1997

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The relation of prehistoric human groups to bison populations in the Central Plains has long been the subject of both speculation and debate. Recent research has shown that bison are relatively sensitive to changing environmental conditions (Bamforth, 1988; Bozell, 1995; Speth and Parry, 1978; Emerson, 1990). This sensitivity is visible in physiological and behavioral adaptations used by bison to deal with change. Likewise, evidence for these adaptations is present in faunal assemblages from Central Plains archaeological sites. In order to determine the nature of these adaptive characteristics, a model must be developed which goes beyond traditional presence/absence tabulations of faunal taxa.

With the goal of understanding how human groups dealt with inconsistent bison resources between AD I and AD 1500, a model will be developed that utilizes research from several different fields. This paper is a synthesis of research undertaken in grassland and cultural ecology, archaeology, paleoclimatology and nutrition. Its purpose is to create a diachronic picture of bison availability and its relevance to subsistence. It will then examine cultural implications for prehistoric human populations on the Central Plains. This paper will present a general discussion of human adaptation to dietary stresses. Then, it will explain grassland and bison ecological systems, respectively. These data will then be used to develop a model of bison use, which will be evaluated through the analysis of Central Plains archaeological sites.

Human Responses to Dietary Stress

Archaeologists have long been interested in prehistoric subsistence strategies and the adaptive mechanisms prehistoric groups used to deal with nutritional stress. Four mechanisms are often proposed to explain how prehistoric groups adapted to less than ideal conditions: the utilization of alternative subsistence resources, the intensification of current subsistence resources (at either microscopic or macroscopic levels), social adaptive functions, and residential mobility. These mechanisms are often explained as ideal, isolated modes of adaptation, but within the dynamic sphere of a cultural system, adaptation probably involved a combination of these alternatives.

A commonly perceived mechanism for dealing with nutritional stress is the utilization of alternative resources. As related to the spatio-temporal focus of this paper, this is actually the difference between procuring and producing food. Cultivated plants made up a relatively small percentage of the Plains Woodland diet. Nutrients were procured mainly from local flora and fauna (Adair, 1997; Cashmere, 1997; Kivett, 1970, Bozell and Winfrey, 1994). On the other hand, the diet of Central Plains Tradition groups depended largely on food production (Bozell, 1991; Cashmere, 1997; Wedel, 1986). It is also worth mentioning that neither diet consisted exclusively of either procured or produced food. When confronted with large-scale climatic and environmental change, human groups would find that producing, rather than procuring, food would be more efficient. Therefore, it would be less risky than other alternatives.

While examples of subsistence change and intensification exist in the ethnographic literature, they often require large amounts of data acquired over long periods of time in order to see adaptive mechanisms at work. On the other hand, ethnographically documented groups living in marginal environments deal with dietary stress in other ways. These groups have developed social adaptations. Infanticide, abortion, lactation-induced amenorrhea, post-partem sex taboos (Kelly, 1995; Redding, 1988) and group fissioning are some social mechanisms that have been used to explain population regulation in hunter-gatherer groups. These mechanisms are often able to maintain a population at a level below the carrying capacity of a region (Kelly, 1995).

Mobility is also an option Woodland hunter-gatherers may have used to deal with a changing environment. During periods of nutritional stress, bison herds usually decrease in size and increase in mobility (Bamforth, 1988; Speth. 1983). While it is suggested that limitations on human mobility made following a specific bison herd unfeasible, groups could have made hunting trips to areas where bison would be expected to congregate due to better local forage conditions. An example of this kind of area may be the Black Hills in western South Dakota (Frison, 1991; Reber and Frison, 1980) or the Sand Hills in northcentral Nebraska (Bozell, 1995; Koch, 1994; Kivett, 1952).

A fourth alternative for dealing with a changing environmental regime, would be an intensification of the subsistence strategy already practiced. This can take place at two levels. Microscopic intensification involves only an individual animal (Speth, 1983, 1987; Speth and Spielmann, 1983; Speth and Parry, 1978; Stiner, 1994; Binford, 1978). Late Woodland hunter-gatherers may have utilized more elements of a single animal. The intensive use of a single animal emphasizes the utilization of less desirable parts which are resistant to nutritional stresses and the increased processing of a carcass (Speth, 1983; Speth and Spielmann, 1983; Binford, 1978, 1981). In the case of bison, an increase in butchering intensity may entail the extreme fragmentation and boiling of certain skeletal elements in order to produce bone grease (Binford, 1978, 1981), the utilization of sinus fats in crania (Stiner, 1994; Speth, 1983), the use of secondary marrow elements (i.e. metapodials, mandibles, etc.) (Lyman, 1994), or the use of partially digested rumen from an animal's digestive tract (Todd, 1991).

At the macroscopic level of intensification, human groups may have attempted to procure more faunal resources while using only selected portions of high nutritional value from each animal. This mechanism as applied to bison use on the Central Plains suggests that human hunters could have obtained larger quantities of bison through the use of drives or other communal procurement strategies. Only specific elements that were resistant to nutritional stress would have been selected for processing, decreasing the amount of butchery visible per animal (Binford, 1978). While I have used bison to illustrate the mechanics of this particular adaptation, behavioral studies of modern bison indicate this alternative would have been difficult to execute. Although, it may have been a viable procurement strategy for other herd ungulates. Speth's (1983; Speth and Parry, 1978) research at the Garnsey site in New Mexico has shown that male bison were butchered more intensively than females. He suggested that gender differences in seasonal cycles of nutritional stress were to blame. The sequential mobilization of fat from body elements also implies that even an animal in poor health has fat reserves still available in selected parts (Speth, 1987; Speth and Spielmann, 1983; Stiner, 1994).

Whatever the adaptive mechanisms employed by Plains Woodland and Central Plains Tradition groups in adapting to environmental changes, they adapted successfully as indicated by the continuation of human occupation in the archaeological record. For the purposes of this paper, it is suggested that Late Woodland groups on the Central Plains would have instituted one or a combination of these options in order to deal with climatic and environmental instability.

In what follows, I suggest that bison health (specifically, bison fat levels) would have been an important and limiting factor in the continuation of the Plains Woodland subsistence pattern. Therefore, the changes in grassland composition and bison behavior would have a profound effect on procurement by Woodland groups, resulting in the triggering of adaptive mechanisms to maintain dietary stability through times of poor foraging conditions for bison.

Ecological Relationships Between Grass and Bison

The following sections deal with ecological relations affecting a grassland environment and bison behavior respectively. This information will provide the basis of the model presented in the following section.

Bison population density is dependent on forage characteristics. Therefore the nature of forage must be taken into consideration in model development, as well as bison responses to forage variability.

