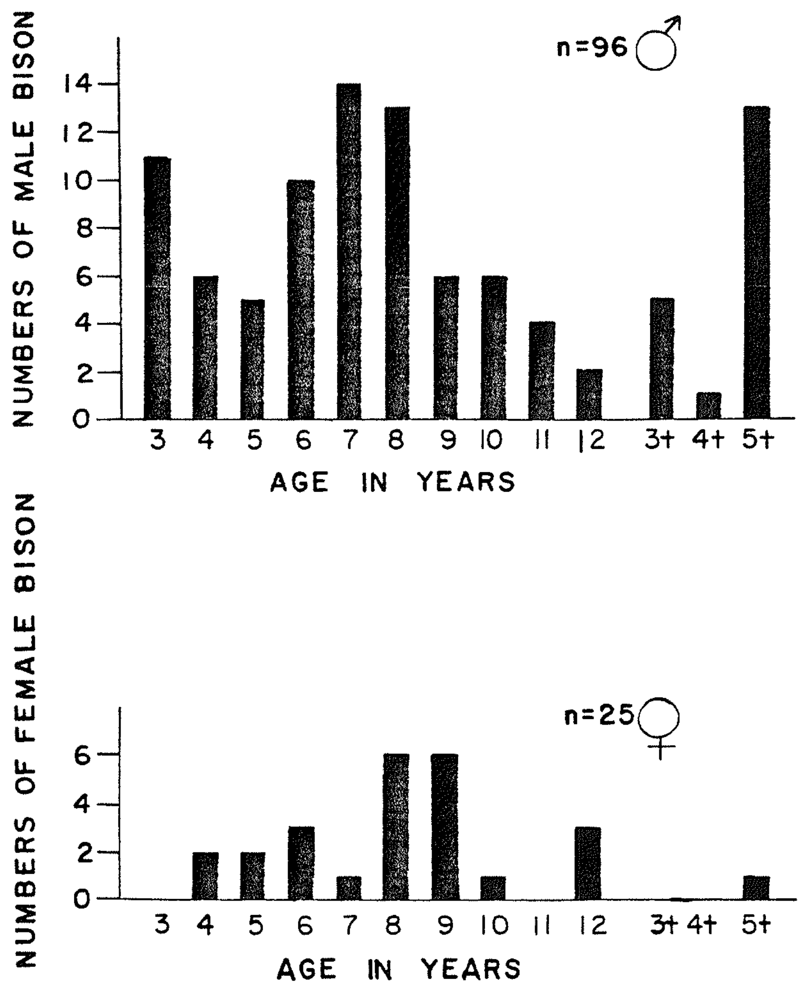


Figure 7: Numbers of Known Sex Bison by Age Group: EINP Sample

25 females (100 elements) and 93 complete sets and three sets of two phalanges each for the males (378 elements). These animals were all killed December 1971 as part of a necessary population reduction program. The bison in this park originated from the Pablo-Allard herd of Montana and were bought by the Canadian government as a conservation measure in 1906 (Banfield 1974:406). Of the total number of animals purchased, 412 were delivered to Elk Island. In June 1907, seven bulls were shipped from Banff National Park to Elk Island, and 325 bison were shipped in October 1909, from Elk Island to Buffalo Park (Bamber 1980:pers. comm.). The remaining Elk Island bison, therefore formed the nucleus of the modern herd, from which this sample was taken. There is no genetic admixture of wood bison even though they are kept in the same park. The two groups of bison are separated by two 7 foot paige wire fences and Highway #16 (Bamber 1980:pers. comm.).

All of the foot bones were collected and boiled during preparation by John Brumley. Recognizing the importance of the integrity of the sample, he excluded any bison whose tags were missing, and did not attempt to "correct" mislabelling. If in preparation any specimens were mixed, they too were excluded from the sample. However even with these precautions it became apparent that at some time two sexing errors were made. These problems were verified by Michael Wilson, who was working on the metapodials of some of the same bison. The sex of bisons #20 and #45 were considered incorrect in the initial record and were therefore excluded in the reference collection (Wilson 1981:pers.comm.).

As stated earlier, in order to apply measuring techniques to the phalanges it was necessary to use only those with a fused proximal epiphysis. Because there is no literature specifically on skeletal maturation for plains bison, it was necessary to use analogues from similar animals of the Family Bovidae. A close examination of Koch (1932), Sisson (1938) and Silver (1963) revealed three different rates of fusion for the proximal epiphysis to the diaphysis of the first phalanx. Koch (1935) stated that for European bison (Bison bonasus) the proximal end of the first phalanx fuses in the middle of the fourth year. Sisson (1938:149) stated that for domestic cattle (Bos taurus) union takes place between one and one-half to two years. Silver (1963:252) stated that for oxen in general, the proximal epiphysis fuses before birth and the distal epiphysis fuses at one and one-half years.

Because of the dissimilarities in the fusion rates, it was decided to turn to the EINP sample itself for aging information. All bison aged three years had completely fused proximal epiphyses. Only a few bison were less than three years, and they all demonstrated incomplete fusion. Although this information does not allow for pinpointing an age at fusion, it is concluded that a fused proximal epiphysis is from a bison at least three years old.

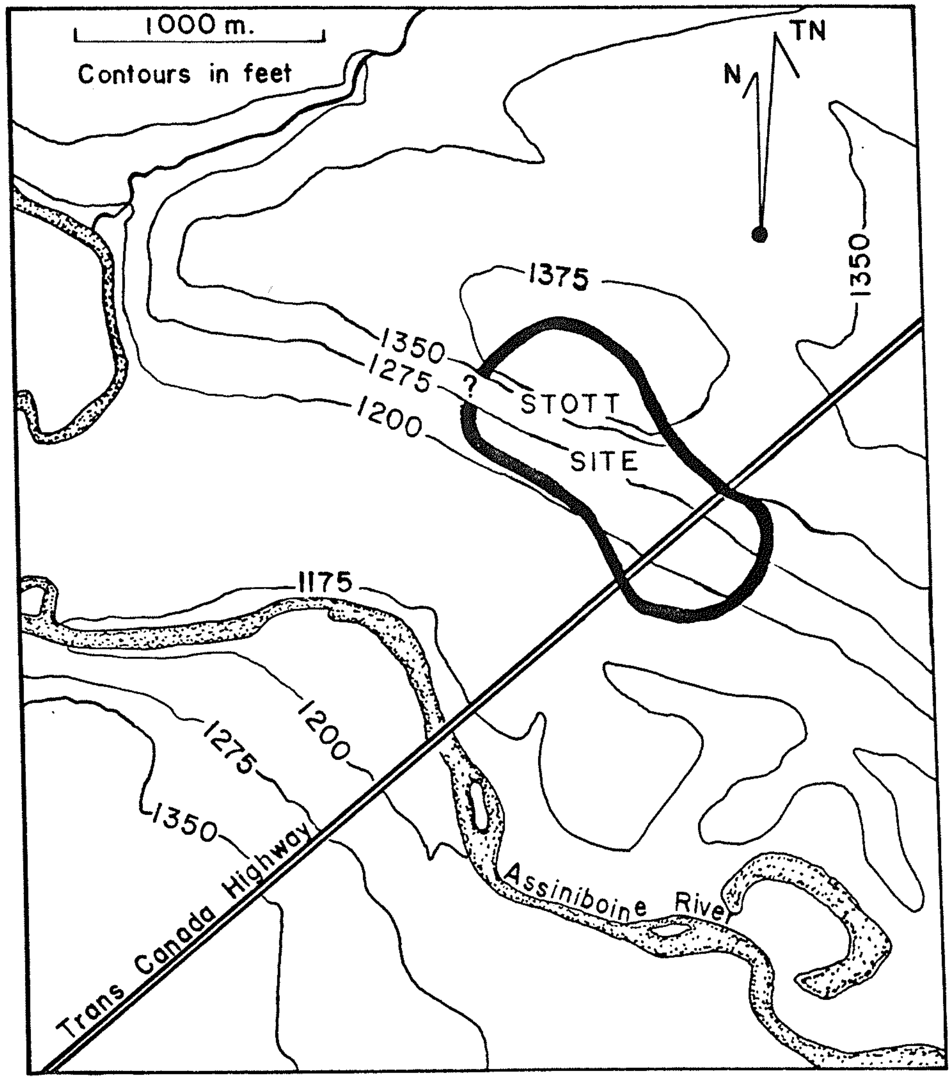
3.2.2 Museum Collections, Central North America

The second set of phalangeal data used for testing the sexing techniques was collected from major museums throughout Canada and the United States and is referred to as the 'Museum sample' (Figure 6). The Museum sample consists of 26 plains bison of which there were seven females and 19 males. The sample includes bison from Oregon, Yellowstone National Park, Montana, North Dakota, South Dakota, Kansas, Nebraska, New York Zoo, Brooklyn Museum, National Zoological Park (Washington, D.C.), Northern Alberta, Elk Island National Park, Prince Albert National Park, Riding Mountain Park, the Assiniboine Park Zoo and one from an unspecified location. Of the total 26 bison, 17 bison were represented by four phalanges, four bison by three phalanges, two bison by two phalanges and three bison by one phalanx; for a total of 87 phalanges. Two additional individuals, which would have made the sample total 28, were omitted because, in one case the lending institution indicated that a mixing of tags may have occurred, and in another case the institution conceded a possible recording error.

3.2.3 Stott Site, Manitoba

The third set of phalangeal data used for the archaeological application of the sexing techniques comes from the Stott Site (DlMa-1), Manitoba (Figures 6 and 8). Excavation and analysis of the Stott Site was begun in 1947 by Bird, followed by MacNeish in 1950 (1954), Syms in 1975 and 1979 (1976,1979), Saylor in 1975 (1976), Wattral in 1976 (1976), Tisdale in 1977 (1978), Hamilton in 1979 (1980) and Pokytylo in 1981. The Stott Site is considered a Late Woodland site with the bulk of the material relating "to at least two Blackduck occupations around A.D. 800 and A.D. 1200" (Tisdale 1978:100). Archaeological evidence has not yet confirmed the location of the kill area, nor is it clear whether a trap or a pound was used to take the bison (Hamilton et al. 1980:167).

Tisdale (1978:1) states that the projected site area covers more than 100 acres and is located along the north side of the Assiniboine River Valley, 7 miles west of the city of Brandon, Manitoba (Figure 8). As pointed out by Hamilton et al. (1980:5) the occupied portion of the site, was "the narrow terraces of various sizes" that occur between "the steep sloping valley walls". Hamilton et al. (1980:5) suggest that the site be considered a multi-component site with "a series of dozens and possibly hundreds of individual occupations by band-size groups of people whose cultural refuse overlapped temporally and



(after Tisdale 1978:34
and Syms 1979:8)

Figure 8: Topographic Map of the Stott Site

spatially". Nonetheless all cultural materials are Blackduck rather than numerous complexes with different cultural values. The occupations at the site are represented by a fairly solid bone bed at about 30-55 cm., with smaller quantities above and below it (Syms 1979:127,129). Smaller clusters of bone scattered on isolated flat areas are considered to represent isolated encampments. The density of the bone bed, which varies, is considered to represent numerous occupations rather than normal variation in deposition (Hamilton 1980). As no sterile layers lie within the bone beds, deposition must have occurred over a short period of time. Even though the site extends over a large area of land, early dates from the east side are similar to dates on the west side thereby establishing contemporaneity (Syms 1976:30, Tisdale 1978:100).

The sample, from five seasons of excavation (1950-1979), consisted of a total of 263 whole and/or nearly complete first phalanges, of which 141 were front phalanges. Due to the low soil acidity, the bone was well preserved and few bones are affected by weathering or water erosion (Tisdale 1978:6). Table 1 summarizes the numbers and condition of the first phalanges at the Stott Site.

TABLE 1

Summary of the Stott Site Bison First Phalanges

DESCRIPTION		NUMBERS OF BONES
A. Those With Fused Proximal Epiphyses		Total = 263
Front Foot		
Complete (L,GL & DH measurements)	74	
Incomplete (any other 3 meas.)	67	
Rear Foot		
Complete and Incomplete	120	
Unclassifiable to Front or Rear		
Fairly Complete	2	
B. Those With Unfused Proximal Epiphyses		Total = 41
Nearly Fused	2	
Unfused	39	
C. Fragments		Total = 88
(Front, Rear or Unclassifiable)		
Those With 0 - 2 Measurements	88	
D. Total Number of First Phalanges		393

3.3 PRELIMINARY TESTS

3.3.1 Replicability of Measurements

Considerable concern has been expressed about consistency in classification and measurement (Fish 1978, Boessneck and von den Driesch 1978:35). In order to examine the replicability of this study's measurements, a small test was conducted. A fellow graduate student with no previous experience with measuring bones was given this study's eight measurement descriptions, diagrams, and a brief review of relevant anatomical terminology as it applies to phalanges. The student was given the necessary tools and ten lateral phalanges from ten bison, 5 males and 5 females. The student was asked to read the notes and to take the eight measurements on each of the 10 phalanges recording the measurements per catalogued phalanx for a total of 80 measurements. No verbal help was given. Within the next two days the same task was repeated twice, still using the descriptions but without referring to the previous days work for a final total of three tests or 240 measurements.

The test at the most basic level demonstrated that my diagrams and verbal descriptions were clear enough to be followed. By taking all of the student's recorded measurements and graphing them, it was found that the most replicable measurements were Length (1), Greatest Length (2), Proximal Width (4), Greatest Proximal Height (5) and Width of Distal End (7). These measurements varied by a maximum of plus or minus 0.2 mm.. The next most replicable measurements were Least Breadth of the Diaphysis (6), and Height of the Distal End (8) which varied at most by plus or minus 0.4 mm. The measurement, Proximal Height (3), varied by as much as plus or minus 0.8 mm. The results of this test indicated that measurement 3 varied more than any of the other measurements.

Next, an analysis was made of my own replicability. I measured the same phalanges in the same manner outline above. The same general trends as the student's were found but with even less variability. Measurements of Length (1), Greatest Length (2) and Proximal Width (4) varied by plus or minus 0.05 mm.. Measurements of Greatest Proximal Height (5) and Distal Width (7) varied by plus or minus 0.1 mm.. Least Breadth (6) and Distal Height (8) varied by plus or minus 0.2 mm.. Measurement Proximal Height (3) varied by as much as plus or minus 0.3 mm.. In 50% of all instances there was no variability.

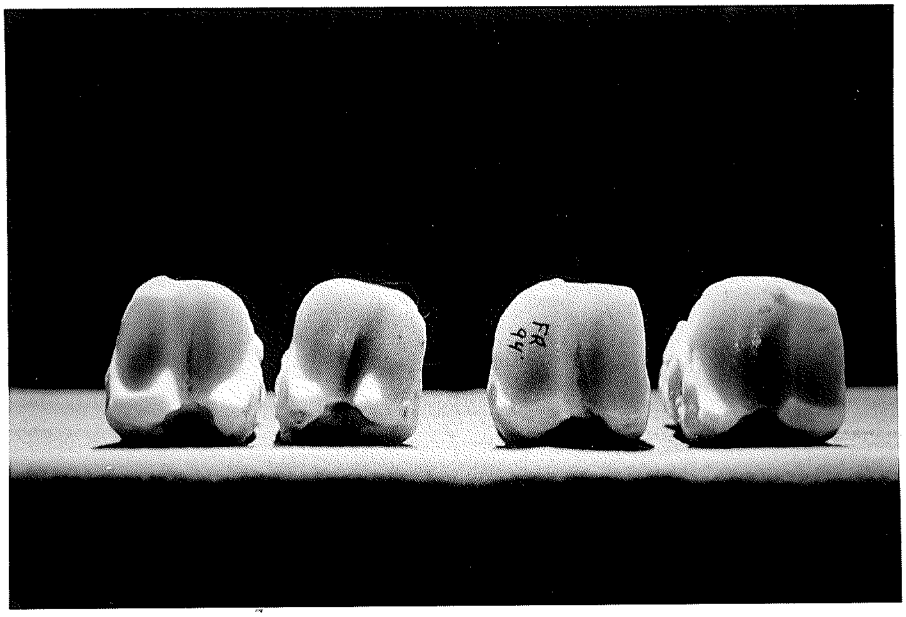
Bedord (1974:200) in her work on metapodials accepted an error of plus or minus 1.0 mm.. Given that the phalanges are approximately 1/3 the length of metacarpals and assuming Bedord's accuracy is acceptable, then an accuracy of plus or minus 0.33 mm. (1/3 X 1.0 mm.) should be acceptable. The variability of Measurement 3, Proximal Height, which was plus or minus 0.3 mm. by my measurements and 0.8 mm. by the student's measurements was too close to the margin of error to be included. The other measurements, 1,2,4,5,6,7 and 8 contained less variation with a range of error at plus or minus 0.2 mm. by my measurements, and were considered useable in this study.

3.3.2 Distinguishing Front From Rear Phalanges

In the archaeological situation it is necessary to be able to distinguish front from rear phalanges for the application of a sexing technique. As both front and rear first phalanges of the Museum Sample were available for study, an attempt was made to select criteria to aid in distinguishing front from rear bones. Dottrens (1946:764-765) had noted for domestic cattle several ways of distinguishing front from rear first phalanges. The distinguishing features were the following: the general silhouette, the proximal end differences, texture of the proximal surface, shape and angle of the articular facet of the sesamoid, and differences in the "V" shape of the palmar proximal articular area (Dottrens 1946:764-765). Duffield (1973:136) suggested that rocking rear lateral phalanges on their palmar surface distinguishes them from front medial phalanges as the axis of the rock is in the reverse direction. Following Dottrens' and Duffield's qualitative observations, an attempt was made to discern front and rear bison phalanges by the same criteria. Of the suggested criteria, only the proximal end differences appeared to aid consistently in distinguishing bison phalanges. Dottrens

(1946:765) described the proximal end of the front phalanges as having a greater width and the rear phalanges as being more elongated in the antero-posterior direction (trans. mine). Therefore, a squarer outline on a proximal articulation indicates front phalanges (Figure 9). A rectangular outline of a proximal articulation with the greater length of the rectangle in the height is used for identifying rear phalanges (Figure 9). Infrequently, due to breakage or individual differences, the proximal articulation is neither square nor rectangular and is unclassifiable.

