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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MASTER OF ARTS

Winnipeg, Manitoba, 1982

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A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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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.

ACKNOWLEDGEMENTS

In particular I am indebted to John Brumley of Medicine Hat, Alberta for generously giving me complete access to the largest known collection of bison foot bones which he spent hundreds of odorous hours preparing. This collection from Elk Island National Park, (Alberta) formed the known sex data base for my work. I also want to thank John and Laurie Milne-Brumley for their gracious hospitality.

Dr. Bob Wrigley, Dr. George Lammers and Jack Dubois, all of the Museum of Man and Nature, Winnipeg, made it easy to gain access to my second data base, a collection of Museum specimens from all over North America. They lent specimens and acted as intermediaries making it possible for me to receive specimens from the following people and institutions, to which I am also grateful:

Dr. S. Anderson, American Museum of Natural History

Barbara Becker, Field Museum of Natural History

Judith Eger, Royal Ontario Museum

Dr. R. Fisher, National Museum of Natural History

Dr. W.A. Fuller, University of Alberta

Dr. J.L. Patton, Museum of Vertebrate Zoology

Nancy Petersen, University of Michigan

Dr. H.C. Smith, Provincial Museum of Alberta

I want to thank Dr. Leigh Syms, now Curator of Archaeology at the Manitoba Museum of Man and Nature for allowing me access to all of the archaeological bone from the Stott Site, Brandon, Manitoba. And I appreciated the hospitality of Dr. and Mrs. Syms while I was in Brandon collecting my sample.

The following people helped locate skeletal material or provide information:

F. Bamber, Elk Island National Park

Dr. E. Birney, University of Minnesota

J. Brumley, Medicine Hat

J. Crabtree, Wichita Mountains Wildlife Refuge

J. Dubois, Manitoba Museum of Man and Nature

Dr. C.R. Harington, National Museums Canada

Sheila Kortlucke, University of Kansas

Dr. N.S. Novakowski, Canadian Wildlife Service

Dr. W.O. Pruitt, University of Manitoba

Dr. H. Reynolds, Canadian Wildlife Service

Dr. G. Scotter, Canadian Wildlife Service

Dr. D.M. Shackleton, University of B.C.

Dr. Shi-Kuei Wu, University of Colorado

Dr. M. Wilson, University of Alberta

Dr. C.G. van Zyll de Jong, National Museums Canada

For help with computers and statistical procedures I want to thank Dr. Arnason, Department of Computer Science and in particular Dr. J. Brewster, Department of Statistics who patiently spent hours in discussion. Greg McClure generously helped write some Fortran programs that could be adapted to several problems. Dan Roscoe saved me from self destruction while I learned the SYSPUB system at the computer center.

Translations from the German literature by Ruth Muller proved invaluable. Dr. Louis Allaire of the Anthropology Department helped to check both my French and Latin translations.

In terms of technical assistance I could not have done without Jim Batura who measured a small sample of the bison bones. Scott Hamilton saved countless hours of additional sorting by having his crew pull out the 1979 phalanges as they catalogued the artifacts. I am grateful to Daniel Bulloch, who did the photography. Dr. C. Meiklejohn, University of Winnipeg, lent equipment for the duration of the project. I want to thank Barbara and Stan Saylor for delivering the Elk Island bone collection to Winnipeg. Also, I appreciated the efforts of Dr. C.T. Shay in finding office space for the writing of this report.

I want to acknowledge the support given by both Robert Fraser and Dr. Howard Savage who encouraged my first faunal interests. Dr. Ross MacPhee initially encouraged me to pursue this unusual topic. And, Dr. Michael Wilson has been especially informative.

Special thanks to my friends: Rebecca Balcom, Daniel Bulloch, Bob Hall, Sharon Keen, James Light, Martin Magne and Larry Stene. Andy Schinkel, you take the cake. I would like to add that I received contagious encouragement from many people during the different stages of this thesis.

My thesis committee has been supportive and stimulating. I would like to thank Dr. Greg Monks, the head of the committee, especially for his ability to offer direction. I would also like to thank Dr. Leigh Syms for his critical appraisal and to thank Dr. William Pruitt for his zoological expertise.

It is time I expressed my appreciation to my parents Mrs. Roberts and the late Dr. J.B. Roberts, who let me collect, bring home and keep all sorts of interesting garbage when I was a kid. Thanks for trying to understand and for helping me financially to engage in this project.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

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