Grass

Bamforth (1988) divides grasslands according to two criteria, the type of grassland and whether a vegetational area is composed of primarily cool season or warm season grasses. Within this classification, there are three basic types of grasslands, those made up of tall grasses, short grasses and those exhibiting characteristics of both (transitional or mid grass). The type of grass found in an area depends largely on the amount of soil moisture available. Tall grasses require higher amounts of moisture than short grasses or transitional prairies. Decreasing moisture levels, due to the dry pacific air mass coming across the Rocky Mountains, create a dry rainshadow in the west and higher moisture levels in the east. Short grasses dominate the western area of the plains and tall grasses are productive along the eastern margins with a shifting area of transitional prairie or mid grass plains in between. The amount of area for each type of grassland is in direct relation to the amount of moisture each region receives (Bamforth, 1988; Wedel, 1986; Wendland, 1978; Johnson and Park, 1996; Barry, 1983; Sears, 1961).

The spatial distribution of these different grasses can be extremely variable as a result of changing climate regimes or even annual differences between wet and dry years. Droughty, or dry conditions, cause the short grass plains to expand to the East, or if extremely dry conditions prevail, tall grass regions can also expand into eastern forest areas (as they did in the Altithermal). Differences in the physiology of these various grasses lead bison to prefer shorter grasses over taller grasses.

While all types of grasses have relatively high nutritional values early in their growing seasons, as the season progresses, tall grasses have an increasingly higher proportion of indigestible fibers to protein. The overabundance of "woody" material in tall grasses results in more work per unit of energy acquired and increased wear on bison dentition (Bamforth, 1988; Speth and Parry, 1980; Speth, 1983). Therefore, bison usually prefer short grasses or specific locations where grasses are being constantly rejuvenated (i.e. prairie dog towns) (Baniforth, 1988, Coppock et al., 1983).

Seasonalitvy (regarding grassland composition) is also relevant to bison nutrition. There are two basic types of grasses in reference to this characteristic. cool (C3) and warm (C4) season grasses. Temperature seems to be a limiting factor in the spatial distribution of these grasses (Bamforth, 1988; Speth, 1983). Cool season grasses experience most of their growth in the spring and sometimes a second growth in the fall, while warm season grasses undergo a single growth period during the summer. Cool regions experience maximum overall growth during the spring and fall, while warmer areas experience maximum growth during the summer. Warm season grasses are more susceptible to fluctuations in precipitation levels. Growth spurts of warm season grasses are preceded by precipitation events. Therefore, warm season grasses attain high levels of protein immediately after these precipitation events. Because the growth of warm season grasses is somewhat erratic (due to erratic precipitation levels), a higher percentage of their protein is stored in indigestible fibers for a large part of the growing season. Cool season grasses tend to present a more constant level of nutrition to ungulate grazers (Bamforth, 1989; Speth, 1983).

Finally, climatic conditions play an important role in the nature and quantity of forage available for consumption. Bamforth (1988) sees both precipitation and temperature as limiting factors for grassland production. A decrease in moisture levels reduces plant density, changes plant diversity and also alters plant physiology. For instance, an abnormally moist spring could cause an increase in cool season grasses while an unusually dry summer could cause a relative decrease in warm season grasses. Also during dry periods, a higher percentage of plant protein is locked up in the aforementioned indigestible parts (stems, roots, etc.). Increased precipitation levels generally alter grassland ecological relationships in an advantageous manner. An increase in plant density, a compositional change to grasses with higher moisture requirements and more continuous growth where protein is distributed throughout the plant, is characteristic of moist conditions. The carrying capacity of a region depends mainly on the variables discussed above. An area with higher levels of precipitation and cooler temperatures is going to maintain a higher carrying capacity than an area with low precipitation levels and warmer temperatures. Forage conditions in these areas are going to differ in terms of forage quality and forage quantity (Bamforth, 1988; Speth, 1983).

Bison

Bamforth (1988) begins his discussion of ungulate nutrition by stating that bison must procure forage of a minimum nutritional value (which he defines in terms of protein). This is due to the nature of ungulate digestive processes. The time spent digesting a specific amount of forage varies in direct proportion to the amount of indigestible fiber in the forage. Bamforth (1988) distinguishes between "tolerant" and "selective" digestive systems. The human digestive system is tolerant because it "passes food through the digestive system in a relatively short period of time, extracting as many nutrients as possible." On the other hand, the ruminant selective system is much more efficient, utilizing symbiotic digestive microbes that are able to break down normally indigestible fibers. These microbes must be maintained with a minimum level of food, limiting travel time between feeding areas (Bamforth, 1988; Cashmere, 1997) and influencing responses to nutritional stress.

At the population level, both herd size and mobility are strongly linked to the availability of water and good forage. As the quality and quantity of forage in a region decrease, bison are forced to migrate more often for longer distances in order to maintain basic metabolic functions. Grazing ungulates tend to maximize forage quality rather than forage quantity (Bamforth, 1988). Bamforth (1988) presents a model of population regulation in bison. In this model, he suggests that a decrease in forage nutrition would first lead to general under-nutrition in individual animals. This would make them increasingly vulnerable to predators and lead to the birth of weak calves that would not survive periods of seasonal stress. The population would continue to decrease until the forces controlling the decline also decreased. An assumption of the model presented in this paper is that bison demography and health would have been affected by changing environmental conditions and a major influence on human subsistence decisions between AD 1 and AD 1500.

Implications of the Bison/Grassland Ecological Model for Human Groups

A general outline of climatic change in North America has been presented by Baerris and Bryson (1965), and more specifically for the Great Plains by Wendland (1978), Barry (1983), Wedel (1986), Johnson and Park (1996). Despite these attempts, only general characteristics of past environments are presently known. The following section will attempt to synthesize the present knowledge of Central Plains palcoclimatology with what has already been discussed about ungulate and grassland responses to environmental change. This author suggests that a change in climate coupled with the availability of imported cultigens played an important role in fostering an environment favorable to the development of agriculture on the Central Plains during the relatively warm, and Scandic climate episode. Poor foraging conditions for bison would have stressed localized, bison dependent Woodland populations to the point that they relied increasingly on nutritional alternatives.

It has been established that bison prefer smaller amounts of high quality forage, rather than greater amounts of mediocre or low quality forage (Bamforth, 1988). When coupled with a general knowledge of prehistoric precipitation and temperature levels, we can infer the general forage conditions during a particular climatic episode (climate episodes taken from Wendland, 1978). The proposed cool, moist conditions that prevailed during the Sub-Atlantic episode (700 BC-AD 500) would have produced relatively high amounts of good forage. Bison populations would have increased across the Central Plains. The warm, dry Scandic episode (AD 500- AD 800) would have produced a lower quantity and quality of forage than the preceding Sub-Atlantic. Bison populations would have decreased and been more mobile, perhaps aggregating in local areas with better forage conditions. The Neo-Atlantic (AD 800-AD 1150) was also warm, but showed relative increases in moisture when compared to the Scandic. Bison populations may have slightly expanded, but would have been more susceptible to droughty conditions, due to the prevalence of warm season grasses whose nutritional value fluctuates widely according to precipitation levels. Finally, the Pacific climate episode (AD 1150-AD 1600) was a period of decreasing precipitation but cooler temperatures. These conditions probably would have provided adequate amounts of higher quality forage. Yet, unlike the preceding Neo-Atlantic, the dominance of cool season grasses would have decreased the variability in bison forage and encouraged larger, sedentary herds, Bozell (1995) has presented a history of reliance on bison in the Central Plains that reinforces this model. Through a quantitative measurement of recovered, unmodified bison bone per cubic meter of excavated area, his data show relatively high bone densities for Middle Woodland (AD 1-AD 500), Middle Missouri (AD 1000-AD 1450) and Coalescent sites (AD 1500-historic). Lower values are associated with Late Woodland (AD 500-AD 1000) and Central Plains Tradition sites (AD 1000-AD 1500).