In attempting to distinguish front from rear phalanges the distal end of the bone was also studied. It was expected, because of the differences in weight carried by front and rear legs and differences in front and rear leg movement, that a morphological difference would be visably discernable. Frequently, the dorsal surface of the distal articulation of the first phalanx in the front feet was either flat or even saddle shaped, whereas in the rear feet the distal articulation had a raised section on the dorsal surface (Figure 9). Without being aware of the sex of the specimens, the available Museum sample was observed for the proximal and distal phalangeal ends. The count of front phalanges (93) is greater than the numbers of front phalanges used in the measurements of Museum specimens (87)



PROXIMAL END, REAR (left) FRONT (right)

DISTAL END, REAR (left) FRONT (right)

Figure 9: Photographs of Distinctions Between Front and Rear First Phalanges

because of the fact that some specimens were sent articulated and could therefore be observed but not measured. The proximal end profiles of the Museum sample, at the front foot were square and at the rear foot were tall rectangles. From the figures in Table 2, it was apparent that if the dorsal surface of the distal end was flattened or saddle shaped there would be a 95.0% chance that it was a front phalanx. If the distal end was raised there is a 92% chance of it being a rear phalanx. Eighty-four percent of the indistinguishable phalanges were rear phalanges and only 16% were front phalanges.

The reading of the proximal end profile should be readily relied upon to distinguish front from rear phalanges. The distal dorsal surface observation can however be used to distinguish those specimens which are otherwise questionable based on the outline of the proximal end. However, in certain instances, some phalanges may remain unclassifiable.

TABLE 2

Tally of Distinctions Between Front and Rear Phalanges, Museum Sample

A. OBSERVATIONS, PROXIMAL END PROFILE

	Square	Tall Rectangular	Indistinguishable
Front	93 (100%)	0	0
Rear	0	86 (100%)	0

B. DISTAL END PROFILE (DORSAL SURFACE)

	Flat, Saddle-Shaped	Raised	Indistinguishable
Front	84 (95%)	5 (8%)	4 (16%)
Rear	4 (5%)	61 (92%)	21 (84%)

3.3.3 Application of a Phalanx Index

As mentioned in Chapter 2, Duffield (1973) proposed that Empel and Roskosz's sexing technique developed on European bison be applied to North American bison. Their phalanx index (width divided by length and multiplied by 100), reliably separated the sexes of European bison aged five years and older (Empel and Roskosz 1963:275).

In order to test Duffield's suggestion, the phalanx index was applied to a portion of the EINP sample, the right lateral phalanges, for a total of one quarter of the whole sample. The results indicated that the phalanx index did not accurately separate the sexes for this sample of North American bison. The female bison index ranges from values of 48.17 to 57.02 and the male bison index from 49.35 to 60.86. A study of these figures indicated that only 12% of the bison were accurately assessed according to sex. An index result below 49.35 indicated females correctly and an index above 57.02 indicated males. The overlapping area contained 88% of the sample and extended from 49.36 to 57.01. As the phalanx index was inapplicable to the EINP population to distinguish sexes, the technique was not pursued further.

In this chapter, the eight measurements chosen for study have been described and illustrated. The reliability of reproducing accurate measurements has been tested resulting in seven of the eight measurements being accepted

(L,GL,PW,GPH,LB,DW and DH). Also, a method based on the shape of the proximal end and distal dorsal surface has been described to aid in separating front from rear phalanges, a necessary step in analysis. And finally, a sexing technique proposed by Duffield (1973) has been attempted and found to be ineffective in making the appropriate sexual distinctions. This study will proceed into a description of the search for a suitable technique for sexing bison first, front phalanges.

Chapter IV

THE SEXING TECHNIQUES AND THE INTERPRETATION OF THE STOTT SITE

The EINP sample is the largest single collection of known sex bison pedal elements in North America. It is expected that a sexing technique developed from the modern EINP sample and tested on the Museum sample could be applied to all plains bison (*Bison bison bison*) of the last 5,000 years. However, there is evidence in the literature to suggest a size diminution within the species during the last 5,000 years (Wilson 1980:81). It may be that the technique developed on modern bison will be applicable to bison older than 100 years in terms of patterned separation, but not in terms of absolute values.

A sexing technique was pursued that would use as few variables as possible in order to reduce the number of measurements taken and in order to include as many archaeological specimens as possible. As the phalanx index tested in Chapter 3 did not work and as no separation using a single measurement in the EINP sample occurred, further analysis including a one-way analysis of variance, testing of normality, a stepwise discriminant analysis and a bivariate scatter was begun.

4.1 ONE-WAY ANALYSIS OF VARIANCE

In order to examine the equality of the means of the two groups of known sex: (the Elk Island National Park sample and the Museum sample), a one-way analysis of variance (F-test) was conducted on the 7 measurements chosen for study. Tests were not run on a comparison of the three groups because the Stott Site material of unknown sex could not be included in the known sex groupings. The F-test is one-tailed (Kirk 1969:59) and is mathematically equivalent to the t-test when there are only two groups to compare (Sokal and Rohlf 1969:204). The test statistic cannot prove equality but it can detect probable inequality. The null hypothesis was that the two samples could be considered drawn from the same population, the alternative hypothesis was that they were not from the same population.

The male bison from both the EINP sample and the Museum sample were compared in three groupings (Table 3). In one case the grouping consisted of all first front phalanges, in the second grouping only left lateral or right medial (LLRM) bones were considered (N=223). In the third grouping only left medial or right lateral (LMRL) bones were considered (N=225). A significance level of 0.05 was chosen which has an area of rejection at values greater than 3.89 with df=1 (Kirk 1969:528). In each of the three groupings the F statistic for measurements 4,5,6 and 7 is large enough to reject the null hypothesis. In the grouping of all bones,

TABLE 3

Results of a One-Way Analysis of Variance Using the Known-Sex EINP and Museum Samples

MALE F STATISTICS, SIGNIFICANCE LEVEL .05, DF=1

Measurements	Grouped	LLRM	LMRL
	n=448	n=223	n=225
1 L	1.76	0.35	1.57
2 GL	5.41	1.67	3.86
4 PW	44.45	20.06	24.15
5 GPH	38.14	17.26	20.05
6 LB	40.35	16.66	23.47
7 DW	20.29	9.04	11.22
8 DH	3.62	0.76	3.22

FEMALE F STATISTICS, SIGNFICANCE LEVEL .05, DF=1

Measurements	Grouped	LLRM	LMRL
	n=125	N=62	N=63
1 L	1.10	0.81	0.34
2 GL	0.83	0.59	0.26
4 PW	5.06	2.90	2.11
5 GPH	0.17	0.00	0.27
6 LB	1.18	0.33	0.89
7 DW	0.11	0.10	0.03
8 DH	1.72	1.56	0.30

Grouped = all phalanges, LLRM & LMRL combined

LLRM = those classed as either left lateral or right medial

LMRL = those classed as either left medial or right lateral the F statistic for measurement 2 was also high enough to reject the null hypothesis, but notably was not as high as measurements 4,5,6 and 7. There was little evidence that the two male populations could be considered dissimilar when using measurements 1 and 8, Length and Distal Height respectively. Some evidence demonstrated dissimilarity for measurement 2, Greatest Length. Considerable dissimilarity was suggested for measurements 4,5,6 and 7. From these results, measurements 1,8 and to some degree measurement 2 show the least sensitivity to differences between bison populations and are therefore most useful in the development of a sexing technique.

The one-way analysis of variance test was also run for the female bison of the EINP and the Museum samples. Groupings were arranged in the same manner as for the males. With a smaller sample size of a minimum of 60 specimens, one degree of freedom and a level of significance at 0.05, the rejection area is above 4.00 (Kirk 1969:528). The interpretation of the data in Table 3 suggest only one rejection of the null hypothesis in the grouped category for measurement 4 (Proximal Width). In all other categories there is no evidence to suggest they have dissimilar means. These results from the females suggest that all of the measurements could be used to establish a sexing technique applicable to other bison populations. However, the results of the male one-way analysis of variance indicated that a technique involving the males is limited to the measurements 1,2 and 8 (L, GL and DH), which necessitates that the females are likewise limited.

Because of the indication from the one way analysis of variance that the three variables, L,GL and DH were the best, work was carried out using these three variables. The other variables in other combinations may also offer clear seaparations, but it was not my intention to test all the possible combinations. I was interested in finding at least one technique which worked to separate the sexes. In order to do so I turned to a stepwise discriminant analysis. Later, a second technique was created, but it resulted in less certainty than the stepwise discriminant analysis. The second technique is included in Appendix B.

4.2 STEPWISE DISCRIMINANT ANALYSIS, SDA

4.2.1 Development of the SDA on the EINP Sample

Sokal and Rohlf (1969:489) advocate the use of discriminant function analysis as a "very useful devise whenever we need to identify unknown specimens and assign them to previously recognized groups". A discriminant function analysis is similar to the t-test in that its purpose is "to discriminate between two groups of data that are each characterized by several different variables" (Doornkamp and King 1971:236). The t-test which uses one variable to attempt the separation may or may not be able to show complete separation with no overlap. Discriminant analysis is useful in that two or more variables can be considered at one time. Each variable is taken as a proportion of its value and "the value of the product may be thought of as projected on to a discriminant axis. This is an axis so placed that the separation of the two groups is brought to a maximum." (Doornkamp and King 1971:237).

Before the application of the SDA, a test was conducted using the complete EINP sample on the previously chosen three measurements (L,GL and DH) to examine if the curves of each were normal. Normal to near normal trends are considered by Oxnard (1973:8) to be a prerequisite to sound multivariate statistics. Normality is indicated by a Sigmoid curve on arithmetic graph paper (Oxnard 1973:83, Sokal and Rohlf 1969:119). The results of these tests demonstrated that measurements L, GL and DH produced Sigmoid curves and were therefore considered normal (Figure 10).

For a discriminant analysis function the Stepwise Discriminant Analysis (SDA) program offered in the BMDP p-Series (Dixon and Brown 1979) was chosen as the most appropriate method for discerning male from female phalanges. Given the results of the one-way analysis of variance and that the Length, Greatest Length and Distal Height measurements were normal, the measurements were entered in the SDA program to compute a linear

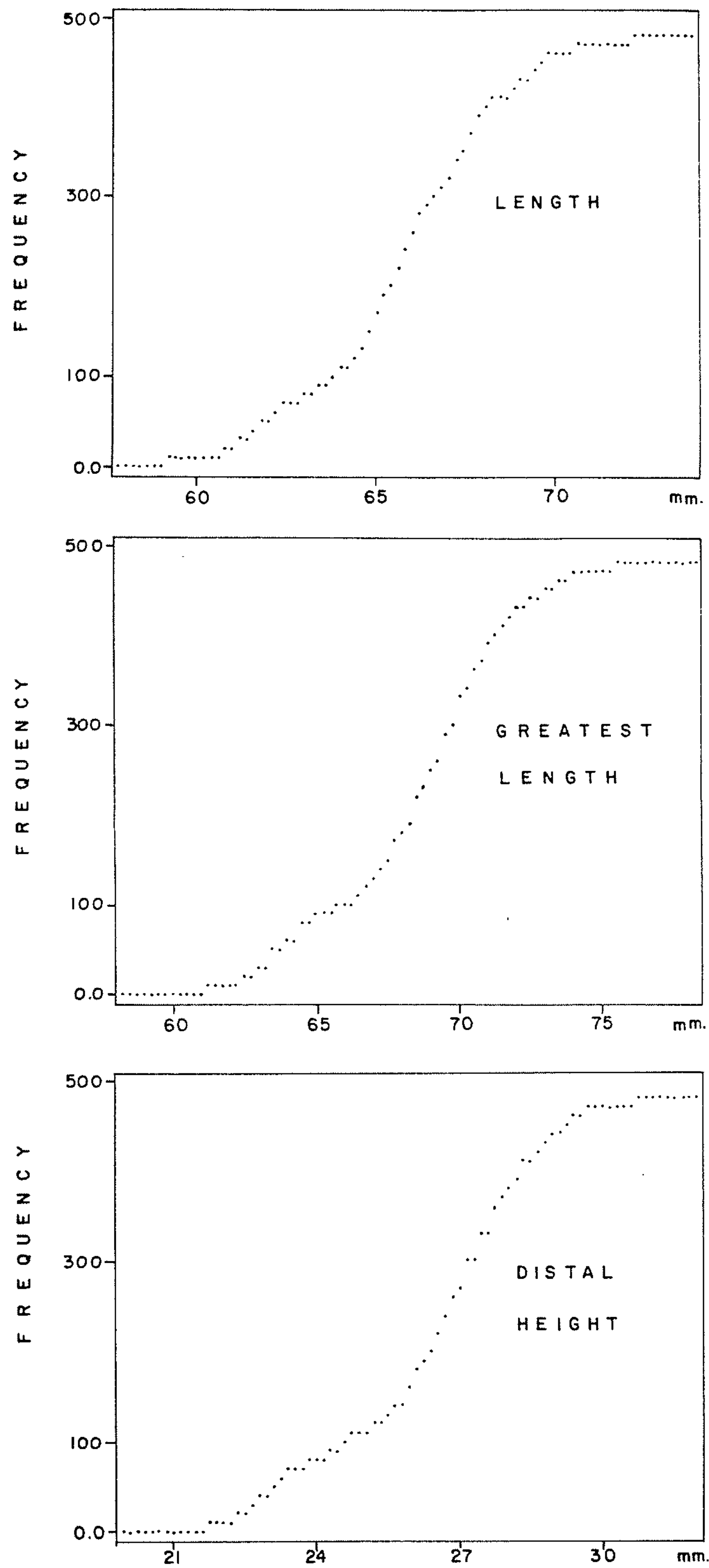


Figure 10: Cumulative Frequency Plots for the Three Measurements, L,GL and DH Based on the EINP Sample

classification function. All attempts to use two measurements were unsuccessful. For example, GL and DH, DH and L, and GL and L were all tested but at most produced insufficient separation for further application in discriminating between males and females. Equations were developed using the two morphologically discernable categories of LLRM and LMRL but they too were ineffective for application to unknown sex samples.

The total EINP sample was used for the development of an effective discriminating equation. The equation is as follows: function = (GL X 0.52067) + (DH X 0.54678) - (L X 0.29469). The product of this linear function can be seen for the EINP population in Figure 11. To transcribe the canonical variables into typical values above zero, the same function was applied to the EINP sample and the results plotted as a histogram (Figure 12). In order to read or plot values accurately, the figures on the "y" axis of the histograms represent the maximum value included in that slot. For example a value of 25.91 is in slot 25.92 and value 29.17 is in slot 29.34. Separation is clearly marked at slots 28.98 and 29.16, which include values from 28.81 to 29.16.

To increase the likelihood of the applicability of the discriminant technique to slightly smaller samples, as might be expected from some archaeological sites, it was decided to try to increase the linear separation shown in Figure 12. A clearly patterned bivariate separation was aimed for, in