The following discussion of prehistoric human adaptation to the Central Plains environment will focus on the climate of the Sub-Atlantic, Scandic, Neo-Atlantic and Pacific episodes, which affected human subsistence patterns throughout the Middle Woodland (AD 1-AD 500), Late Woodland (AD 500-AD 1000) and Central Plains Tradition (AD 1000-AD 1500), respectively. While these cultural distinctions represent real variability in the archaeological record, the limits of these categories probably do not accurately reflect cultural change. Since this paper is not concerned with broad issues of cultural taxonomy, it will continue to use these terms for arbitrary divisions of prehistory with simply the realization that their limits poorly represent reality.

No Early Woodland manifestations (BC 500-AD 1) are known to exist within the study area (Bozell and Winfrey, 1994). Middle and Late Woodland sites are in existence and taxonomic trends can be extrapolated from recovered archaeological materials. The Plains Woodland period exhibits a number of new innovations, among the most evident of which is the widespread use of ceramics. The characteristics of Plains Woodland vessels include elongated bodies, conical bases, direct rims with flat or rounded lips and thick. cord-roughened walls (Kivett, 1970; Hill and Kivett, 1940). An increased use of plant foods in the diet associated with larger refuse middens (therefore longer occupation periods) indicates complex relationships between social groups and their environment. Regionally, bison is thought to have been a valuable resource supplementing the diverse hunting and foraging strategies of Plains Woodland groups (Bozell, 1995; Bozell and Winfrey, 1994; Wedel, 1986).

The Woodland pattern of subsistence on the Central Plains utilized a diverse suite of resources. Recent research has emphasized both floral and faunal diversity in the Woodland subsistence pattern (Mick, 1983; Bozell and Winfrey, 1994; Adair, 1997). Cashmere (1997) and Bozell (1995) have explored the implications of Neo-Atlantic conditions in relation to grassland and forage conditions during the Plains Woodland period. As discussed above, shorter growing seasons and generally cooler temperatures created forage of predominantly cool season grasses. These grasses provided a higher protein to carbohydrate ratio than warm-season grasses. Since carbohydrates were relatively abundant in these grasses, an animal would not have needed to draw upon its own fat reserves in order to process protein. An animal that retains its fat reserves has a much better chance of surviving periods of nutritional stress (Speth, 1983; Bamforth, 1988). Therefore, grassland conditions during the relatively moist, cool Sub-Atlantic would have been very favorable to bison providing optimal hunting and procurement opportunities for human groups. Herds during this period would have been larger and less mobile than during the later Scandic episode.

Regionally, there seems to be a reduction in bison use during the Scandic (Bozell, 1995). Riparian fauna and semi-domesticated plants were utilized more intensely during this period (Cashmere, 1997; Kivett, 1952). Cashmere (1997) suggests that this period is a transition from a diverse horticultural pattern to intense agricultural pattern. While beyond the scope of this paper, some mention of this phenomena and its suggested causes could shed some light on human/bison relations at this time. Some authors suggest this subsistence change is a result of bison nutritional stress and increased herd mobility (Cashmere, 1997). Other authors believe this transitional period before the domestic crops and cultivated fields of the plains villagers simply implies that humans in the New World were "ready" for intensive agriculture (Rindos, 1984). Finally, some authors approach this period through an evolutionary perspective in which certain adaptive social or cultural traits were favored over others in relation to the changing environment (Adair, 1997). One advantage of archaeology's diachronic perspective is hindsight. From this, we are able to determine many "push" and "pull" mechanisms at work during this period, as well as admitting that there are many more we undoubtedly know nothing about.

Archaeologically, there is evidence that Central Plains groups began to focus more on the cultivation of domesticates beginning in the Late Woodland (Scandic) and continuing throughout the Neo-Atlantic. It is suggested that the climate change between the Scandic and the Neo-Atlantic would have also affected human subsistence patterns. The "push and pull" mechanisms (ecological and climatic) present during the Late Woodland gradually selected for changes in subsistence, that focused increasingly on cultivated resources and labor intensive bison processing techniques. While a definite boundary between hunter-gatherers practicing limited horticulture and horticulturalists incorporating limited hunting and gathering would be arbitrary (and may not mean anything anyway), the subsistence patterns on opposite sides of this transition have visibly different qualities.

Central Plains Tradition (CPT) assemblages, while having distinct ceramic and lithic characteristics, developed a different diet and settlement pattern from their Woodland predecessors. Hamlets of 2-3 houses each in the west and small, unfortified villages of up to 31 lodges in the east are present from 1000-1400 AD. These groups were fairly sedentary, probably engaging in both seasonal and local hunting strategies with regard to faunal procurement (Logan, 1996; Bozell, 1991). Wedel (1986) maintains that Upper Republican diet consisted mainly of locally obtained bison and cultivated domesticates. Wood (1969) on the other hand, suggests these groups left their crops for seasonal hunting trips to the west, much like historic groups (upon which his model is based). Neither of these authors examine the bison contribution to the Upper Republican diet relative to either the Plains Woodland subsistence pattern or to other faunal and floral resources utilized. As stated above, Bozell (1995) offers evidence for lower rates of bison use for groups during this climatic period. An examination of selected, published faunal assemblages reiterates the fact that numbers of bison elements recovered are few when compared to respective Woodland sites (Falk, 1969; Grange, 1980; Bozell, 1995, 1991; Koch, 1994).

It has been proposed that the arid, warm Scandic would have nutritionally stressed the bison population available to Late Woodland groups forcing them to rely upon alternative resources, in this case, the increase use of carbohydrate-rich cultigens. As groups relied increasingly on cultivated plants, they became more sedentary, using local lithic materials. In addition, they continued curating already existent exchange links to the east, west and south (Wedel, 1986; Logan, 1996). These trade networks could have been used as both a resource buffer during times of stress and as a source of exotic materials and ideas.

Increasing sedentism and the successful continuation of agricultural practices would have encouraged an intensive agricultural strategy, even after a reversion to the warm, slightly more moist conditions of the Neo-Atlantic expanded bison populations slightly again. The climate during this period would have been very favorable to maize cultivation. Yet, bison populations were probably still variable for reasons stated above. Inter-annual variability in rainfall could imply increased use of bison resources during moist years and a dependence on agriculture during drier years. While feasible in the central and eastern portions of the study area, bison undoubtedly remained a staple for those groups in areas where maize horticulture was, at best, an activity involving risk. CPT hunting camps in western portions of the study area with relatively high amounts of bison could be the result of a few years of above average rainfall (Logan, 1996).

This model predicts that bison populations were abundant and generally in good health during the early and middle Plains Woodland periods. Climatic degeneration during the latter portion of the Late Plains Woodland caused bison to experience nutritional stress and regulate their populations accordingly. Woodland groups, faced with decreasing bison availability, relied increasingly on cultivated plant foods to maintain dietary stability. This reliance on domesticates encouraged sedentism and localized catchment areas. Even after the prevailing climate became more advantageous to bison (around 1100 AD) their numbers would have still fluctuated with wet and dry years. Increasing population size and variability in bison availability were probably factors in the continuation of agricultural practices by CPT groups.

Evaluation of the Model

As indicated. many options were available to Woodland groups who found it increasingly difficult to gather necessary fat resources from bison. It is suggested that Woodland peoples would have first resorted to more intense processing of bison elements. This alternative is a conservative strategy for increasing bulk fat procurement and these groups would have been relying on previously known resources. Prehistoric Plains groups routinely dealt with seasonal fluctuation in bison nutrition and alternative butchering processes would have been common knowledge. This woodland adaptation would have become more intense in the warming and drying of the Scandic episode, culturally corresponding to the late Late Woodland and groups that were transitional between Late Woodland and CPT peoples.

This intensifying use of bison would manifest itself in the archaeological record in many different ways. The diversity of skeletal elements selected for marrow procurement would have expanded to include alternative elements, such as metapodials (Binford, 1978; Speth, 1983). A good indicator of the intensity of marrow removal is fragment length (Villa and Mahieu, 1991; Lyman, 1994). In this study, fragment length would be expected to decrease throughout the Middle and Late Woodland periods, reaching its lowest point near the end of the Scandic and early Neo-Atlantic when cultivated grains are first evident in the study sample.

Bone grease extraction may have been another method used by groups to counter nutritional stress. The production of bone grease accesses intra-bone structural fats, which are less susceptible to resource fluctuations (Binford, 1978). An increase in the fragmentation levels of vertebrae and articular ends of long bones may indicate grease extraction. Bone grease, and the boiling of cranial elements for sinus fats, would introduce a higher frequency of axial and cranial elements to a habitation site assemblage.

Finally, reliance on non-bison fauna may have increased, focusing the hunting strategies on animals where fat levels are not linked to foraging conditions (i.e. riparian fauna).

While an increase in microscopic subsistence intensity may alleviate short term stress, as stress increased throughout the Scandic, this alternative may have become increasingly costly in terms of time and labor relative to the amount of fat procured from an unhealthy animal. In this event, an increase in horticultural products making up the subsistence base would have provided necessary, protein-sparing carbohydrate supplements to human populations. Horticultural resources had been available since the Middle Woodland and trade patterns to the east would have made a gradual transition to agricultural dependence relatively easy. Higher amounts of cultigens have been reported from the late Scandic and Neo-Atlantic (Bozell and Winfrey, 1994; Bozell, 1995). The increase in agricultural intensity would have lessened reliance on animal fats. Fauna were still a necessary source of protein, but the need to extract sufficient amounts of fat to metabolize that protein, was lessened by the incorporation of more carbohydrates into the subsistence pattern. This pattern may be evident in the archaeological record by an increase in agricultural "tools", more remains of domesticated cultigens, a higher diversity of those cultigens and a relaxation of butchering intensity. Elements such as scapulae would occur in higher frequencies and show wear. While the proper excavation/laboratory techniques for recognizing plant remains have not been universally applied (Adair, 1997), macrobotanicals or other evidence of increased cultigens used (such as larger storage pits) may indirectly aid this evaluation. Finally, the relatively intense, fat-oriented butchering patterns that characterized the late Late Woodland and Scandic would decrease in intensity.

Meat removal, marrow retrieval and bone grease extraction, respectively, require increasing amounts of labor. Labor intensive techniques may have been used to counter nutritional strain on bison. As the nutritional stress experienced by bison increased, corresponding increases in labor investment would also occur. In order to discern these processes in the archaeological record, different tools will be used to look at Central Plains faunal assemblages. Element frequencies will be used to discern temporal patterns in elemental processing. Then, the degree of fragmentation for each assemblage will be determined. The maximum length of skeletal elements will be examined with the idea that a smaller average, maximum length reflects an increase in processing intensity (Villa and Mahieu, 1991). In addition to the maximum fragment length, the NISP:MNE ratio (Number of Identified Specimens: Minimum Number of Elements) will also be used to gauge the degree of fragmentation. Levels of fragmentation have implications for desired animal products (meat, bone or grease). Finally, a tabulation of impact and cut marks will further refine our understanding of the prehistoric butchering patterns in question. All of these methods are subject to other taphonomic biases such as weathering, deterioration, and carnivore modification. Therefore, I will try to be explicit about site histories as well.

The Sample: (see Figure 1)

Site selection criteria for inclusion in this study focused mainly on geographic area and bison NISP. All sites are located in central Nebraska. With the exception of the McIntosh site (which is in the eastern Sand hills), all sites are located in what is today considered mid-grass or transitional plains, and are. to some extent, palimpsest deposits with different taphonomic histories.

Schultz Site (25VY1)

The earliest of the sites examined. the Schultz site, is the type site of the Middle Woodland, Valley complex. Excavated in 1939 by the Nebraska State Historical Society (Hill and Kivett, 1940), 25VY1 is a proposed village site consisting of 15 major features. At least eight (possibly as many as 10) of the features in this "small, compact site" were house floors (Adair, 1997; Bozell and Winfrey, 1994; Winfrey, 1991). Structures were represented by semisubterranean basins with a central fireplace. Hill and Kivett (1940) speculate a covering of skins or mats over a pole frame. There were also numerous storage/refuse pits and a midden area. Features and "significant" artifacts were mapped during excavation.

Hill and Kivett (1940) suggest some permanency of occupation due to the depth of the cultural laver (16-40 inches), but do not specify seasonality except to say that this village must have been occupied throughout most of the year. It has been suggested by later researchers (Winfrey, 1991) that the spatial distribution of cultural materials at 25VY1 is characteristic of a winter occupation. This interpretation is based on the location of the hearths inside the structures and the location of the midden area in relation to other features.

At the time of excavation. Valley ceramics were known only from the earliest of three pottery bearing horizons in Ash Hollow Cave (Garden County, NE) (Hill and Kivett, 1940). At present, the known distribution of Valley ceramics is quite extensive, ranging from village sites along the Missouri and west along the Platte, Loup and Niobrara rivers. Ceramics have been reported as far west as central Wyoming, north to North Dakota and south to central Kansas. The date of occupation (based on typology) for the Schultz site is estimated to be between AD 1 and AD 600. No vegetal remains were recovered (Adair, 1997; Bozell and Winfrey, 1994).

Wallace Site (25GO2)

Also dating to the Middle Woodland period is the Wallace site. Excavated by a University of Nebraska fieldschool in 1988, multiple C14 samples date this site between AD 425 and AD 650 making its occupation either contemporary to, or slightly later than, the Schultz site. Wallace ceramics show characteristics of both Valley (east) and Keith (west) groups. Most sediment was screened through 1/8 inch dry screens, although 1/16 inch screen samples and flotation samples were also taken. Features included: one hearth. two possible pits and two well defined midden areas. Perception of both pit features was difficult due to extensive rodent disturbance. *Antilocapra americana* (antelope) accounted for 56% of the faunal sample while *Bison bison* (bison) only contributed 6.2% (Adair , 1997; Winfrey, 1991). This may imply substantial differences in animal procurement and/or paleo-ecological factors from the other sites involved in this study where bison is the dominant fauna.