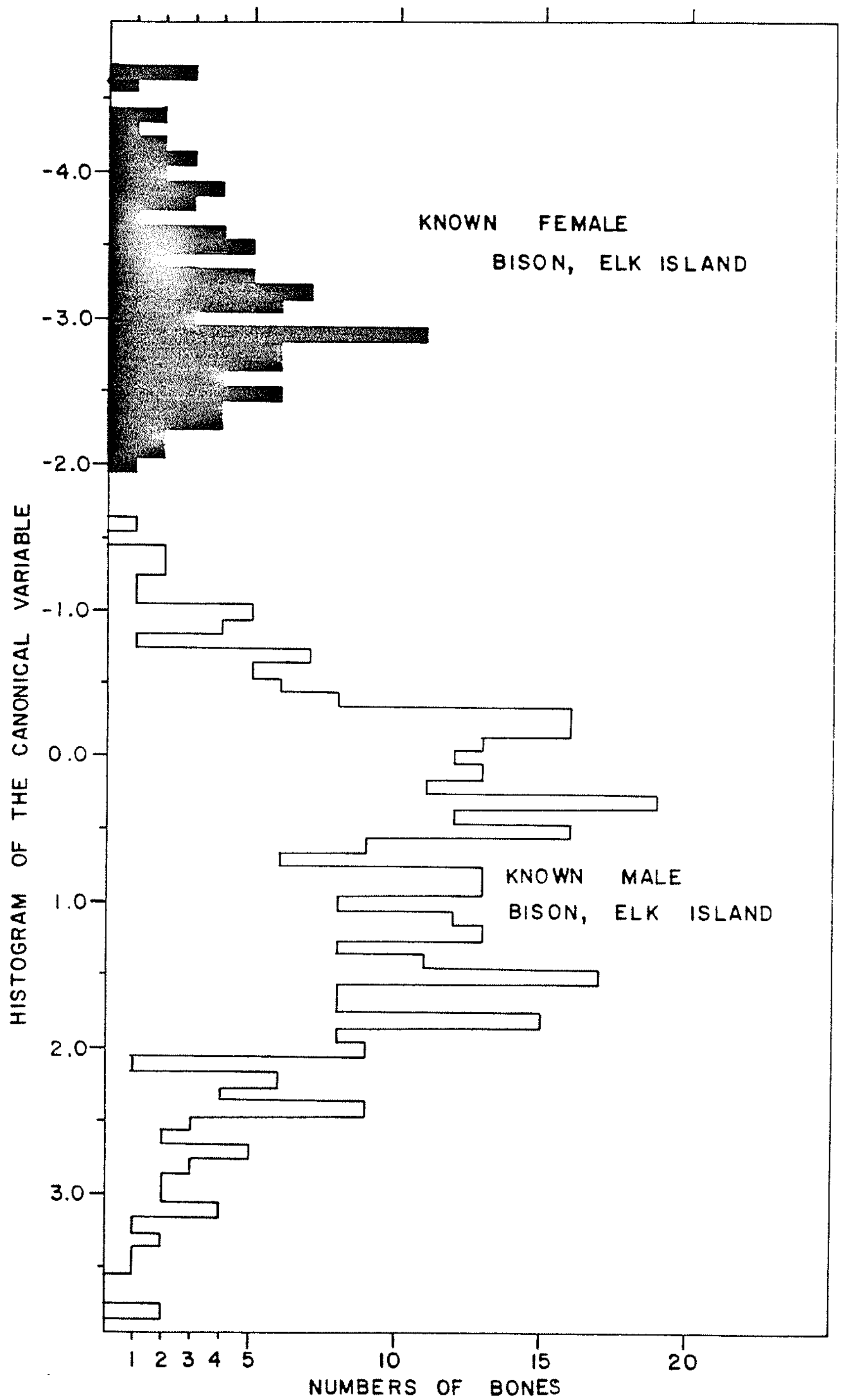


Figure 11: Histogram of the Canonical Variables, EINP Sample

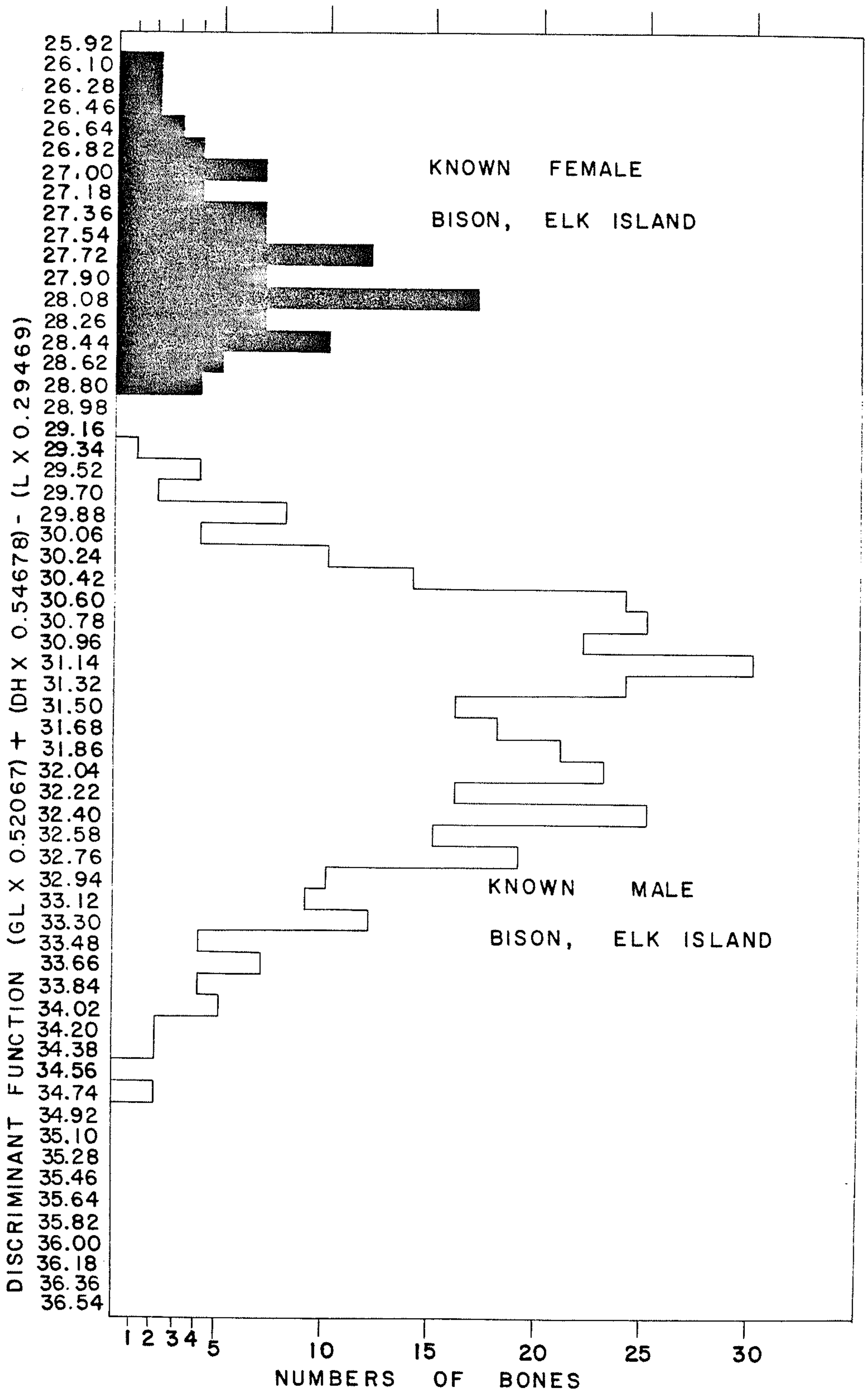


Figure 12: Histogram of the Discriminant Function Equation on the EINP Sample

order to avoid the possibility of an ambiguous interpretation. When the function was plotted on the X axis and any of the three measurements were plotted on the Y axis a clear separation of the male and female bison occurred at slots 28.98 and 29.16 (Figure 13). The EINP sample in each instance separated into clear male and female groupings.

4.2.2 Testing of the SDA Equation on the Museum Sample

The SDA function of (GL X 0.52067) + (DH X 0.54678) - (L X 0.29469) was applied to the Museum sample and plotted as a histogram (Figure 14). Correct separation is clearly marked in the Museum sample at slots 29.16 and 29.34. It is expected that the shift in separation, from 28.98 and 29.16 in the EINP sample, may be due to sample size and differences inherent in comparing a single breeding population like the EINP sample with a smaller and more diverse collection from many areas of North America. Also, the Museum sample is made up of animals collected from as early as the 19th century and perhaps the higher separation area is evidence of a shift in sexual dimorphism of the bison, even as recently as the last one hundred years. Even though the area of division of the EINP and Museum samples is slightly different, the values at slot 29.16 establish a break for both samples. When the discriminant function was plotted on the X axis and any of the other three measurements on the Y axis, the same clear separation was

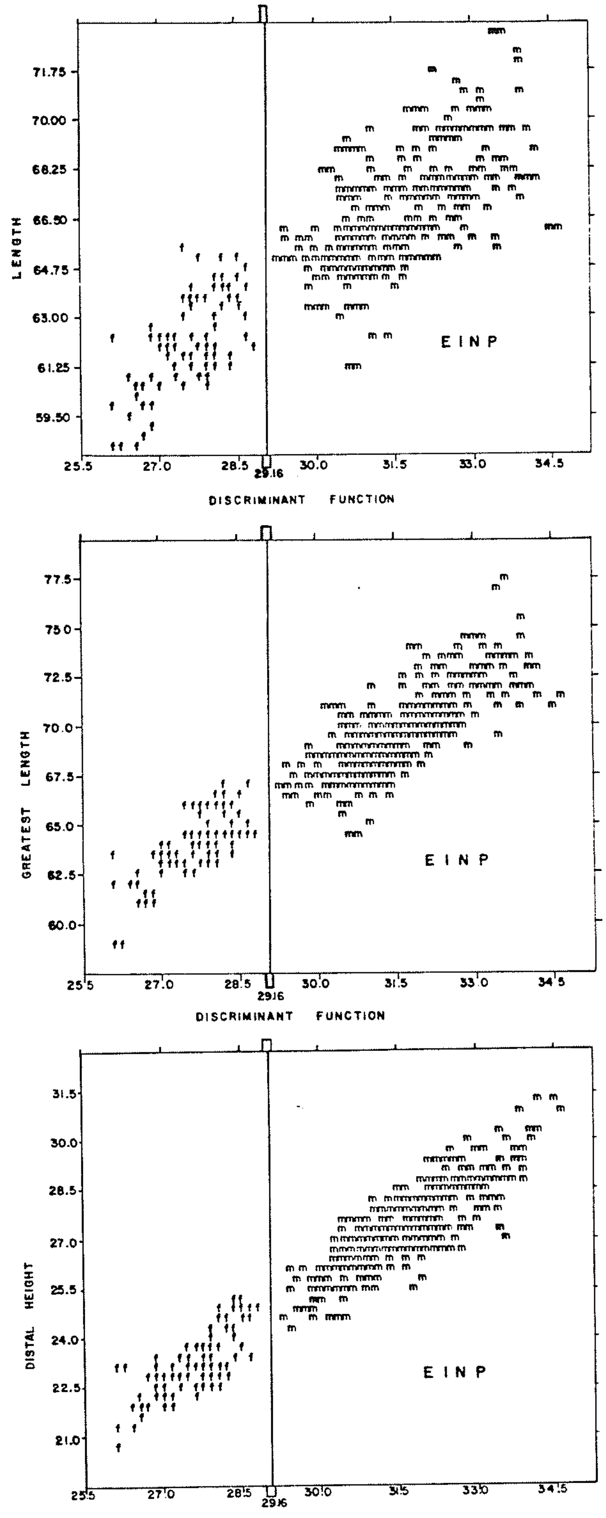


Figure 13: Discriminant Function Against Length, Greatest Length, Distal Height for the EINP Sample

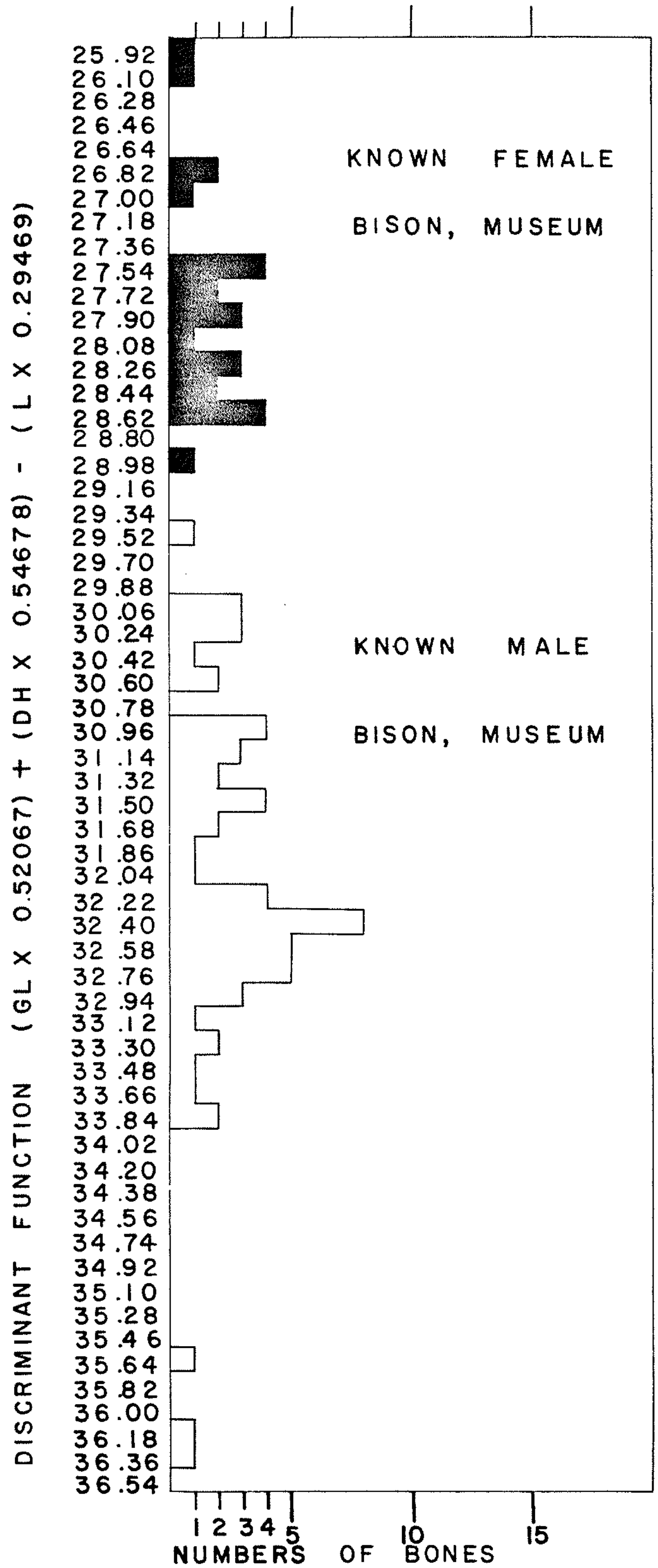


Figure 14: Histogram of the Discriminant Function Equation on the Museum Sample

demonstrated as for the EINP sample at slot 29.16 (Figure 15).

4.2.3 Application of the SDA Equation to the Stott Site Sample

The results of the SDA equation as it applied to the Stott Site can be seen in Figure 16. Since it has been proven that phalanges of male and female bison of known sex from two different samples can be readily separated graphically, it is assumed that the same separation will apply to discriminate the sexes of bison in the archaeological sample.

In order to interpret the graphs of the archaeological phalanges, the pattern of separation, rather than the statistical value, established by the EINP sample was chosen to distinguish the sexes. The literature has already established that horn cores of the modern genus bison have been diminishing through the last 5,000 years, with measurable changes evident within the period of the last few thousand years (Wilson 1980:81). It is expected that other measurable skeletal differences have occurred since 800-1400 A.D. (van Zyll de Jong 1981: pers. com., Reynolds 1981: pers.com.). Therefore it is likely incorrect to try to apply statistically a single value as the separation line to a population which has documented evidence of becoming smaller within the last 5,000 years. As the patterned separation was so clear for the EINP and Museum samples

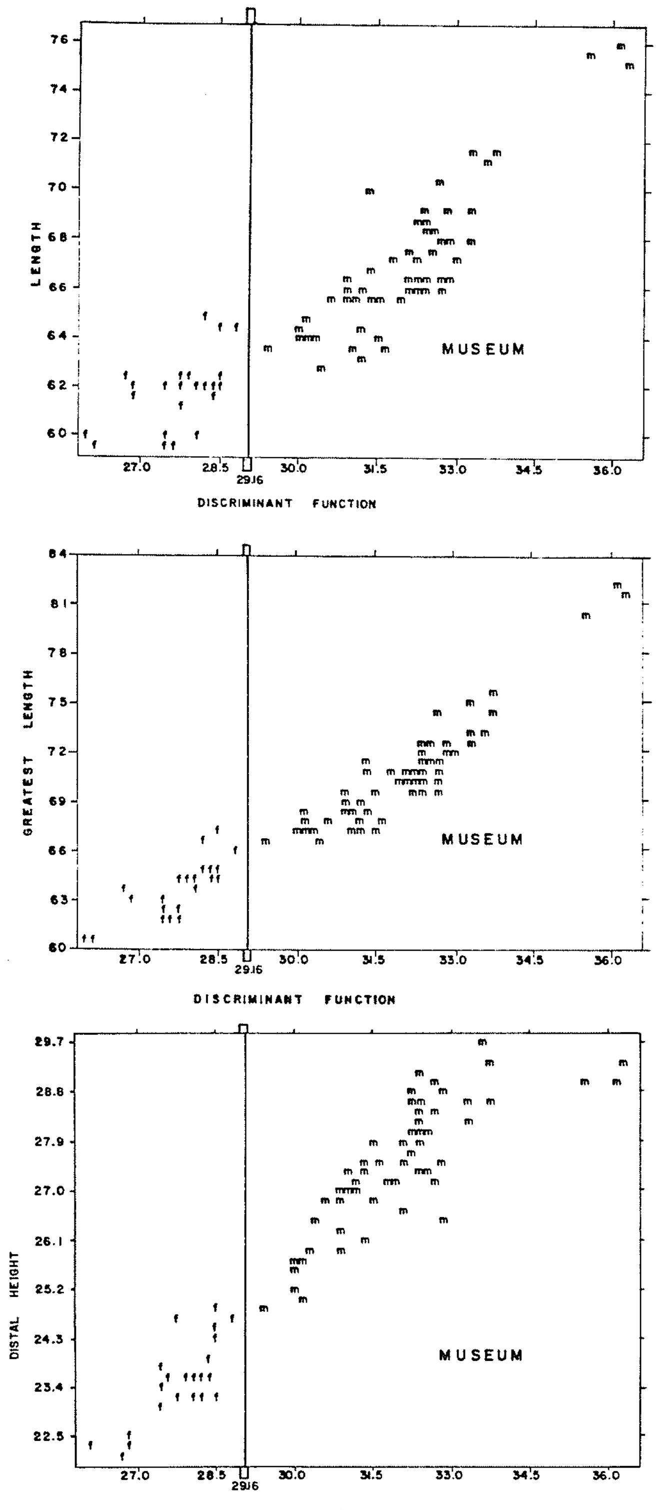


Figure 15: Discriminant Function Against Length, Greatest Length and Distal Height for the Museum Sample

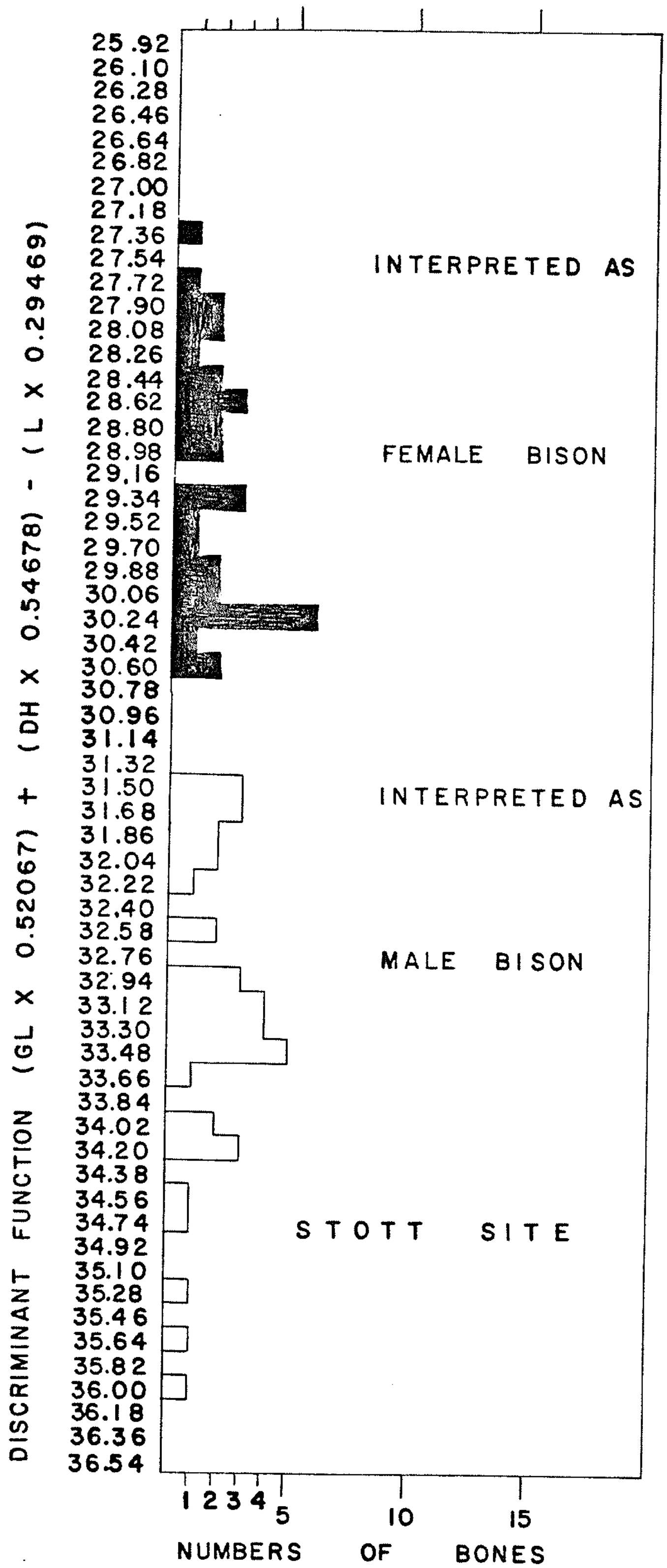


Figure 16 Histogram of Discriminant Function Equation on the Stott Sample

(Figures 13 and 15), it is expected that the same clear separation in a sufficiently large sample correctly divides the males and female adult bison phalanges.