Winfrey (1991) suggests a "single, limited occupation of unknown duration" based on the spatial analysis of cultural materials. An interior hearth, an absence of aquatic fauna and "distinct" midden areas indicate 25GO2 was most likely occupied during the winter as a base camp.

Packer Site (25SM9)

Excavated by an avocational archaeologist in 1980 and reported by Bozell and Rogers (1989), the Packer site is culturally affiliated with the Great Oasis tradition along the Missouri River in northeastern Nebraska and northwestern Iowa. While this site lies almost 150 miles south and west of what is generally considered Great Oasis territory, its location in Sherman county and its relatively abundant bison remains make the Packer site appropriate for this study. C14 dates between AD 900 and AD 1050 (Bozell and Rogers, 1989) place the occupation of this site towards the height of the proposed Neo-Atlantic climatic episode. Taxonomically, I will consider it to be a cultural transition between the Middle Woodland and Central Plains Tradition villages. The bison sample at the Packer site was recovered from a subterranean pit. This feature was completely excavated and all materials were 1/16" wet screened (Bozell and Rogers, 1989). Bozell and Rogers (1989) believe this pit to be a single component of a large, semisedentary occupation that was occupied between late fall and late spring, similar in seasonality to both the Schultz and Wallace sites. This seasonality estimate is based on analysis of molar eruption patterns and annual growth rings in mammalian dentition. Charred corn kernels were also recovered from the pit (Bozell and Rogers, 1989). This is the earliest site in this study to contain evidence of maize.

McIntosh Site (25BW15)

Due to the paucity of bison in most CPT assemblages, a cold-season bison sample was unavailable for this study. The McIntosh site fulfills both site selection criteria, but represents a warm season occupation. This must be considered during comparison with the rest of the study sample. The McIntosh site is the most recent site included in this study (AD 1292-AD 1441) (Koch, 1994). A variety of features were excavated by the Nebraska State Historical Society between 1987 and 1989 on the shore of a permanent Sandhills lake. These features include: 1 structure, 1 midden area, 4 basin features, and 18 refuse/storage pits. An estimated 50% of the site had been impacted by construction activities, including the truncation of 15 refuse/storage pits. There was no evidence of superimposed features or stratified cultural deposits that would indicate more than a single occupational event (Koch, 1994). It was occupied during the Pacific climatic period, during which lower average temperature and rainfall discouraged reliance on horticultural products throughout the mid-grass plains (Wedel, 1986). Koch (1994) suggests the McIntosh site was occupied for a longer duration than a temporary camp. Seasonality estimates were based on the analysis of large numbers of fish annuli and the presence of seasonal birds. These data suggest a human presence at the site from late spring through late fall (May-late November) (Koch, 1994). Variation in the McIntosh bison with the other study sites could be due to three unrelated factors: a unique geographical location in the Sandhills which is traditionally resistant to climatic change, an occupation during the warm season which affects the species available for procurement as well as the health of those species, and a macrobotanical sample that contains maize, beans and other cultivated foods.

Methods

A variety of methods will be used to determine the nature and intensity of butchering practices as practiced by Woodland and Plains Village people. The current study is limited to the analysis of *Bison bison* remains and does not take into consideration other medium or small animal materials even though pronghorn dominate the Wallace assemblage and the McIntosh site contains substantial amounts of fish and birds. Descriptive (i.e. element, portion, segment, side, proximal/distal fusion, and maximum length/width), diagenetic (abrasion, weathering, and deterioration), and modification characteristics (breakage, carnivore modification, butchery type, and location) were recorded for each identified specimen. Figure 1a shows the basic quantitative characteristics of the four sites in question.

Taphonomy

Since the depositional histories of archaeological sites vary widely according to both paleoenvironmental and geographic factors, any intersite comparison must take into consideration factors which are not related to cultural activities. Taphonomic studies have indicated that non-human agents can influence the nature of faunal assemblages, even those which were originally deposited by humans (Binford, 1981; Lyman, 1994; Todd, 1987). In order to establish a common baseline for the sites in the comparison, certain attributes of the assemblages have made evident the extent to which non-human agents were involved in the survival of faunal remains. Once this taphonomic history is outlined, cultural factors affecting the assemblage can be determined more confidently.

Overall, the condition of excavated bone in the sites used for this study was good. Both the Packer and Wallace sites show extremely low frequencies of weathered and severely weathered bone (Weathering stages from Behrensmeyer, 1978). The Schultz site had a slightly higher rate of weathering (8%). Finally, 21% of the McIntosh bison were weathered to stage two, but less than 2% were weathered to stage three or more (see fig. 2). Weathering has had minimal influence in the site histories of the Schultz, Wallace, and Packer sites, but has had slightly more influence on the McIntosh materials. This may have affected certain observations recorded for that fauna, such as cut mark visibility or carnivore modification, as well as deleted some low density elements from the assemblage.

While values for weathering indicate good overall preservation, three of the four collections show much greater occurrences of carnivore modification. The Packer site showed very little evidence of carnivore modification (3%). On the other hand, the Schultz, Wallace and McIntosh sites had moderate to high amounts (43%, 21% and 38% respectively) (see fig. 3). Although carnivores may not mask butchering patterns as effectively as weathering and deterioration of bone, they probably indicate some elements that had been removed from the assemblage were not the result of transport decisions made by people.

Results

Element frequencies of all four assemblages are shown in figures 4a-4d. Generally, the Schultz site shows a relatively low frequency of axial and front limb elements with a much higher proportion of distal rear limb elements. The highest value for the assemblage is for distal metatarsals and second highest is distal tibiae. The high use of these distal elements indicate a reliance on animal fats and some nutritional stress in the bison themselves (Binford, 1978; Speth, 1983). This would correspond well with Winfrey's (1991) estimation of the Schultz site being a winter occupation.

The highest %MAU (Minimum Animal Unit) value for the Wallace site bison is for scapulae (1 left, 1 right, 2 unsided). Carpels have the next highest value and first phalange has the third, while cranial and the articular ends of some long bones (distal femora, proximal tibiae) have a moderate value. The high frequencies of low-utility elements in this assemblage may be due to idiosyncratic or localized procurement patterns or reliance on non-bison fauna (antelope). The moderate values of long bone articular ends, cranial and metatarsal elements suggests bone grease manufacture and intensified marrow processing of distal elements.

The highest %MAU value in the Packer site is for distal femora. This, coupled with similarly high values among vertebrae and cranial elements, suggest bone grease extraction to a higher degree than that of either the preceding Wallace and Schultz sites or the succeeding McIntosh site. While distal femora frequency could indicate a focus on bone with high meat yield, no other long bones show a similar frequency. Therefore, this is unlikely.