When the discriminant function was plotted against any of the other three measurements, it was noted that separations occurred which were similar to the EINP and the Museum Samples (Figure 17). The separation is not at the same statistical value but is very clear. For clarity in Figure 17, the line of separation at 30.97 was chosen as it is half way between the values included in slots 30.78 and 31.32. In each instance 34 bones were relegated to the female category and 40 bones to the male category. The reference numbers of these bones are listed in Table 4 and further data can be found in Appendix A.

In order to test whether or not the same bones from the Stott Site were being relegated to the same category consistently, short Fortran programs were run for each graph to print the reference numbers of the smaller and larger bones. In no instance was a bone placed in the male category in one analysis and the female category in another analysis.

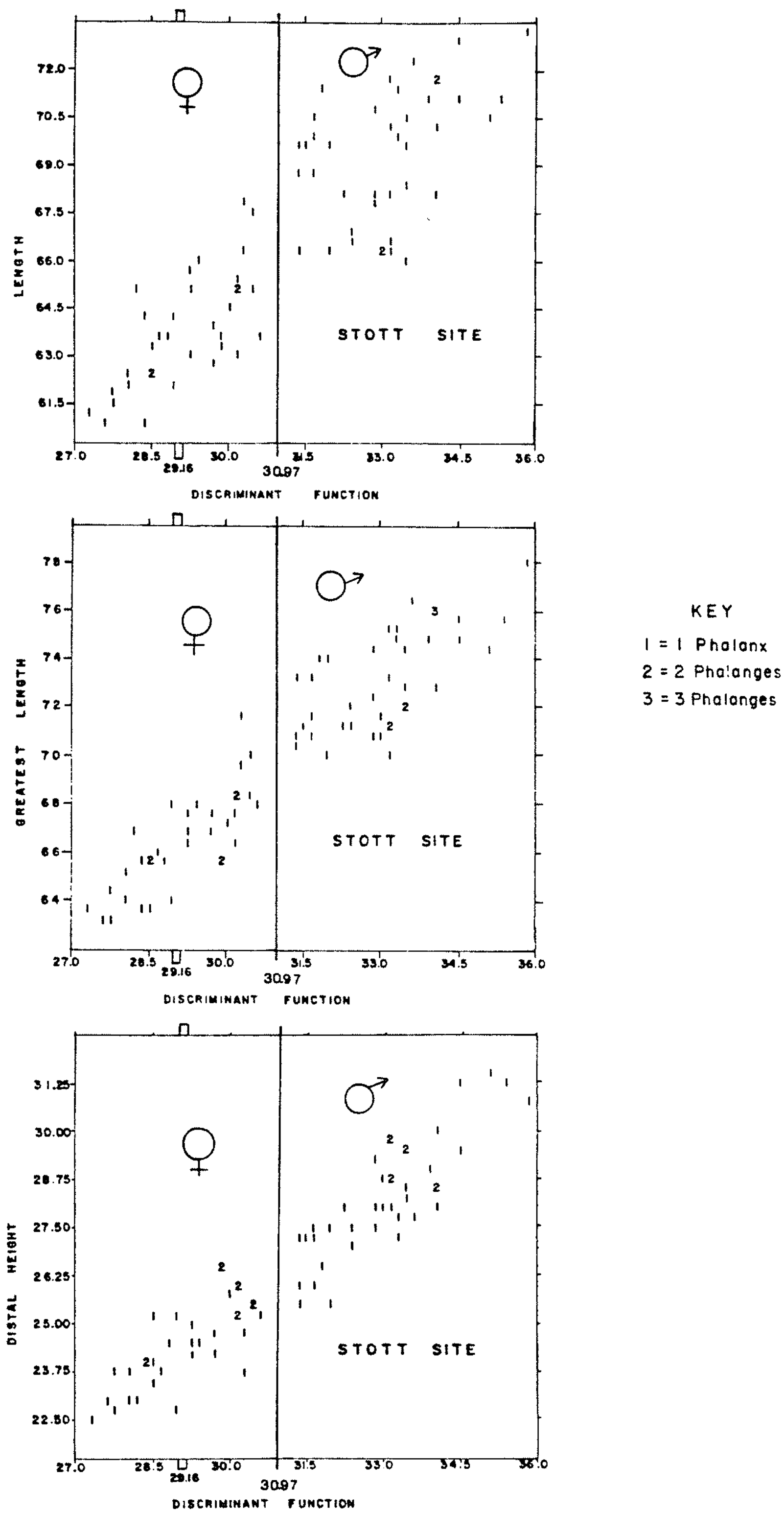


Figure 17: Discriminant Function Against Length, Greatest Length and Distal Height for the Stott Site Sample

TABLE 4

Reference Numbers for Stott Site Male and Female Bison as Determined Using the Discriminant Function

FEMALES N=34			MALES N=40			
253	344	406	251	301	433	463
272	346	421	256	302	443	465
274	354	434	259	303	444	467
284	355	447	260	304	448	472
286	359	453	263	320	451	474
296	360	455	264	345	456	475
297	372	466	268	363	457	493
300	385	471	278	364	459	497
322	391	479	290	420	460	503
323	394	501	295	425	462	515
342	404	507				
		523				

A decision was made to follow the patterned separation rather than the statistical value for application to the archaeological sample. An alternative explanation was to follow the statistical value of separation at slot 29.16, or to argue that no analogy between modern and prehistoric bison can be drawn. It was noted for the Stott Site that if the value 29.16 had been chosen as the separation point there would be an absence of females corresponding to values 25.92 to 27.18 and an absence of males from values 30.78 to 31.32 (Figure 16). Speculation arose concerning these absences, as to whether or not certain age or weight classes were represented, possibly indicating a cultural bias for selectively not killing these animals.

A Fortran program was run to determine if the EINP animals of particular ages or weight fit into the empty slots for the Stott Site. The results did not indicate any particular age or weight category for either the males or females. The females ranged from 4 - 10 years and from 580 to 1465 pounds. The males were from 3 - 12 years and weighed between 995 and 1885 pounds. Therefore the argument of the likelihood of the absence being due to cultural selection of certain age or size grouping was weakened.

It is recognized that the separation slot between values 30.78 and 31.32 for the Stott Site assumes a rapid change in the evolution of bison in the last 1,000 years. References to subspecific changes in as short a period of time as 1,000 years has been hypothesized by Degerbøl (1957:46,47) to explain the dwarf reindeer of the Angmagssalik district of Greenland. A duration of 10,000 years was required for subspecific differentiation of the bear (*Ursus arctos nemoralis*) in Denmark (Kurtén 1955:117).

The amount of documented diminution in horn cores of bison was taken from data in diagrams by Wilson (1980:82) and percentage changes through time were calculated in order to establish a reference of change. From 10,000 B.P. to 200 B.P. the maximum and minimum horn core values have each been reduced by 40%. Horn cores were reduced by 28% comparing 7,000 B.P. to 200 B.P. and reduced 18% by comparing 4500 B.P. to 200 B.P. A rough estimate of a 4% size reduction every 1,000 years can be calculated from these figures.

In order to defend the likelihood of the shift in sexual dimorphism, the percentage of horn core diminution was compared to the percentage of phalangeal change from the Stott Site to the EINP sample, a period of 1,000 years. The minimum and maximum values from the stepwise discriminant function per sex were recorded and the percentages calculated. For both the minimum and maximum values the EINP females appear 5% smaller than the Stott females. The EINP males minimum values have been reduced by 7% and their maximum values reduced by 4% from the Stott males. These percentages are slightly higher than the amount of skeletal change evidenced by the horn core measurements.

If calculations had been made using the statistical value of 29.16 as the separation point, the EINP females at the minimum range have been reduced by 5%, but at the maximum values have not been reduced at all. For the EINP males, the minimum values have not been reduced and the maximum values were reduced by 4%. If the separation point at slot 29.16 is maintained as correct in application to the Stott material, then it appears that at some levels no changes occurred. This paucity of change seems to disagree with the evidence from the diminution of horn cores taken from Wilson (1980:82). Also, the 4% change calculated from Wilson's figures dated up to 200 B.P. excludes an indication of how rapid change has been in the last 200 years. The EINP sample was killed in 1971 due to a park reduction program, and was probably necessitated by an overpopulation of bison. If the forage was already being affected the bison may have been becoming smaller. Also, the population is at least slightly inbred. These additional factors, introduced by man, may have increased the amount of diminution that was already occuring naturally.

In spite of the fact the Guthrie (1980:55) argues relative evolutionary stability of phalanges, it is my opinion that along with horn core diminution, the phalanges also change. The phalanges have become smaller and appear to reflect a reduced weight load over the front feet.

The strongest evidence toward accepting the shift in the area of sexual distinction comes from several examples. In trial runs of both the stepwise discriminant analysis and the bivariate scatter, different variables were used. When a nearly complete split occurred for the EINP sample and was tested on the Stott Site sample, the area of the split was always present and always at higher values. An example that this fact was not inherent in the measurement variables that were being repeatedly tried (L, GL and DH), can be shown by a bivariate scatter of DW against PW X GPH X DW. A histogram of this plot resulted in a near complete separation for the EINP sample at roughly "X" equal to 33 and "Y" equal to 40,000 mm. For the Stott Site the division is slightly higher at "X" equal to 35 and "Y" equal to 50,000 mm.

In the next best stepwise discriminant analysis found nearly to separate the EINP sample (based on four measurements GPH,LB,DW and DH) a higher value of separation was demonstrated by the Stott Site phalanges than by the EINP phalanges. The division for the EINP area was at slots 25.8 and 26.4 and included one misclassified item. The division for the Stott Site occurred at slots 27.6 to 28.2 and included one item. The Stott area of separation is eight slots higher than for the EINP sample. This eight slots difference is also evident in the proposed stepwise discriminant analysis technique which incorporates the measurements, Length, Greatest Length and Distal Height. In repeated examples the separation shift is higher for the Stott Site phalanges than for the EINP sample. It is likely that the change in the area where sexual distinction occurs is a real one and not simply a result of sampling, a particular combination of variables or a particular kind of analysis.

4.3 THE INTERPRETATION OF THE STOTT SITE

The phalangeal measurements can add at least three major contributions to the archaeological information of the Stott Site. They can offer information about bison in terms of evolutionary change, the sex of individual bison and the calculation of minimum numbers of individuals. This information in turn can lead to interpretation of hunting patterns and, if one wanted, calculation of amount of useable meat.

4.3.1 Evolutionary Change

As stated in the section on the application of the stepwise discriminant function to the Stott Site, if the separation area for the Stott Site is between values 30.96 and 31.14 than a rapid change in sexual dimorphism is indicated. The results from this body of work are understood to be an indication of one small portion of bison evolution. Before this change can be totally accepted it would be necessary to test several large dateable archaeological collections before the evidence is completely verified.

4.3.2 Sex and MNI

The sex and minimum number of individuals can be calculated using the results of the phalangeal sexing technique for the Stott Site. The application of the equation derived from the SDA and its graphing as a bivariate scatter, indicated 34 (46%) female bison bones and 40 (54%) male bison bones.

The minimum numbers of sexable bison, unsexable bison and juveniles were estimated using the above figures, faunal counts, the site data (Hamilton *et al*. 1980, Syms 1981 pers. comm.) and considerations for the calculations of MNI in Appendix C. From a total of 182 first phalanges, there were 23 females, 27 males, 26 unsexable bison based on highly fragmented bones and 28 juveniles less than three years old, for a final total of 104 bison. Of course, one would want to compare this estimate to MNI estimates from other skeletal elements in order to derive an overall estimate for the site.

4.3.3 Hunting Patterns

It is apparent from the analysis at the Stott Site, that the sexes were killed in close to equal numbers. The adult female bison represent 46% (23) and the adult males represent 54% (27) of the sexable adults. The number of juveniles (less than three years) were represented in proportion to the number of female bison. For example, pregnancy rates were presented as 52% by Meagher (1973:64) and as 87% by McHugh (1958:32). Meagher (1973:64) also stated that "half of the calves surviving their first winter die before two and one-half years". Working from the Stott Site with 23 females over age 3 and an average of the two pregnancy rates at 69.5% ([52+87]/2), it is expected there would be 16 newborn calves. Within a 2 1/2 year span, there could be another 2 sets of calves born (16 + 16 +16 = 38). By applying Meager's average, only half of the first 16 would survive to two and one half years for a total of 30 juveniles in attendance of 23 adult females over a 2 1/2 year period. This is very nearly equal to the number of Stott Site juveniles (28).

However, if the 26 unsexable adult bison are represented proportionately to the sexes bison, 46% female and 54% male, then the survival rate could be recalculated to a total of 60 expected juveniles. If this is the case then the juveniles are underrepresented in proportion to the female bison at the Stott Site.

4.3.4 Available Meat Calculations

In order to calculate the amount of meat available from the known sex bison, figures were adapted from Halloran (1957:139) on live and dressed weight of American bison. Dressed weight is described as the weight of the meat, fat and bones of the four quarters minus the hide, head and entrails (Halloran 1957:139). As the head and some of the entrails were eaten by historic Native groups and would likely have been eaten prehistorically, and as only the marrow of the bones would have been eaten, Halloran's figures can only be used as a rough estimate. The dressed weight for bulls aged three to 14 years was averaged (737 lb.) and multiplied by the MNI of male bison (27), for a total of 19,900 pounds. The dressed weight for cows aged three to 12 years was averaged (491) and multiplied by the MNI of female bison (23) for a total of 11,295 pounds. The 26 unsexable bison could have added between a minimum of 12,765 pounds if they were all females, to a maximum of 19,160 pounds if they were all males. In order to estimate juvenile poundage Halloran's (1957:139) averaged dressed weights for one to two year bulls and cows were further averaged for an approximate 406 pounds per animal. Therefore, the juvenile bison at the Stott Site could have contributed 11,368 pounds (406 X 28). The sample of excavated bone material represents a possible minimum of between 55,328 to 61,723 pounds of bison meat available for consumption from only a small portion of the Stott Site over at least a 600 year period.

In summary, it has been demonstrated that a sexing technique can be developed from phalangeal measurements of Length, Greatest Length and Distal Height in a stepwise discriminant function. Without question, the technique can be applied to modern bison of the last 100 years. Application of the visual separation is required to distinguish the sexes from an archaeological context. From the visual application of the discriminate function the sex and minimum numbers of bison at the Stott Site were calculated. From these estimations, prospects of evolutionary change are suggested as well as an assessment of prehistoric hunting patterns and meat available for consumption.

Chapter V

CONCLUSIONS

The sexing technique has been developed using the largest collection of plains bison front first phalanges of known sex which are from Elk Island National Park, Alberta. The technique has been tested on a sample of known sex Museum collections from North America and then applied to the Stott Site in Manitoba.

Sexes can be distinquished using an equation developed from a stepwise discriminant analysis. This equation is dependent on three measurements: Length, Greatest Length and Distal Height as follows: (GL X 0.52067) + (DH X 0.54678) - (L X 0.29469). The values of slot 29.16 (28.99 to 29.16) indicate the area of separation for the modern samples. Values below 28.99 are female and above value 29.16 are male. The technique when applied to an archaeological sample should be interpreted using the results of the modern known sex samples and the Stott Site materials as models. Evidence from the Stott Site dated 800-1400 A.D. indicates a separation for the sexes at slots 30.96 and 31.14. Collections older than 5,000 years should not be attempted until further work has been done and further archaeological assemblages have been studied.

Similar sexing techniques may be possible for other Artiodactyls, but it is expected that the separation would be less clear than for bison because of the reduced weight differences over the forelimb in comparison to other cervids and bovids. The innominate may provide an accurate method of distinguishing the sexes, either by size and shape of the birth canal or possibly the presence of suspensory tuberosities for the attachment of the penile ligaments as is reported for some cervids (Taber 1956:18, Dubois 1980, pers. com.). However, in terms of archaeological application, innominates are usually found whole only at catastrophic kill sites and repeated recovery of one specific area of the innominate at non-catastrophic kill sites would be unlikely.