Finally, the McIntosh site shows a high scapulae value and consistently high values for the rear limb. Vertebrae generally are more available than in the two Woodland sites, but less available than those in the Packer (transitional) site. Front limb elements have frequency values consistently higher than those of the other sites and overall, rear limb elements also occur in higher frequencies than in the other three sites. Meat use was probably higher. Overall, the McIntosh bison show a more consistent use of bison elements throughout the entire skeleton. This may be related to the fact that this was a warm-season occupation site, so grazing animals were under less nutritional stress.

While element frequencies can often reveal issues regarding differential use of whole skeletal units and their potential fat content during nutritional stress, another method must be used to gauge how butchering intensity changed through time. In order to observe this, the maximum length of each identified fragment was recorded during analysis. It has been suggested (Lyman, 1994; Villa and Mahieu, 1991) that fragment length can be linked to marrow usage and bone grease production, both of which would have been adaptive behaviors undertaken by late Woodland peoples prior to extensive reliance on horticultural products. Average maximum length of long bone fragments in these assemblages show that the smallest longbone fragments come from the Packer site, and the other three sites have a much higher average maximum fragment length (see fig. 5).

NISP:MNE ratios are also used to determine a relative degree of fragmentation (Lyman, 1994; Villa and Mahieu, 1991). Axial elements, especially pelves are more fragmented in the two later sites. Both sites also show a high degree of fragmentation for scapulae and distal femora. McIntosh alone shows high values for distal humeri (see fig. 6).

Finally, a gauge of relative butchering intensity can be the frequency of butchering marks on the bone themselves. A tabulation of impact scars shows a trend in a decreasing percent of impact scars through time with a low during the most recent period represented by the McIntosh site (see fig. 8).

Discussion

The examination of archaeological data for the study period has resulted in a complex picture of prehistoric dietary adaptation. The model presented in the preceding pages proved rather simplistic. In reality, many product oriented, adaptations, as well as many environmental and cultural factors that triggered these adaptations were present.

The Schultz site bison were primarily butchered for marrow resources. The archaeological evidence supports the model's suggestion that these bison were in relatively good health. Despite the winter seasonality estimate, the target resource in these animals was marrow, rather than more labor intensive products such as bone grease. Some seasonal nutritional stress is indicated by the high frequency of distal elements such as metapodials, distal radii and distal tibiae (Binford, 1978; Speth, 1983). Apparently, little meat was utilized.

Bison may not have played an important subsistence role at the Wallace site. A large percentage of the assemblage was pronghorn and the bison sample is small. In bison, the higher frequencies of axial elements, coupled with their low levels of modification may indicate more localized catchment areas. However, fragmentation of axial elements is higher than in the Schultz site, perhaps the result of increased bone grease recovery. Maximum fragment length of long bones and NISP: MNE ratios for both front and rear limb elements display a low level of fragmentation. Overall, the inhabitants of the Wallace site probably relied more on bone grease and less on marrow than the Schultz site inhabitants.

The Packer site has both a high frequency and fragmentation level for axial elements. This may mean bone grease is a valued commodity. A high percentage of axial elements bearing cut marks could be the result of meat procurement, but is more likely the product of excellent preservation. The Packer site may show more cut marks than other sites simply because they are preserved better. There is almost no indication of butchery on either the front or upper rear limbs. Distal femora were prevalent in the assemblage and modified often. Overall, the Packer site shows much evidence for bone grease extraction, but less emphasis on other butchering processes such as marrow or meat processing. Both bison and human populations at the Packer site were under nutritional stress and exhibit the highest reliance on labor-intensive bone grease extraction within the study sample.

The McIntosh site is unique in this study. Due to its warm season occupation, it shows consistently high levels of butchery throughout the entire skeleton. Meat is a typical goal of summer bison hunting, either for immediate consumption or storage (Reeves, 1990; Frison, 1991). This processing bias is evident in the assemblage, but bone grease manufacture and marrow extraction were also important activities, either for cold-season storage or as an indication that horticultural products were not yet available in quantities needed to replace animal fat as energy efficient protein processors.

Conclusions

This analysis has shown that the changes in bison processing through periods of nutritional stress are not simple and straightforward. Nutritional options present in bison would have provided human groups with labor-intensive alternatives that could be used to meet fat requirements. The beginnings of intensive agriculture provide even more variables to take into consideration.

Overall, one is able to see some trends in butchery patterns based on the products procured (see figure 8). Based on the character and location of cut marks, meat was not an important product in all sites, except the most recent in this study. This indicates a certain degree of nutritional stress in the bison, probably related to the cold-season seasonality estimate of the three sites. Secondly, marrow retrieval is important in the Schultz and McIntosh sites, but is not as prevalent in the

Wallace and Packer assemblages. This may be due to increased nutritional stress on bison to the extent that marrow was no longer a product worth procuring. Finally, grease extraction seems to have intensified throughout the time period, attaining its most intense use in the Packer and McIntosh sites. The relatively low reliance on other products (marrow and meat) at the Packer site indicates bone grease extraction was necessary to procuring requisite fats from bison while the intensive use of all bison products at the McIntosh site is more indicative of warm-season surplus-storage activities.

The analysis of these fauna indicates nutritional stress in bison populations climaxing during the Scandic episode with corresponding increases in butchering intensity. Yet, variability in product orientation is evident. A larger sample that controls for geographic area, seasonality, and predominant fauna may further realize the nature of Woodland reliance on bison and the effects of this reliance on the beginnings of intensive agriculture on the Central Plains.

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APPENDIX

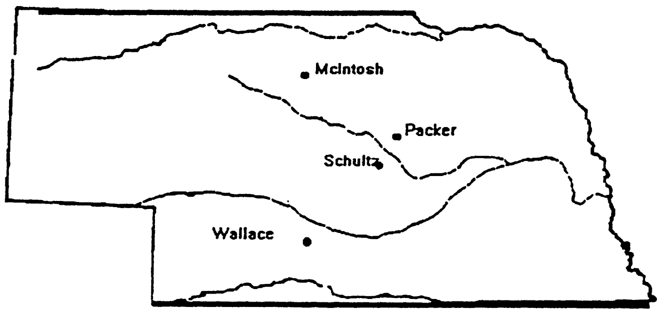
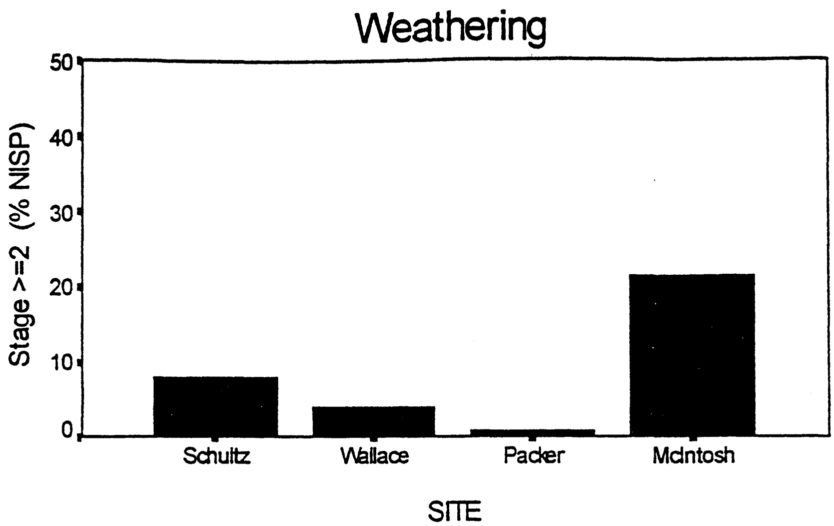


Figure 1. Site map

SITE	NISP	MNI	MAU
Schultz (25VY1)	299	17	14.50
Wallace (25GO2)	126	4	2.00
Packer (25SM9)	305	5	4.50
McIntosh (25BW15)	530	8	6.00

Figure 1a.