Other long bones on the forelimb might be used for sexing bison. Work is presently being done by Michael Wilson on the metapodials of the EINP collection. It is likely that a stepwise discriminant analysis could be used to sex front second phalanges and perhaps the carpals.

It is not the intent of this thesis to explain the cause of the divergence between the three samples, but some of the following considerations may have produced the observed variation. The collection on which this sexing technique has been developed is the largest known sex group of bison in North America, still, the females are underrepresented. In order to increase the female representation of the EINP sample, a researcher could use specimens from the next herd reduction. Once the samples were prepared and the measurements taken, the samples could be included with these data and the stepwise discriminant function re-evaluated. Until that time, the function as it presently stands is the most precise way to determine bison sex based on first phalanges.

When the three samples are graphed together as in Figure 18, the similarities and differences of the groups are more easily discerned. The Museum sample contains one large male bison (represented by the three bones in the uppermost size range in Figure 18). This bison is from the Swan Hills area of Alberta where the emperor grizzly (Ursus arctos imperator) is particularly large (Soper 1964:288). It may be that the Swan Hills offers a habitat for bears and bison that is especially suitable for growth or this individual may be an unusually large specimen. The inclusion of this bison has extended the size range expressed in the rest of the Museum sample.

On the other hand, the EINP sample, because it comes from a group of confined animals, is slightly inbred with a predisposition toward less size variation than could be expected in an entirely free-ranging population. The sample from the Stott Site contrasts with both the Museum and EINP samples in that it is from a free-ranging herd. Also as Uerpmann (1978:42) points out, "...the population being

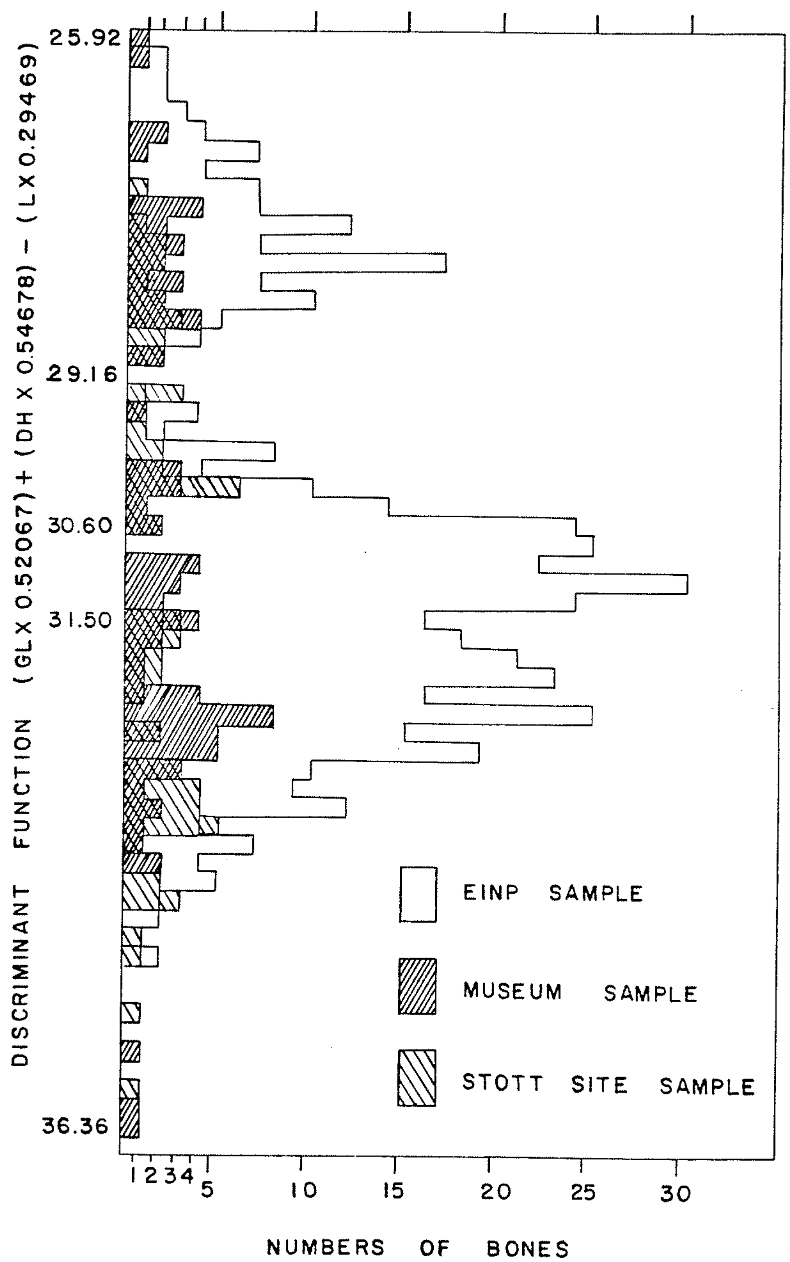


Figure 18: Discriminant Function Expressed by All Three Samples

dealt with in zooarchaeology is a sample from a succession of generations." At the Stott Site it is assumed that related individuals are represented from a 600 year period, whereas the EINP generations are from a period of 65 years. The Museum sample does not contain generations, but single animals collected continent-wide since 1886. Therefore, differences may be due to widely variable environmental conditions and different breeding populations.

As demonstrated for the Stott Site, knowledge of the sex of bison can be used to calculate minimum numbers of individuals and to assess hunting patterns. At certain sites it may be possible to discern differential butchering patterns based on sex information (Bedord 1974:240). In special instances of a sealed catastrophic kill, seasonality may be inferred from herd composition. Once the sexing technique using the stepwise discriminant function is used and reported in the literature, there is a good chance that differences in utilization of bison based on sex will begin to add an interesting aspect to our archaeologically understood history of North America.

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Appendix A

MEASUREMENTS

The following list is the Master Key to the phalangeal data.

Col. 1-2	Stott Site Excavation Units		01-79
		F 4	90
		F 6	91
		T 1	92
		B	93
		C-S	94
		MacNeish Trench	95
Col. 3-4	Stott Excavation Levels		01-18
		Surface	20
Col. 5-7	Reference Numbers,	EINP	000-244
		Stott Site	245-351
		Museum	600-630
Col. 8	Front Phalanx		1
Col. 9	Male		1
	Female		2
Col. 10	Left Side		1
	Right Side		2

Col. 11	Lateral	1
	Medial	2
Col. 12	Right Lateral or Left Medial	1
	Left Lateral or Right Medial	2
Col. 13-14	Age in Years	03-12
	3+ Years	13
	4+ Years	14
	5+ Years	15
Col. 15-18	Weight in Pounds	
Col. 19-22	Length in millimeters	
Col. 23-26	Greatest Length "	
Col. 27-30	Proximal Height "	
Col. 31-34	Proximal Width "	
Col. 35-38	Greatest Proximal Height "	
Col. 39-42	Least Breadth "	
Col. 43-46	Distal Width "	
Col. 47-50	Distal Height "	
Col. 51-54	Index of Prox. Width/Length	

Elk Island National Park, Female Bison

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Col.5              L    GL   PH   PW   GPH LB   DW   DH
    0171212104058060.061.330.230.031.626.029.823.050.0
    0171222204058060.461.530.530.231.726.230.222.850.0
    0171211204058060.162.031.428.833.127.129.821.847.9
    0171221104058060.462.431.329.032.427.229.321.748.0
    0181221105093063.965.831.631.034.427.830.223.248.5
    0181211205093063.665.831.331.033.727.730.723.448.7
    0181222205093063.364.531.732.334.427.631.324.851.0
    0181212105093063.164.632.532.234.327.831.125.051.0
    0211221112095062.363.532.231.535.329.630.824.050.6
    0211211212095062.463.232.731.035.129.430.523.449.7
    0211222212095061.963.032.332.535.629.031.024.652.5
    0211212112095061.963.033.133.035.229.431.224.453.3
    0221221109097062.063.730.731.433.028.529.322.650.6
    0221211209097062.063.531.531.433.728.629.122.350.6
    0221222209097061.662.932.232.135.328.230.623.452.1
    0221212109097061.863.532.732.635.528.630.223.952.8
    0241221108100564.366.332.033.134.230.530.923.751.5
    0241211208100564.466.231.433.134.130.230.323.251.4
    0241222208100565.165.432.534.136.229.931.524.352.4
    0241212108100565.065.733.034.436.129.531.524.653.0
    0261221108102064.767.132.131.034.729.630.123.348.0
    0261211208102064.266.831.830.734.430.130.122.747.8
    0261222208102065.266.031.833.635.129.130.623.051.5
    0261212108102065.365.832.033.335.128.830.322.851.0
    0321221104095060.762.731.330.332.626.930.022.449.9
    0321211204095060.862.131.430.232.526.529.321.950.0
    0321222204095060.662.332.031.433.626.130.023.651.8
    0321212104095060.961.632.131.633.226.529.923.451.9
    0351221105085061.864.032.530.234.528.830.323.348.9
    0351211205085061.964.432.430.034.628.930.022.848.5
    0351222205085061.663.932.231.934.727.529.824.351.8
    0351212105085061.763.532.331.434.027.529.723.950.9
    0531221106114063.264.532.132.633.930.230.123.251.6
    0531211206114063.664.432.232.433.329.730.023.150.9
    0531222206114063.864.432.533.834.529.931.125.153.0
    0531212106114063.864.532.834.034.629.331.124.953.3
    0541221112099063.765.733.931.937.230.030.622.450.1
    0541211212099064.065.935.331.338.029.630.822.248.9
    0541222212099063.864.433.432.935.628.531.223.751.6
    0541212112099063.864.734.033.337.030.330.823.252.2
    0571221108088063.865.832.231.034.029.030.522.848.6
    0571211208088063.966.031.531.833.928.430.523.249.8
    0571222208088064.065.233.833.136.528.430.824.851.7
    0571212108088063.965.132.832.635.728.430.924.451.0
    0601221106099062.364.533.932.736.430.230.222.652.5
    0601211206099062.064.233.832.936.330.730.622.953.1
    0601222206099061.263.133.033.234.728.931.024.054.2
    0601212106099061.562.732.732.934.829.030.523.853.5
    0691221108101261.264.031.830.234.629.029.122.649.3
    0691211208101261.665.032.730.535.729.229.522.449.5
    0691222208101261.263.432.131.635.428.429.923.751.6
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Col.5              L    GL   PH   PW   GPH LB   DW   DH
     0691212108101260.963.132.031.634.528.529.523.451.9
     0721221107109063.764.731.932.433.729.031.023.750.9
     0721211207109063.864.332.532.933.929.031.223.851.6
     0721222207109063.764.033.234.134.529.832.725.153.5
     0721212107109063.464.432.534.134.629.232.224.553.8
     0761221109087558.861.431.530.333.126.729.622.051.5
     0761211209087558.661.031.230.432.527.229.322.151.9
     0761222209087558.659.130.931.431.726.930.123.053.6
     0761212109087558.459.230.931.131.426.930.523.153.2
     0791221108146562.164.230.530.932.628.329.821.949.9
     0791211208146562.164.031.030.833.028.430.021.849.6
     0791222208146561.862.930.932.032.928.030.623.251.8
     0791212108146562.463.230.732.432.228.230.523.251.9
     0841221109092561.164.132.032.035.830.832.223.152.4
     0841211209092561.063.932.531.836.131.232.223.152.1
     0841222209092562.164.432.934.236.230.933.924.855.0
     0841212109092562.264.633.234.136.530.634.024.554.8
     0851221110117559.461.830.831.533.128.229.721.453.0
     0851211210117560.061.930.631.233.428.329.821.252.0
     0851222210117559.761.230.532.432.928.130.722.754.3
     0851212110117559.261.230.332.033.228.030.022.854.0
     0961221112094561.364.833.831.735.928.130.223.351.7
     0961211212094560.464.134.031.635.628.530.222.652.3
     0961222212094561.463.932.833.435.029.031.624.054.4
     0961212112094561.163.333.233.335.128.831.523.854.5
     0981221106101561.764.132.632.134.328.630.822.652.0
     0981211206101561.763.732.032.333.628.530.222.352.4
     0981222206101561.063.232.732.834.429.030.622.753.8
     0981212106101561.263.232.232.833.928.530.522.753.6
     1001221109100062.363.631.631.633.328.829.422.150.7
     1001211209100062.563.532.031.533.828.929.822.450.4
     1001222209100062.063.131.432.633.328.430.423.352.6
     1001212109100062.363.132.032.333.729.030.222.851.8
     1021221109102561.464.533.133.235.329.830.522.954.1
     1021211209102561.764.633.432.435.029.330.723.052.5
     1021222209102562.263.633.533.734.529.031.420.654.2
     1021212109102562.163.633.233.734.329.231.423.854.3
     1081221109105061.563.531.832.033.328.330.423.252.0
     1081211209105062.163.532.732.333.728.230.122.752.0
     1081222209105061.663.632.332.935.127.431.924.453.4
     1081212109105061.563.632.832.935.227.231.524.353.5
     1111221115100062.964.633.131.534.928.731.223.750.1
     1111211215100062.464.132.632.035.428.430.823.651.3
     1111222215100062.663.433.233.035.528.531.224.852.7
     1111212115100062.663.533.333.035.528.531.824.652.7
     1131221108105064.566.732.531.736.929.531.522.749.1
     1131211208105064.566.733.532.138.530.031.522.649.7
     1131222208105063.164.531.533.034.728.031.122.852.3
     1131212108105063.064.532.433.335.828.331.622.852.9
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<u>Elk Island National Park, Male Bison</u>