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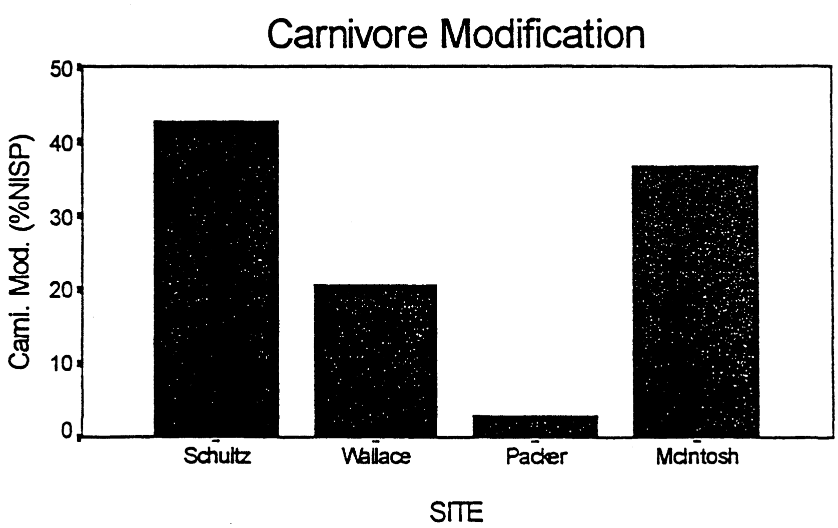

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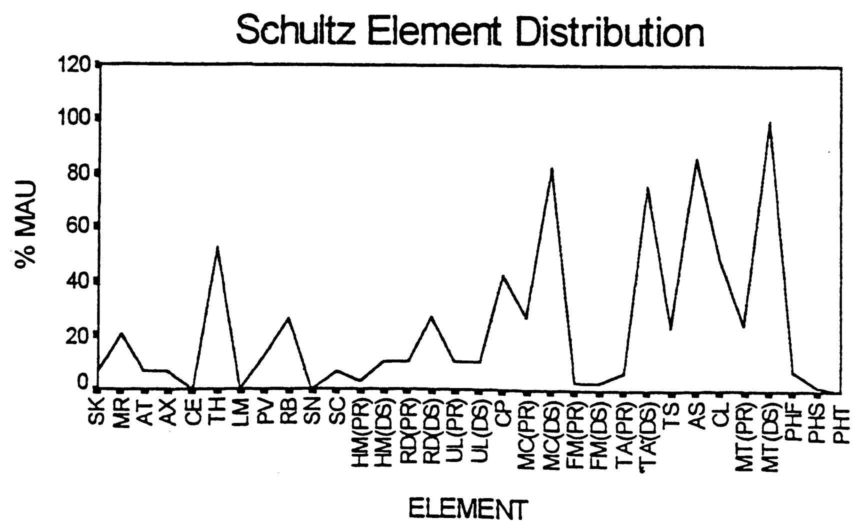

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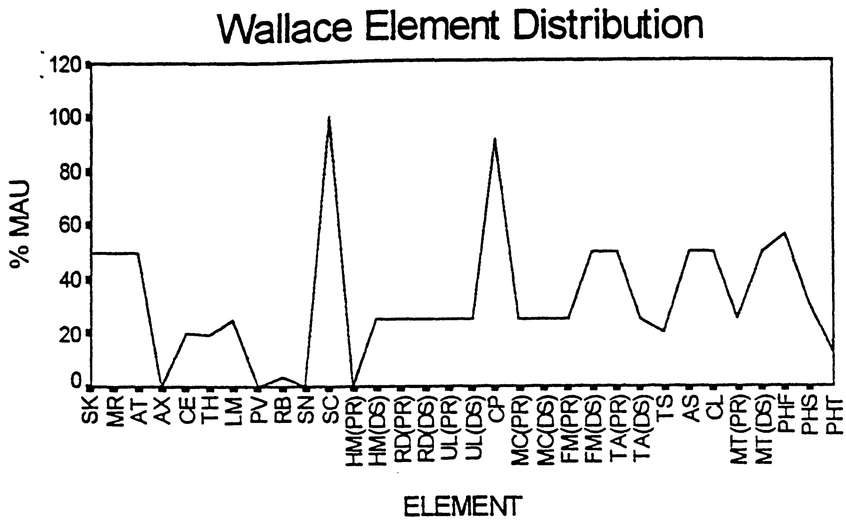


Figure 4b.

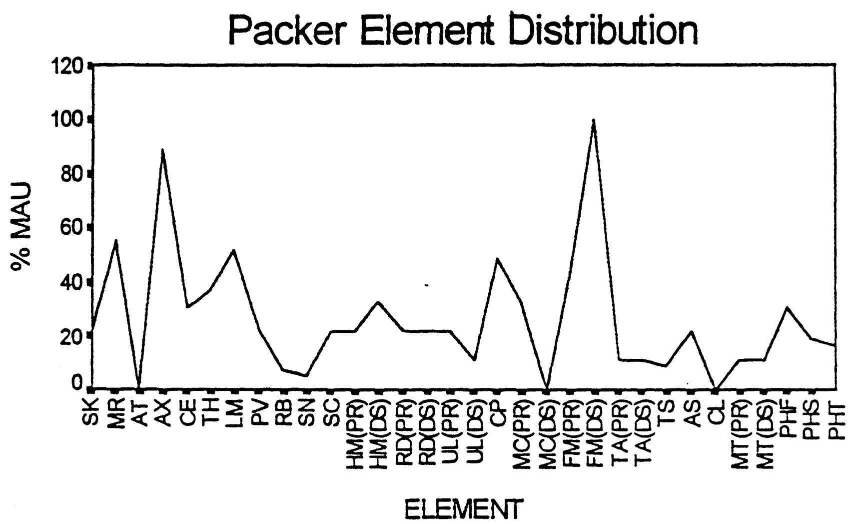


Figure 4c.