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Col.5                   L    GL   PH   PW   GPH  LB   DW   DH
        000112220310406 6.068.636.735.738.832.035.126.754.1
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0001122203104066.068.636.735.738.832.035.126.754.1
0001112103104065.867.936.436.037.932.035.326.954.7
0001111203104065.868.636.834.039.031.034.725.951.7
0001121103104065.969.236.434.139.031.234.826.251.7
0031122203110069.070.236.037.438.333.035.426.354.2
0031112103110069.270.435.837.238.433.036.426.353.8
0031111203110068.970.934.635.638.433.534.825.251.7
0031121103110069.170.636.035.838.133.534.825.851.8
0041122203112065.568.136.937.040.832.235.827.256.5
0041112103112065.567.837.637.240.332.736.227.456.8
0041111203112064.768.837.335.440.331.436.326.654.7
0041121103112064.869.337.035.640.831.536.226.754.9
0051112114159066.570.038.639.641.534.837.029.059.5
0051111214159066.970.438.437.842.035.436.927.556.5
0061122204155066.271.040.441.844.136.440.631.363.1
0061112104155066.171.441.642.043.936.440.730.963.5
0061121104155067.372.040.739.543.835.239.029.758.7
0061111204155067.071.340.939.644.835.038.829.059.1
0111122203108066.969.636.436.537.831.737.328.254.5
0111112103108067.169.937.036.638.131.237.128.654.5
0111121103108066.568.838.335.439.431.236.226.953.2
0111111203108066.369.238.435.538.830.935.926.753.5
0131122208162064.766.936.238.041.032.735.526.558.7
0131112108162064.467.237.038.240.232.635.326.659.3
0131121108162064.368.336.136.240.331.635.026.056.3
0131111208162064.467.736.436.340.132.035.325.956.4
0191122207152666.268.636.539.738.533.336.228.060.0
0191112107152666.268.436.539.938.533.536.127.960.3
0191121107152665.968.437.538.839.434.035.026.658.9
0191111207152666.168.537.939.039.134.235.426.559.0
0231122203094065.568.334.234.737.130.934.026.053.0
0231112103094065.267.734.035.137.030.933.625.953.8
0231121103094065.768.836.532.738.230.532.424.550.0
0231111203094065.167.235.032.437.530.532.524.549.8
0251122203119567.770.838.037.340.333.636.929.155.1
0251112103119567.170.238.137.539.833.136.929.055.9
0251121103119568.172.038.235.940.032.535.527.052.7
0251111203119567.471.038.235.539.432.435.527.552.7
0291122203108068.970.936.137.139.733.136.728.753.8
0291112103108069.271.335.937.039.733.236.328.653.4
0291121103108068.771.738.236.640.234.336.327.353.3
0291111203108068.371.137.136.340.834.436.627.353.1
0301122204125066.068.235.937.040.431.634.027.656.1
0301112104125065.968.435.737.540.631.634.827.257.0
0301121104125066.269.835.834.740.131.533.926.152.4
0301111204125066.269.536.535.140.731.334.826.453.0
0311122203099564.766.835.636.038.932.037.728.155.6
0311112103099564.866.835.436.838.231.537.828.256.8
0311111203099564.768.336.535.139.732.936.126.954.2
0311121103099564.568.537.034.840.731.536.027.054.0
0331122205138067.670.637.638.539.733.437.928.357.0
0331112105138067.770.337.438.539.634.539.229.356.9
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Col.5               L    GL   PH   PW   GPH  LB   DW   DH
     033111120513806 7.670.537.037.139.534.136.828.454.9
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Col.5               L    GL   PH   PW   GPH LB   DW   DH
     0331111205138067.670.537.037.139.534.136.828.454.9
     0331121105138067.570.437.637.140.234.537.328.955.0
     0341122207138067.669.636.037.539.833.436.727.955.5
     0341112107138067.669.535.837.539.832.836.127.155.5
     0341111207138067.570.337.036.540.333.534.825.454.1
     0341121107138067.670.636.237.240.433.134.525.655.0
     0361122203098065.267.535.534.138.030.535.628.352.3
     0361112103098065.667.535.934.538.129.835.327.852.6
     0361111203098065.968.634.232.736.830.235.226.349.6
     0361121103098066.068.535.032.836.529.535.026.349.7
     0371122206101066.369.236.736.337.432.037.029.954.8
     0371112106101065.969.536.535.637.632.637.130.454.0
     0371111206101066.371.235.734.639.230.635.327.052.2
     0371121106101066.170.535.534.439.031.435.627.252.0
     0381122203178063.065.736.237.639.634.036.627.259.7
     0381112103178063.065.637.237.639.933.836.127.159.7
     0381111203178063.466.237.636.840.934.534.425.658.0
     0381121103178063.266.536.536.241.634.333.825.957.3
     0391122205156069.272.238.240.042.636.037.928.057.8
     0391112105156069.872.238.340.342.436.338.027.757.7
     0391111205156069.771.839.037.943.036.537.426.054.4
     0391121105156069.572.438.837.942.636.738.326.954.5
     0401122215114066.169.037.037.440.632.034.426.556.6
     0401112115114066.068.337.437.941.431.733.926.457.4
     0401111215114065.669.036.536.140.530.933.325.455.0
     0401121115114066.269.436.535.940.031.033.625.654.2
     0411122203092064.666.835.236.037.131.036.026.855.7
     0411112103092064.866.935.136.036.931.335.326.655.6
     0411111203092064.567.835.134.536.631.434.625.153.5
     0411121103092064.567.736.034.536.932.334.825.553.5
     0421122205148068.270.537.639.237.835.236.426.557.5
     0421112105148068.570.838.039.941.334.836.326.258.2
     0421111205148067.769.635.137.240.432.335.525.954.9
     0421121105148068.069.835.537.640.433.035.725.955.3
     0431122203096066.066.435.034.436.331.433.726.152.1
     0431112103096065.866.934.635.036.630.933.726.253.2
     0431111203096065.668.033.633.536.531.333.724.951.1
     0431121103096065.167.834.133.736.231.433.324.251.8
     0441122209166067.870.239.039.342.736.236.826.958.0
     0441112109166067.770.937.739.541.934.735.727.858.3
     0441111209166067.872.239.337.942.035.036.026.755.9
     0441121109166067.871.638.938.442.436.736.628.056.6
     0461122204104066.068.336.337.038.731.836.027.856.1
     0461112104104065.768.036.237.438.931.935.527.457.0
     0461111204104064.967.636.635.838.832.034.626.855.2
     0461121104104065.668.637.036.238.931.534.326.955.2
     0491122207152066.268.237.737.341.433.937.428.456.3
     0491112107152065.768.038.037.640.834.137.728.557.2
     0491111207152065.667.738.136.040.634.035.826.454.9
     0491121107152066.468.837.736.041.034.135.826.354.2
     0501122208164065.769.037.338.941.434.138.327.559.2
     0501112108164065.768.135.738.640.434.237.127.258.8
     0501111208164066.369.238.237.240.733.736.426.056.1
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Col.5                 L    GL   PH   PW   GPH LB   DW   DH
     0501121108164066.069.738.537.940.834.636.026.157.4
     0511122212159064.868.536.839.240.534.536.426.860.5
     0511112112159065.268.537.038.939.834.035.926.859.7
     0511111212159064.768.537.737.741.134.436.226.158.3
     0511121112159064.667.937.837.540.835.035.226.758.0
     0521122209182068.873.039.240.443.037.439.330.258.7
     0521112109182068.371.839.340.342.736.338.429.259.0
     0521111209182068.973.539.138.743.336.338.128.156.2
     0521121109182068.774.038.839.143.536.437.227.856.9
     0551122207160068.772.337.840.742.136.037.428.759.2
     0551112107160067.771.837.840.642.135.737.629.460.0
     0551111207160069.673.038.640.143.037.536.527.257.6
     0551121107160069.973.638.640.242.737.436.627.157.5
     0581122206140065.168.337.039.040.734.936.928.359.9
     0581112106140065.167.837.638.840.635.336.927.859.6
     0581111206140065.468.736.936.240.433.736.426.155.4
     0581121106140064.969.137.037.040.434.136.426.057.0
     0711122205142368.072.236.839.439.833.438.530.257.9
     0711112105142367.571.937.038.740.032.837.629.657.3
     0711111205142367.972.039.438.342.234.338.028.856.4
     0711121105142367.972.139.638.042.634.638.128.856.0
     0731122207161567.469.936.939.540.234.537.428.858.6
     0731112107161567.170.038.139.440.935.138.029.258.7
     0731111207161567.370.538.136.940.533.537.227.354.8
     0731121107161566.369.538.036.839.733.836.026.955.5
     0741112107146566.368.336.839.338.733.637.229.559.3
     0741111207146566.868.935.637.238.133.336.227.555.7
     0751122207156567.871.338.039.740.435.039.531.358.6
     0751112107156568.069.737.038.241.235.537.728.956.2
     0751111207156567.771.237.537.141.535.435.327.254.8
     0751121107156567.871.139.138.240.834.638.228.956.3
     0781122209156567.069.938.338.340.233.137.229.457.2
     0781112109156567.370.337.737.840.533.537.229.856.2
     0781111209156566.269.338.036.441.132.835.527.755.0
     0781121109156567.070.537.437.041.233.936.027.455.2
     0861122209188567.069.737.438.741.433.436.426.557.8
     0861112109188566.369.636.938.741.233.136.826.658.4
     0861111209188565.568.936.836.439.834.036.326.055.6
     0861121109188566.169.537.236.340.433.435.725.854.9
     0871122211171570.673.239.742.043.437.539.629.159.5
     0871112111171571.074.440.441.944.437.340.329.359.0
     0871111211171570.574.339.940.343.336.538.927.957.2
     0871121111171570.474.339.239.942.536.938.227.656.7
     0901122206161564.867.738.038.240.834.136.527.558.9
     0901112106161567.870.137.737.740.533.336.127.855.6
     0901111206161567.670.738.535.640.034.935.426.452.7
     0901121106161564.568.437.836.340.732.233.526.956.3
     0911122211141568.970.238.338.840.834.539.329.456.3
     0911112111141569.570.638.038.540.734.138.329.555.4
     0911111211141568.971.637.637.641.333.535.727.354.6
     0911121111141568.671.338.037.640.834.036.327.454.8
     0921122209144565.467.737.438.241.733.837.226.558.4
     0921112109144565.467.537.838.341.633.536.626.358.6
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Col.5                L   GL   PH   PW   GPH LB   DW   DH
     0921111209144564.669.436.837.040.734.036.525.457.3
     0921121109144565.368.936.237.040.134.136.525.656.7
     0931122211166570.573.238.139.142.634.537.526.755.5
     0931112111166570.573.639.739.042.534.637.426.655.3
     0931111211166570.274.037.636.941.633.534.925.452.6
     0931121111166570.474.038.737.542.633.535.025.853.3
     0941122208164066.569.636.538.739.933.237.327.858.2
     0941112108164066.169.237.238.741.233.536.427.558.5
     0941111208164066.269.937.538.641.034.034.627.658.3
     0941121108164065.969.837.837.040.833.634.727.156.1
     0951122215158564.667.138.440.441.134.737.728.262.5
     0951112115158564.667.238.139.741.234.637.727.861.5
     0951111215158565.168.337.838.641.734.834.526.459.3
     0951121115158565.168.038.439.242.535.234.126.160.2
     0971122206144565.066.935.037.538.932.836.025.957.7
     0971112106144565.266.634.437.439.232.535.925.857.4
     0971111206144564.668.634.636.140.434.035.024.555.9
     0971121106144565.369.435.336.240.034.635.124.655.4
     1011122215174067.872.141.140.244.035.938.127.759.3
     1011112115174067.671.240.840.544.436.338.427.759.9
     1011111215174068.672.141.739.644.635.638.326.157.7
     1011121115174068.872.342.239.145.136.837.026.256.8
     1031122212187572.375.542.343.545.437.641.429.160.2
     1031112112187572.275.742.843.045.738.840.428.859.7
     1031111212187573.077.542.041.745.036.837.726.957.2
     1031121112187573.176.941.241.845.036.137.027.457.2
     1041122206160066.969.337.438.239.833.037.227.057.1
     1041112106160066.369.037.438.140.633.137.826.957.5
     1041111206160067.170.137.536.140.833.435.825.253.8
     1041121106160067.269.838.136.440.333.036.125.654.2
     1051122215172567.169.038.040.142.336.538.028.459.8
     1051112115172567.868.938.940.242.335.037.728.359.3
     1051111215172567.069.838.538.442.735.536.726.957.3
     1051121115172566.869.038.638.242.434.836.826.657.2
     1061122215155068.071.237.538.940.434.738.228.357.2
     1061112115155068.271.437.238.640.433.837.828.256.6
     1061111215155066.771.238.536.440.033.637.026.754.6
     1061121115155067.571.638.737.039.634.636.726.554.8
     1101122206162565.769.635.437.138.532.736.226.856.5
     1101112106162565.969.835.637.439.232.635.426.656.8
     1101111206162566.370.037.536.039.134.034.224.754.3
     1101121106162566.069.537.136.039.633.533.825.154.5
     1121122210155063.966.936.338.639.334.036.126.760.4
     1121112110155064.167.136.838.640.134.035.826.660.2
     1121111210155064.066.838.137.039.233.234.025.557.8
     1121121110155064.767.537.637.039.633.734.025.757.2
     1161122206130567.070.439.237.840.332.736.828.256.4
     1161112106130567.470.238.638.039.633.436.928.256.4
     1161111206130567.270.339.836.141.433.036.226.653.7
     1161121106130567.271.038.936.541.033.136.627.254.3
     1171122204102565.268.336.135.739.232.336.127.254.8
     1171112104102565.168.038.036.139.632.035.926.555.5
     1171111204102565.068.737.034.839.632.534.825.653.5
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Col.5 L GL PH PW GPH LB DW DH

1171121104102564.768.536.534.338.632.534.325.253.0
1181122208147565.568.136.739.740.633.836.628.260.6
1181112108147565.368.436.339.139.434.136.227.359.9
1181111208147565.369.637.037.940.033.835.726.958.0
1181121108147565.268.736.338.239.734.136.227.158.6
1191122207160068.869.836.638.840.133.238.026.956.3
1191112107160069.070.437.039.340.034.037.826.757.0
1191111207160068.470.836.336.439.734.835.724.753.2
1191121107160068.471.236.337.140.035.035.624.654.2
1201122206143065.168.338.237.441.433.237.528.357.4
1201112106143065.268.739.337.642.233.438.128.557.7
1201111206143064.567.238.436.041.833.336.927.255.8
1201121106143064.467.537.936.441.133.736.427.256.5
1211122210157565.066.935.236.938.432.534.425.956.8
1211112110157565.067.235.337.139.232.535.426.157.1
1211111210157564.667.436.035.839.533.334.025.155.4
1211121110157565.268.335.536.039.433.233.625.655.2
1241122208150064.566.937.638.339.833.235.227.259.4
1241112108150064.367.336.038.238.833.735.027.959.4
1241111208150063.367.536.537.238.533.434.326.458.8
1241121108150064.869.137.437.740.333.434.626.058.2
1251122209167570.472.940.240.743.135.739.528.957.8
1251112109167570.273.039.140.542.536.039.429.257.7
1251111209167570.574.339.539.643.236.537.627.856.2
1251121109167571.274.540.440.344.037.037.027.456.6
1261122210167567.071.138.040.642.335.738.528.460.6
1261112110167567.171.338.840.643.035.538.128.360.5
1261111210167566.971.837.639.041.436.036.527.458.3
1261121110167567.070.937.038.540.735.536.127.157.5
1271122207140065.569.037.038.239.333.037.227.258.3
1271112107140065.069.036.237.739.633.437.727.958.0
1271111207140065.969.535.936.440.131.734.625.755.2
1271121107140066.169.935.736.840.332.035.025.955.7
1301122207142566.870.439.038.841.133.437.728.958.1
1301112107142567.170.138.539.040.734.538.229.158.1
1301111207142566.669.137.637.140.033.135.926.655.7
1301121107142566.869.338.137.440.032.936.127.156.0
2011122208154065.868.236.737.340.734.036.127.056.7
2011112108154065.868.436.537.641.234.536.227.157.1
2011111208154065.567.937.236.040.034.534.525.455.0
2011121108154066.267.837.236.240.235.034.426.154.7
2021122210174067.470.339.440.043.236.338.029.159.3
2021112110174067.470.039.339.742.035.638.129.058.9
2021111210174067.470.239.538.542.436.036.727.257.1
2021121110174067.870.339.638.443.035.636.027.456.6
2031112107175068.771.739.841.045.238.139.630.159.7
2031111207175068.272.640.139.444.137.738.827.957.8
2041122215172567.570.038.038.641.934.038.229.457.2
2041112115172567.469.538.139.042.534.938.429.757.9
2041111215172567.870.936.937.041.434.337.628.054.6
2041121115172568.071.938.637.441.934.837.828.455.0
2051122207180068.172.939.940.742.735.338.728.859.8
2051112107180068.172.640.340.743.135.638.529.359.8

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Col.5              L    GL   PH   PW   GPH  LB   DW   DH
    2051111207180067.972.940.440.044.635.737.727.658.9
    2051121107180067.973.340.539.243.535.837.328.157.7
    2111122207162068.270.337.338.541.434.536.728.756.4
    2111112107162067.971.239.039.640.834.738.630.858.3
    2111111207162068.071.038.937.839.734.437.528.655.6
    2111121107162067.771.337.637.141.635.036.127.554.8
    2121122210166065.770.638.138.741.235.538.428.558.9
    2121112110166066.670.239.939.242.735.439.328.558.9
    2121111210166064.369.838.636.342.734.035.826.256.4
    2121121110166065.369.938.236.841.134.335.826.056.4
    2131122208146066.468.836.237.637.833.035.629.356.6
    2131112108146067.169.745.239.948.035.036.229.459.5
    2131111208146066.170.744.337.444.535.935.027.156.6
    2131121108146066.269.435.536.337.132.734.627.354.8
    2141122215172067.870.937.839.440.735.337.328.258.1
    2141112115172067.770.738.539.741.235.338.828.358.6
    2141111215172067.571.037.837.840.835.436.426.756.0
    2141121115172067.870.538.738.141.335.636.426.656.2
    2151122215177066.669.538.538.543.334.837.528.057.8
    2151112115177066.569.639.238.543.035.037.427.857.9
    2151111215177067.270.639.537.841.434.537.427.156.2
    2151121115177067.070.039.937.842.034.137.226.656.4
    2161122208174566.870.339.539.441.135.036.627.659.0
    2161112108174566.269.837.838.740.534.236.527.858.4
    2161111208174565.670.139.037.241.935.836.326.456.7
    2161121108174566.471.340.337.842.935.036.527.056.9
    2171122215174064.767.436.138.041.535.635.226.658.7
    2171112115174065.067.335.539.740.935.834.725.961.1
    2171111215174065.668.434.638.840.935.534.225.259.1
    2171121115174065.768.535.538.841.535.734.224.859.0
    2181122207155063.266.237.737.940.132.035.826.960.0
    2181112107155063.466.638.137.240.332.335.326.958.7
    2181111207155063.266.538.036.239.932.734.125.757.3
    2181121107155063.567.137.536.339.632.434.025.657.2
    2191122208155067.569.736.039.640.234.338.229.258.7
    2191112108155067.770.437.239.540.433.338.228.858.3
    2191111208155067.671.538.037.640.335.438.627.955.6
    2191121108155067.271.437.837.240.435.837.727.255.4
    2201122204148065.868.036.837.040.033.437.028.056.2
    2201112104148066.068.637.237.539.833.637.528.256.8
    2201111204148066.468.736.836.340.134.536.026.254.8
    2201121104148066.069.337.236.440.334.636.425.955.2
    2211122210156066.970.437.438.241.434.637.128.457.1
    2211112110156067.170.137.638.641.635.436.827.957.5
    2211111210156066.570.736.037.040.134.734.826.755.6
    2211121110156066.570.836.637.039.834.734.726.955.6
    2221122215176067.569.538.039.441.735.337.428.058.3
    2221112115176067.469.537.539.042.134.036.227.657.9
    2221111215176067.269.437.137.840.436.535.626.456.2
    2221121115176067.469.637.237.840.236.335.326.256.1
    2231122208181069.772.940.040.444.636.340.030.358.0
    2231112108181069.873.639.040.143.836.439.729.957.4
    2231111208181069.573.141.338.343.635.938.128.655.1
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Col.5               L    GL   PH   PW  GPH  LB   DW   DH
     2231121108181069.773.440.238.443.036.037.529.255.1
     2251122213136064.967.736.738.939.934.036.828.459.9
     2251112113136065.268.137.139.140.334.337.228.860.0
     2251111213136063.967.836.437.841.135.035.227.459.1
     2251121113136064.668.336.237.840.435.435.926.958.5
     2281122208161065.069.538.140.041.133.736.927.861.5
     2281112108161065.470.839.040.142.433.837.028.961.3
     2281111208161065.770.539.438.741.934.035.327.958.9
     2281121108161065.969.938.638.241.334.135.427.658.0
     2321122213148561.364.535.637.438.933.035.627.761.0
     2321112113148561.464.736.037.839.233.636.027.761.6
     2321111213148562.266.436.936.739.633.734.627.059.0
     2321121113148562.266.436.836.239.533.534.627.558.2
     2331122213164069.372.138.439.542.935.238.427.757.0
     2331112113164069.672.738.739.741.835.038.127.957.0
     2331111213164069.573.538.837.843.034.536.826.654.4
     2331121113164069.473.038.037.742.034.336.827.054.3
     2341122215168569.371.938.941.743.336.238.628.860.2
     2341112115168569.571.638.841.442.835.938.028.459.6
     2341111215168569.773.239.640.143.736.637.327.257.5
     2341121115168569.873.639.441.044.036.837.327.458.7
     2351122213134065.466.938.238.339.433.835.827.058.6
     2351112113134065.067.138.338.040.034.536.626.958.5
     2351111213134065.267.437.536.239.432.634.224.955.5
     2351121113134065.767.036.236.238.134.034.625.555.1
     2361122213158571.572.540.241.343.135.938.229.257.8
     2361112113158571.672.439.241.443.435.137.728.757.8
     2361111213158570.874.240.139.843.636.838.028.256.2
     2361121113158571.174.440.339.744.036.238.528.255.8
     2371122208171564.866.137.539.841.436.537.627.761.4
     2371112108171564.667.036.639.840.436.937.727.661.6
     2371111208171564.967.637.539.141.137.737.526.660.2
     2371121108171565.268.438.639.341.037.937.328.060.3
     2381122206166565.568.636.437.539.633.636.727.857.2
     2381112106166565.367.636.837.439.733.736.327.457.3
     2381111206166565.268.535.836.040.033.535.826.155.2
     2381121106166564.968.735.736.139.235.035.626.855.6
     2391122215169070.872.438.139.642.434.338.929.855.9
     2391112115169070.471.838.140.142.034.338.829.457.0
     2391111215169069.772.536.538.242.434.038.428.654.8
     2391121115169069.872.637.037.842.834.737.728.954.2
     2401122215171566.369.737.338.140.434.736.227.557.5
     2401112115171566.269.938.838.841.935.336.027.558.6
     2401111215171566.369.538.436.841.834.033.925.655.5
     2401121115171566.670.037.936.640.933.934.726.155.0
     2411122205146567.269.836.637.739.233.336.327.756.1
     2411112105146564.967.737.638.240.734.135.427.558.9
     2411111205146564.667.437.636.541.031.833.426.156.5
     2411121105146567.669.837.735.739.034.234.526.052.8
     2421122204114565.670.037.538.339.932.437.828.458.4
     2421112104114565.769.937.738.240.232.237.528.258.1
     2421111204114565.368.837.436.239.631.035.326.555.4
     2421121104114565.869.438.336.239.731.536.126.655.0
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Col.5 L GL PH PW GPH LB DW DH
2431122206171565.870.338.838.742.633.736.827.358.8
2431112106171566.370.239.938.843.634.836.827.058.5
2431111206171566.069.639.537.142.435.735.025.756.2
2431121106171566.169.839.236.942.435.335.826.655.8
2441122208165569.673.438.039.742.236.237.829.357.0
2441112108165569.673.638.240.142.735.337.228.257.6
2441111208165569.574.038.037.740.035.337.426.754.2
2441121108165569.473.337.037.539.434.335.926.854.0

Museum Sample, Female Bison

Col.5 L GL PW GPH LB DW DH
60312 113 62.464.2 32.333.630.029.723.251.7
60312 113 61.864.2 33.534.528.730.024.354.2
60312 213 62.464.2 32.034.029.829.623.651.2
60312 213 62.464.4 33.334.829.830.624.553.3
60712 113 62.062.9 34.433.729.532.123.755.4
60712 113 62.164.8 33.628.432.523.6
60712 213 62.164.6 33.834.429.032.323.554.4
60712 213 61.862.9 34.534.429.632.023.755.8
60912 113 60.163.4 32.434.330.530.523.253.9
60912 113 59.562.0 33.034.129.130.823.655.4
60912 213 59.862.3 32.534.830.530.523.054.3
60912 213 59.561.8 32.834.328.230.223.455.1
61112 113 61.864.3 32.435.530.430.323.552.4
61112 113 61.962.5 32.734.728.931.224.652.8
61112 213 61.464.2 32.534.529.831.023.952.9
61112 213 61.162.0 32.734.128.730.424.753.5
61712 113 59.560.3 31.432.829.229.622.352.7
61712 213 59.860.3 31.232.828.230.022.252.1
62112 113 64.766.4 31.936.129.031.723.349.3
62112 113 64.265.9 33.736.328.631.924.652.4
62112 213 64.566.9 32.436.229.032.023.350.2
62112 213 64.265.0 33.435.027.832.224.852.0
62712 113 62.463.4 32.035.328.229.322.251.2
62712 113 62.063.1 31.836.126.528.822.451.2
62712 213 61.762.8 31.535.426.028.122.551.0

Museum Sample, Male Bison

Col.5 L GL PW GPH LB DW DH
60011 113 67.670.6 39.444.034.738.927.958.2
60011 113 67.471.2 41.043.635.238.328.160.8
60011 213 67.270.6 39.444.335.138.627.158.6
60011 213 67.071.7 40.943.035.139.328.261.0
60211 113 69.071.8 41.243.437.039.328.859.7
60211 113 69.070.6 42.243.237.739.429.261.1
60211 213 68.970.8 42.343.037.039.128.861.3
60611 213 45.9 38.529.0
60611 113 46.3 38.729.1
60511 113 66.370.6 40.646.135.837.128.461.2
60611 113 45.6 38.128.6
60611 213 44.8 37.827.8
60811 113 66.270.1 37.541.234.037.828.356.6
60811 113 66.570.4 39.041.034.639.028.558.6

Col.5		L GL	PW GPH LB DW DH
60811	213	66.569.9	39.240.934.838.328.458.9
60811	213	66.269.6	37.742.134.038.128.656.9
61011	113	66.670.6	39.139.932.934.826.158.7
61011	113	65.468.3	39.939.634.438.927.561.0
61011	213	65.568.4	39.039.833.637.427.059.5
61011	213	66.069.5	39.139.332.935.126.059.2
61211	113	64.467.2	37.642.636.336.225.758.3
61211	113	63.267.1	39.842.137.040.127.162.9
61211	213	63.466.3	37.242.735.037.224.958.6
61211	213	63.567.8	39.842.137.539.727.562.6
61311	113	65.868.9	36.239.831.534.127.055.0
61311	113	65.469.3	38.139.133.835.326.958.2
61311	213	65.968.3	37.739.433.035.426.957.2
61311	213	65.568.7	36.240.131.634.426.355.2
61411	113	66.369.4	36.339.130.337.328.754.7
61411	113	66.370.3	34.939.130.536.227.552.6
61411	213	67.270.5	35.339.331.137.028.152.5
61411	213	66.069.7	36.339.530.737.528.955.0
61511	113	75.580.5	44.747.840.540.629.059.2
61511	113	76.182.0	43.648.141.239.229.057.2
61511	213	75.181.4	45.348.340.841.529.460.3
61611	113	68.471.5	40.943.137.537.127.959.7
61611	113	68.3	40.641.237.237.928.459.4
61611	213	68.1	40.541.737.237.828.159.4
61611	213	68.8	40.442.539.437.427.058.7
61811	113	69.971.1	41.442.437.837.627.459.2
61811	113	68.771.8	39.743.336.536.928.057.7
61811	213	70.374.2	39.844.536.537.627.156.6
61811	213	68.872.4	40.641.636.438.627.459.0
61911	113	64.368.0	39.241.737.536.327.160.9
61911	113	63.466.9	40.041.838.736.727.363.0
61911	213	63.967.3	39.040.537.936.427.961.0
61911	213	62.866.4	40.442.837.936.326.464.3
62011	113	66.572.8	37.541.334.337.326.556.3
62011	213	65.670.0	38.940.333.438.227.159.2
62211	113	68.6	39.542.934.338.529.657.5
62211	213	69.273.0	39.343.835.037.828.756.7
62311	113	71.073.4	40.141.936.338.829.756.4
62311	113	71.675.3	39.242.836.538.928.654.7
62311	213	71.674.7	38.842.936.638.928.354.1
62311	213	71.674.6	40.541.935.839.629.456.5
62511	113	63.866.9	41.040.337.735.625.764.2
62511	113	63.867.3	39.440.636.733.925.261.7
62511	213	63.867.0	40.941.337.636.226.064.1
62511	213	64.768.2	39.840.538.535.025.161.5
62811	103	64.867.6	37.840.333.535.525.858.3
62811	103	65.567.6	38.842.934.136.926.959.2
62811	203	66.268.4	38.942.433.537.227.058.7
62811	203	64.567.1	38.241.733.535.425.659.2
62911	113	66.070.0	40.343.636.536.927.861.0
62911	213	66.070.0	40.443.936.737.428.361.2
62911	213	66.171.0	38.842.535.434.426.758.6
63011	113	67.972.3	39.141.835.736.428.757.5

Col.5		L	GL	PW	GPH	LB	DW	DH	
63011	113	67.8	72.4	39.0	42.9	35.5	34.7	27.6	57.5
63011	213	67.8	71.4	39.3			36.5	28.4	57.9
63011	213	68.2	72.4	39.0	43.1		34.8	27.4	57.1

Stott Site Sample

Col.5		L	GL	PW	GPH	LB	DW	DH	
03052451	213				38.5	30.4	33.5	26.3	
03082511	213	69.5	71.3	35.8	40.1	32.5	37.0	27.2	51.5
03082531	213	63.0	66.5	33.8	37.0	31.3	32.3	24.2	53.6
03092561	113	68.6	70.8	36.2	38.5	31.1	36.2	27.5	52.7
04032571	213	68.7		41.3	43.5	35.0	39.0	28.4	60.1
04062581	213	68.6				35.1			
04062591	213	70.2	73.2	39.6	42.4	37.2	39.2	28.7	56.4
05052601	213	70.6	74.3	41.4	43.4	36.0	38.0	28.4	58.6
05052621	113		67.0	35.7	35.4	30.3		24.6	
05052631	113	66.2	70.1	40.4	42.1	34.5	37.5	27.4	61.0
05052641	113	68.2	70.8	41.6	45.2	37.3	41.5	29.3	60.9
05052681	213	66.2	70.6	37.7	40.3	35.0	38.2	28.8	56.9
05062701	113			34.6					
05062711	213			37.3		33.3	32.7	28.7	
05062721	113	63.6	68.1	34.5	37.7	30.9	32.5	25.3	54.2
05062741	113	64.0	67.7	34.1	36.6	30.3	34.3	24.3	53.2
05062751	113		65.5	36.4		34.0			
05072761	213		64.0	33.3		29.8	32.7	25.2	
06042781	113	71.0	74.8	38.9	46.3	37.8	38.3	29.1	54.7
06042791	213			33.4	35.6	31.0	31.6	24.7	
07032821	113		65.5	32.7	36.1	29.8	32.2	23.1	
07042841	213	63.7	65.5	34.9	36.5	29.9	34.3	26.6	54.7
07042861	113	64.2	65.7	33.1	37.8	30.5	33.7	24.0	51.5
07052881	113	61.8		34.3	37.1	30.5	32.4	24.7	55.5
07052901	113	66.4	70.6	35.3	37.8	33.4	34.1	25.9	53.1
07062921	113		75.0	42.6	42.9	37.1	37.5		
07062951	113	71.8	75.1	40.3	42.7	34.9	38.1	27.9	56.1
07072961	113	63.2	65.4	35.1	36.1	31.2	32.5	23.9	55.5
07072971	213	60.8	63.5	32.0	32.5	26.8	29.8	24.1	52.6
07072981	113	61.3		31.9	36.2	29.9	31.2	22.4	52.0
07072991	113			34.3	35.8	30.2	32.4	24.0	
07073001	213	60.9	63.3	32.1	35.5	27.8	30.8	23.0	52.7
07073011	213	70.0	71.7	41.3	44.1	35.0	37.0	27.2	59.0
07073021	113	69.6	72.8	41.0	42.9	36.8	39.9	29.4	58.9
07073031	113	70.7	74.3	40.1	43.9	36.2	36.4	27.4	56.7
07073041	113	71.3	75.3	38.8	43.9	34.9	38.0	27.7	54.4
07073051	113					37.6	37.8	28.1	
07073061	213	67.2	70.3	38.3	40.4	31.7			56.9
07073151	113		66.5			32.5	36.1	25.3	
07073161	113			33.9	37.6	30.7			
07063201	213	72.4	76.4	38.5	43.4	36.2	37.8	27.8	53.1
07083211	213		74.0	40.0		35.0	39.6	28.5	
07083221	213	64.3	68.1	33.5	36.7	30.1	32.3	22.7	52.0
08043231	213	63.6	66.1	34.3	37.7	32.2	32.4	23.7	53.9
08053281	213	65.1	67.2	35.5	37.8	31.6			54.5
09083311	113		69.9	33.6		29.2	32.3	23.5	
09093361	213	68.5		41.7	43.4	36.1	40.1	30.0	60.8

Col.5		L	GL	PW	GPH	LB	DW	DH	
09113421	113	61.9	63.3	29.9	34.4	27.1	30.7	23.8	48.3
09113441	213	65.8	67.7	33.4	37.4	29.8	32.0	24.6	50.7
09113451	213	68.0	72.6	41.5	45.0	38.3	39.5	29.9	61.0
09113461	213	62.8	66.6	32.4	36.4	30.5	31.9	24.8	51.5
09123501	213		64.4	33.4	35.4	28.7		25.5	
09123541	213	65.1	68.3	34.8	38.5	31.9	32.7	25.3	53.4
09123551	113	64.6	67.0	35.6	37.2	31.1	32.7	25.8	55.1
09133591	213	65.0	66.7	33.3	34.7	28.9	32.4	24.9	51.2
09133601	113	65.9	68.0	32.5	36.9	28.6	32.0	24.5	49.3
12043631	113	67.0	71.8	38.6	42.7	35.9		27.0	57.6
12053641	113	66.6	71.3	40.9	43.7	36.5	39.3	28.7	61.4
14043651	213	61.4		34.2	37.5	32.4	34.1	24.1	55.7
14053661	113		66.2	33.2		28.5	31.5	23.1	
15063681	113	62.2		32.5	35.4	30.8	31.5	22.7	52.2
17083721	213	61.6	64.3	31.8	35.6	29.6	31.5	22.7	51.6
21073751	113			33.1	37.1	31.5			
35073781	113	69.7				33.3			
38183811	213	65.2			38.6	31.0			
45063841	213	60.7	64.7	32.7	36.3	30.4			53.8
52063851	113	65.1	68.5	33.5	36.5	28.3	31.5	25.5	51.4
53073861	113	68.8		39.1	45.7	34.0	39.2	29.4	56.8
55053871	113	70.8		37.2	40.9	34.5	37.3	26.6	52.5
55053881	113		66.8	33.5		29.7	33.2		
56053891	213	61.6	64.5	32.8	35.3	29.2			53.2
57053901	213	63.4		34.2	37.0	30.6		22.9	53.9
57063911	113	63.5	65.5	33.1	35.6	30.6	32.8	24.5	52.1
59053941	113	62.0	64.0	35.3	37.4	30.6		25.3	56.9
64044031	113					30.7	33.2	25.3	
64044041	213	65.5	67.5	34.5	36.9	30.0	35.0	26.1	52.6
64054061	113	66.4	69.7	33.9	37.2	29.4	31.7	24.7	51.0
64064101	113	67.2		39.5		35.5			58.7
64064111	113			41.8	43.4	37.5		29.0	
65074131	213			34.9	36.7	31.3	35.0		
65094151	213				37.3	30.5	33.6	24.7	
68054181	113	64.3		34.9	38.9	29.8	35.6	24.9	54.2
68054191	213		71.8	41.9		36.2	38.8	28.0	
68054201	113	71.8	76.0	41.0	45.9	37.9	38.8	28.6	57.1
68064211	213	62.9	66.4	33.2	37.3	28.7	32.5	25.9	52.7
69054221	113			35.9	39.2	32.9			
69074251	113	67.7	72.2	37.5	42.8	33.3		27.9	55.3
70034271	213					31.3			
70034281	213		70.7	34.5	36.7	32.8	33.9	25.8	
72044301	213	66.6	68.6	33.9	36.5	30.1	32.5		50.9
72074331	113	71.2	75.7	40.1	43.7	36.5	39.3	29.5	56.3
72084341	113	67.5	69.9	35.7	39.2	34.3	33.5	25.4	52.8
72094361	113	63.5	66.5	34.8	37.4	30.9	32.8		54.8
74024411	113		66.2	34.2	38.5	32.6	32.4	25.0	
74044421	113		73.0	42.2	45.6	37.6	39.2		
74044431	113	68.7	70.4	35.0	38.8	30.7	33.4	27.3	50.9
74054441	113	70.6	74.4	42.5	43.1	39.0	41.4	31.4	60.2
74064451	113		67.8	34.0	36.2	30.8			
74074461	113	67.2		33.7	37.3	31.8	33.5	25.0	50.1
74074471	113	62.4	63.6	33.8	34.7	29.9		25.3	54.1

Col.5		L GL	PW GPH LB DW DH
74124481	213	72.874.6	42.046.336.141.031.357.6
75054491	213	64.867.4	36.538.032.5 56.3
75064511	213	71.573.9	35.941.431.936.326.450.2
75074521	213	71.875.7	39.545.236.6 55.1
75084531	213	62.365.0	32.735.928.932.322.952.4
75084551	213	67.971.5	34.738.730.733.123.851.1
75094561	113	69.773.0	40.844.035.638.925.558.5
75094571	113	68.271.0	40.343.335.837.828.059.0
75094591	113	68.571.9	42.643.738.239.929.562.1
75114601	113	71.175.6	43.645.139.239.831.261.3
75104611	113		31.5
75104621	213	66.470.0	39.840.535.238.829.759.9
75104631	113	66.671.0	39.242.335.238.927.658.8
78064641	213	63.1	30.6
78074651	213	73.178.1	44.246.039.242.230.760.4
78094661	113	65.168.2	33.836.331.134.425.351.9
78104671	113	69.573.9	37.541.536.237.325.653.9
78104681	213	72.9	39.345.736.4 27.853.9
78114711	199	62.164.0	31.635.528.530.223.850.8
78124721	113	68.271.1	37.239.631.437.429.754.5
78144731	113	66.4	30.8
78144741	213	66.071.9	40.443.034.638.028.361.2
78144751	113	66.471.5	39.344.034.736.928.059.1
79064791	113	63.465.5	35.337.331.3 26.555.6
79064801	113	64.7	34.3 29.3 53.0
79074851	213	73.2	44.838.441.431.2
79084891	213	62.6	30.8
90044931	213	70.275.8	40.948.539.139.727.958.2
92054971	213	71.675.8	43.648.438.7 28.660.8
93004991	213		32.036.128.8
93005001	113	67.0	42.141.834.5 28.362.8
93005011	213	61.363.4	33.536.330.331.922.554.6
93095031	113	70.473.2	37.141.033.435.626.152.6
94005051	213	72.875.2	41.130.6
94005061	213	71.7	36.541.431.5
94005071	113	65.266.9	32.034.627.831.123.149.0
94005081	113	73.8	38.542.834.036.626.9
95 5091	113	70.7	40.544.737.937.026.457.2
95 5101	113	67.0	35.539.230.934.626.6
95 5121	113	70.9	42.642.438.640.430.560.0
95 5151	213	69.874.8	41.842.437.238.227.259.8
95 5211	113	63.2	36.038.632.6 56.9
95 5231	213	62.565.5	32.735.228.831.523.552.0
95 5251	213	74.8	39.643.537.937.527.6
95 5281	113		28.8
95 5341	213		27.331.224.2
95 5351	213		33.940.629.8

Appendix B

SECOND SEXING TECHNIQUE

A description follows of a second sexing technique, that of plotting the index of Greatest Length X Distal Height against Greatest Length, in a bivariate scatter.

B.0.5 Development of the Second Technique, EINP Sample

It was expected that a common bivariate scatter using two variables, the sort typically used in osteological analyses (Oxnard 1973:6), might aid in distinguishing the sexes. The advantage of a technique based on two measurements is the possible increase in numbers of archaeological specimens that could be included in the analysis. Even if most first phalanges had the three measurements required for the application of the discriminant function discussed in the main body of the thesis, it is expected that more bones may have only two of the three measurements. The disadvantage of a less complicated method was the likelihood of a less clear separation of the sexes.

There were several combinations of the three variables (L,GL and DH) attempted and these are listed in the following table (Table 5).

TABLE 5

Tested Variable Combinations

VARIABLES	TRANSFORMATIONS	OUTCOME
L	L X GL	NO SEPARATION
GL	L X GL	NO SEPARATION
DH	L X GL	SLIGHT SEPARATION
L	L X DH	NO SEPARATION
GL	L X DH	SLIGHT SEPARATION
DH	L X DH	NO SEPARATION
L	GL X DH	SLIGHT SEPARATION
GL	GL X DH	GOOD SEPARATION
DH	GL X DH	SLIGHT SEPARATION
L	L X GL X DH	SLIGHT SEPARATION
GL	L X GL X DH	SLIGHT SEPARATION
DH	L X GL X DH	SLIGHT SEPARATION

The clearest separation was found by plotting the transformation of the measurements Greatest Length X Distal Height (GL X DH), against the measurement Greatest Length (GL) for the EINP sample. The bivariate scatter of these variables shows a complete separation of the males from the females (Figure 19). If desired, the regression for the "Y" variable can be plotted for the group and a dividing line drawn perpendicular to the regression, half way between the closest male and female. The perpendicular line for the EINP sample intersects the "X" axis at value 1800 with "Y" equal to 58.

B.0.6 Testing of the Second Technique, Museum Sample

When the index of (GL X DH) was plotted against GL in the Museum sample, complete separation was found (Figure 20). However, the regression for the Museum group differs from the regression for the EINP group. When the perpendicular is drawn half way between the closest male and female, it intersects the "X" axis at value 1845 with "Y" equal to 58. In this particular case the separating line could have been drawn to intersect the "X" axis at 1800 as for the EINP sample, but as the regression for the Museum group is slightly different it would likely be misleading to do so.

The Museum group, in my opinion, is demonstrating that even as little as one hundred years ago, the bison population was likely sufficiently different so that the area of separation for the sexes was slightly higher than for the modern bison sample from EINP taken in 1971.

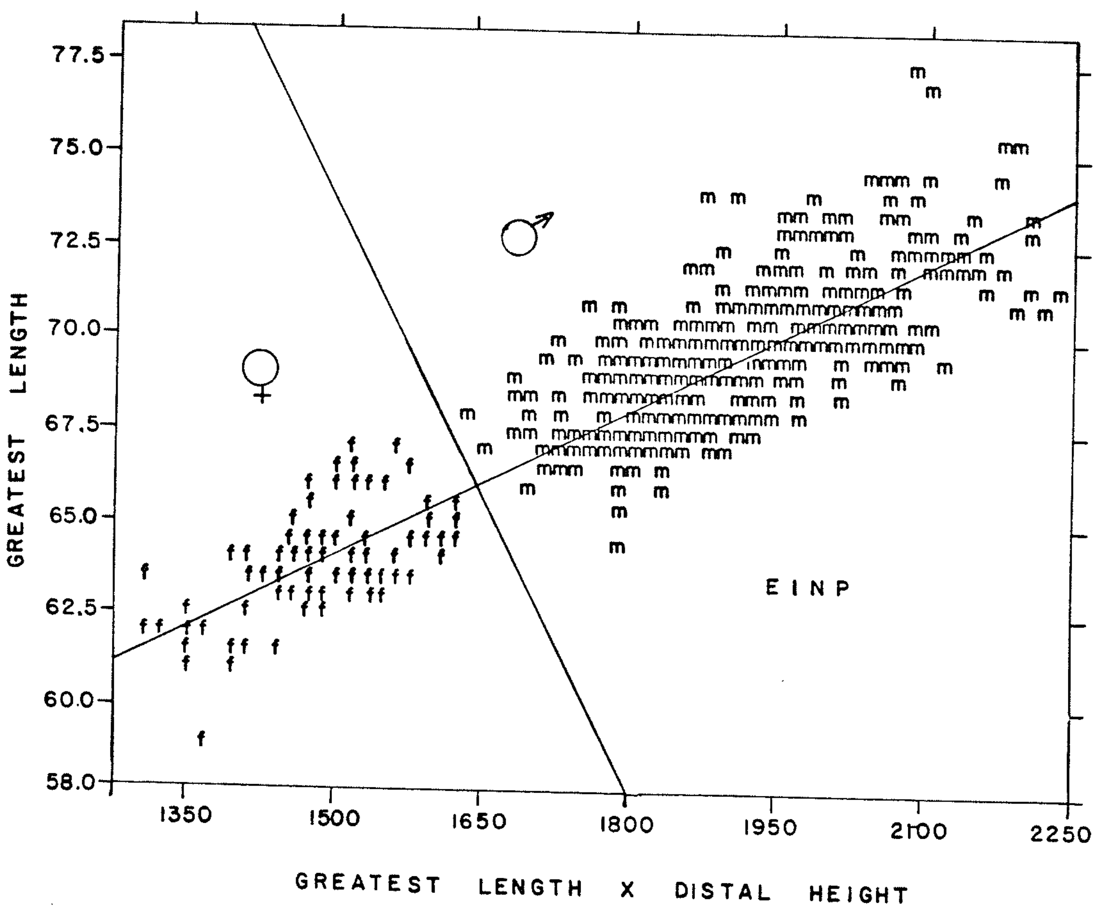

Figure 19: Second Technique, GL X DH Against GL, EINP Sample

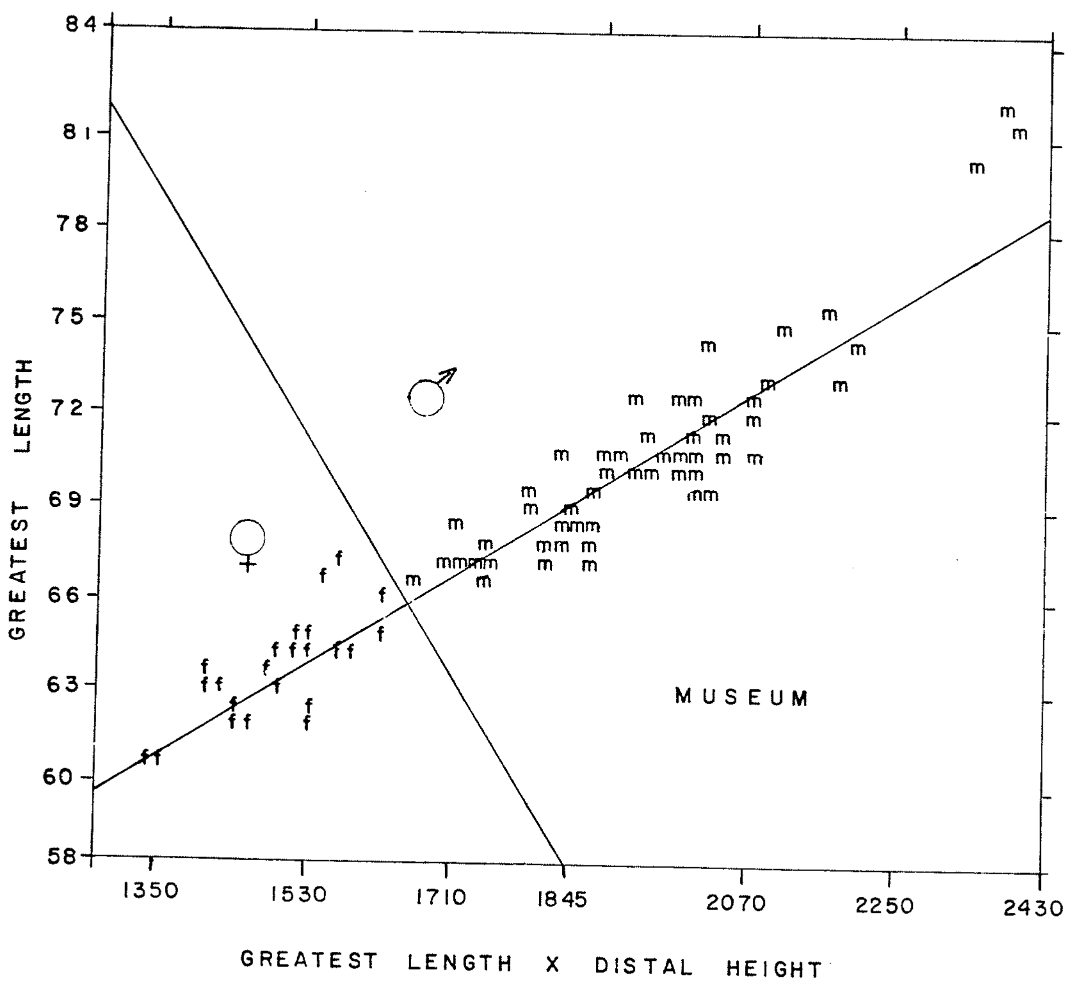

Figure 20: Second Technique, GL X DH Against GL, Museum Sample

B.0.7 Application of the Second Technique, Stott Site

Whereas 74 bones were used in the application of the stepwise discriminant analysis at the Stott Site, a sample of 88 bones were complete enough for the two measurements required for the index method. When the index of (GL X DH) was plotted against GL, a separation was apparent, but at higher values than indicated by either of the EINP and Museum samples. By following the visual separation, and the previous sexing results from the stepwise discriminant analysis, the separating line was drawn to intersect the "X" axis at 2175 with "Y" at 58. When this separation is made, there were 43 bones classifiable as female and 45 bones classifiable as male (Figure 21). The 14 additional reference numbers made classifiable by this method are listed in Table 6. They are additions to those reference numbers listed in Table 4, in the body of the text.

The proportion of male versus female bones is altered only slightly using the index results. By the previous stepwise discriminant analysis, both the percentage of bones and individuals remained the same for each sex. There were 46% adult female bones and bison and 54% adult male bones and bison. By the index method 49% of the bones and individuals were classed as female and 51% of the bones and individuals were classed as male bison.

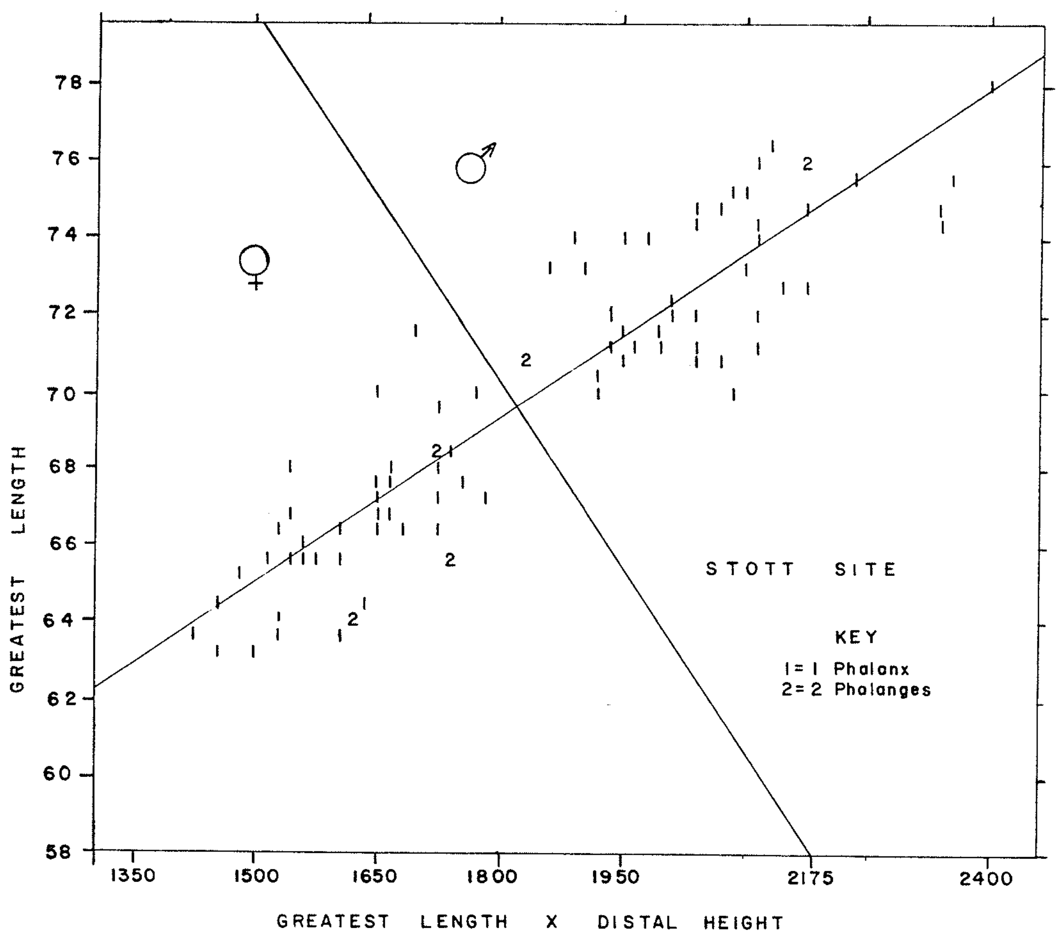

Figure 21: Second Technique, GL X DH Against GL, Stott Site Sample

TABLE 6

Additional Reference Numbers for Stott Site Male and Female Bison as Determined by the Second Technique

ADDITIONAL FEMALES		ADDITIONAL MALES
262	350	321
276	366	419
282	441	428
315	518	508
331		525

This second method is included in the appendix and not in the main body of the text because it is in some ways dependent upon the stepwise discriminant analysis for determining where the patterned split should be read. In the case of the Stott Site, and without another sexing method to rely on, the separation line could have arbitrarily been chosen at a line through the "X" axis at 1900. If both techniques were applied to the Stott Site at exactly the same values as for the EINP sample, this second technique would have misclassified two male bones as female bones.

It is felt that the second method is most useful where only a large sample is recovered and is best used in conjunction with the stepwise discriminant analysis results in order to guide the separating line for the sexes.

Appendix C

CALCULATION OF MINIMUM NUMBERS OF INDIVIDUALS (MNI) FROM THE STOTT SITE PHALANGES, EXCAVATED FROM 1950-1979

The MNI of bison from excavated first, front phalanges at the Stott Site were calculated taking into account the following five main points (Grayson 1973: Bökönyi 1970): a) horizontal location, b) vertical stratigraphy, c) sex, d) morphological category and e) the condition of the phalanx.

In terms of horizontal location, all excavation units were considered separate from each other. It was felt that such a procedure would not unduly maximize the count because the Stott Site has, for the most part, spaced excavation units over a large terraced area. It is assumed that the front phalanges from one bison are not widely scattered.

Vertical separations were made by level, with levels containing no phalanges acting as dividers between levels with phalanges. Where two or three continuous levels contained phalanges, these levels were calculated as one level. If four or more levels were continuous, they were divided into two groups for the sake of calculations. Divisions were also made based on the fact that some of the vertical stratigraphy and artifacts from the 1979 excavation were interpreted as activity foci and are not contemporaneous (Hamilton *et al*. (1980:60-70).

Phalanges of known sex were accounted for. For example, if only two phalanges were present in one level, the MNI count would normally be one bison. However, if one phalanx was male and one was female the MNI could be two bison.

Only those phalanges that could be assigned the morphological category of front, first phalanx were included in the calculation of MNI. It was also necessary to be able to distinguish a left lateral, right medial phalanx (LLRM) from a left medial, right lateral (LMRL) phalanx. Each animal was defined by a presence of a maximum of two LLRM phalanges and two LMRL phalanges. Check Figure 1 for a review of LLRM and LMRL and check Figure 9 for distinguishing front from rear phalanges.

The condition of the phalanx refers to the degree of completeness of the bone. Phalanges with three or more of any of the seven measurements were included in the calculation of MNI even if they could not be sexed. Phalanges with only one or two measurements (fragments) were excluded from calculation because of the inability to categorize most of these bones into front or rear categories and LLRM or LMRL categories.

Juvenile bone, that with either an unfused proximal epiphysis or with a marked proximal fusion line, was used in the calculation of MNI of young bison. Because each bone was usually in two pieces, care was taken to allow both a proximal epiphysis and a distal diaphysis per phalanx. A maximum of eight bones was allowed per animal because of the inability to distinguish front from rear phalanges in skeletally immature bison.

As previously stated in Chapter 4, the calculation of MNI for the Stott Site first phalanges, based on the interpretation of the stepwise discriminant function resulted in 34 bones assessed an MNI of 23 adult females and 40 bones assessed an MNI of 27 adult male bison.