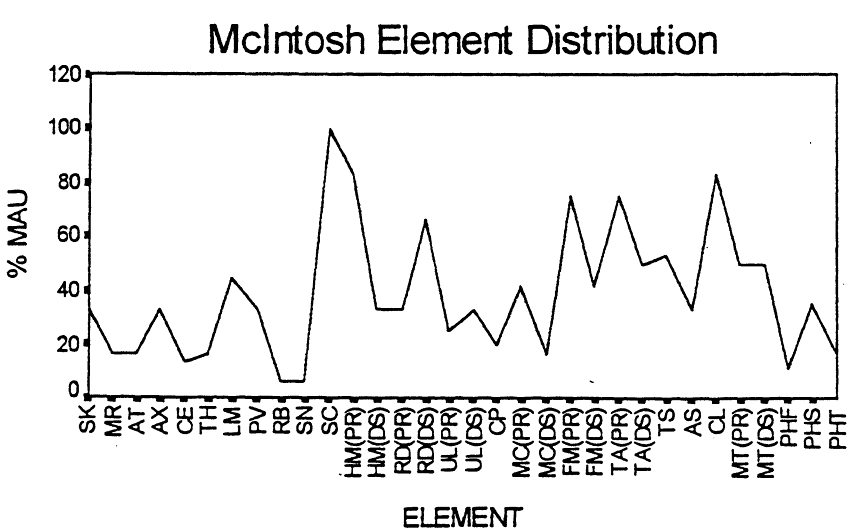


Figure 4d.

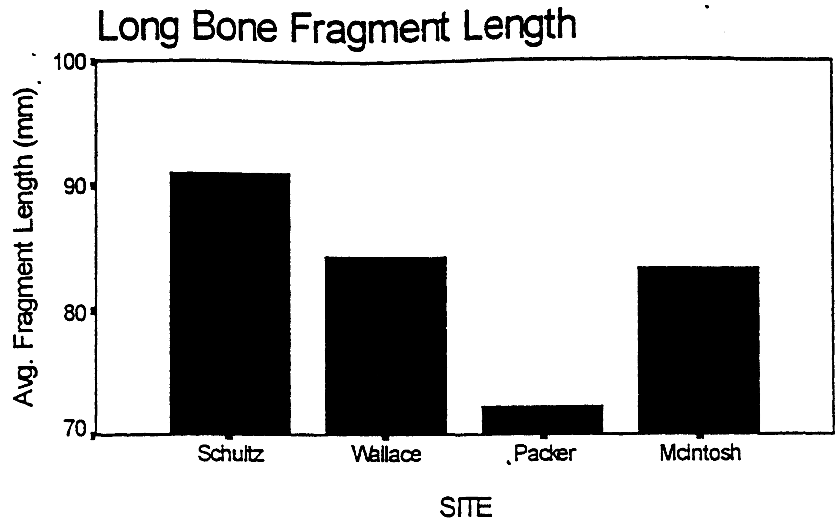


Figure 5.

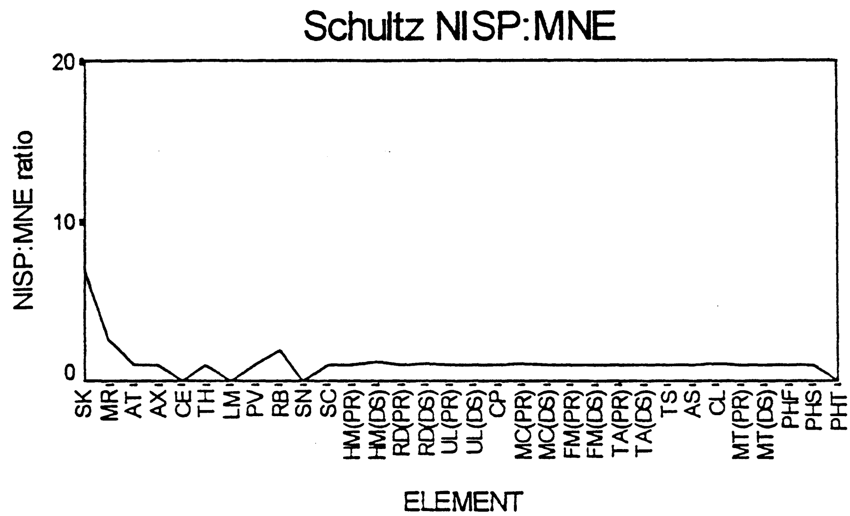


Figure 6a.

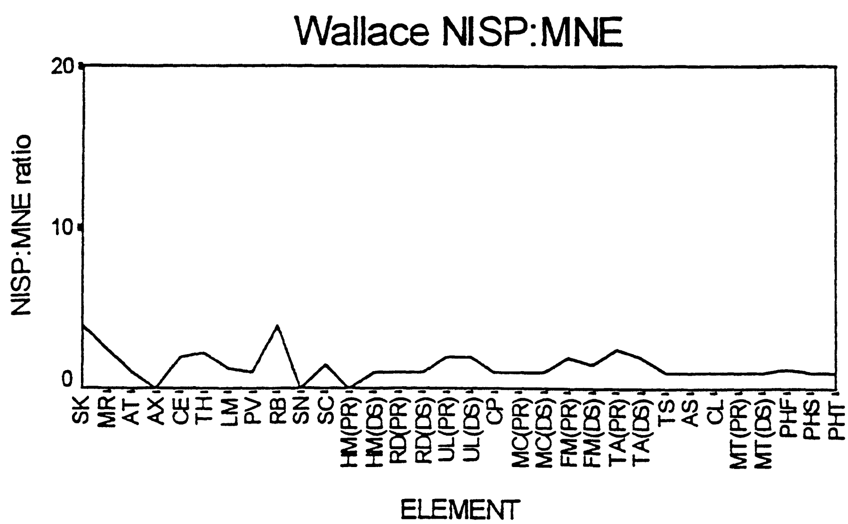
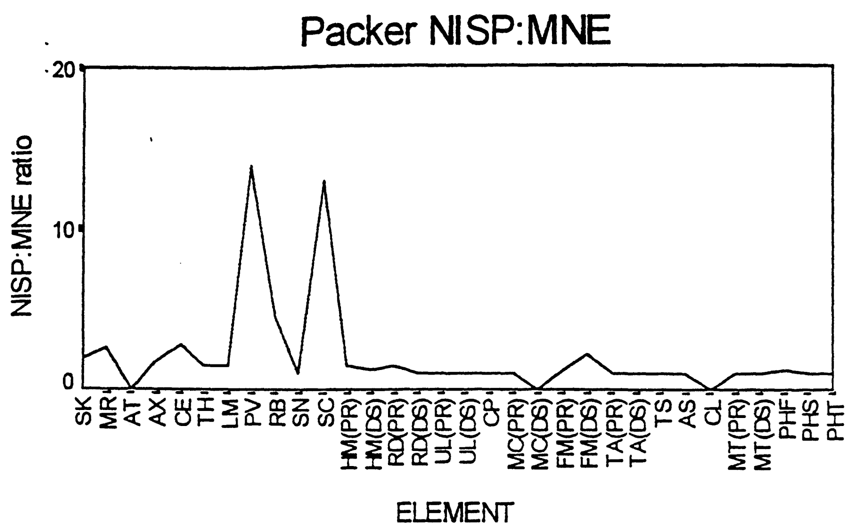


Figure 6b.



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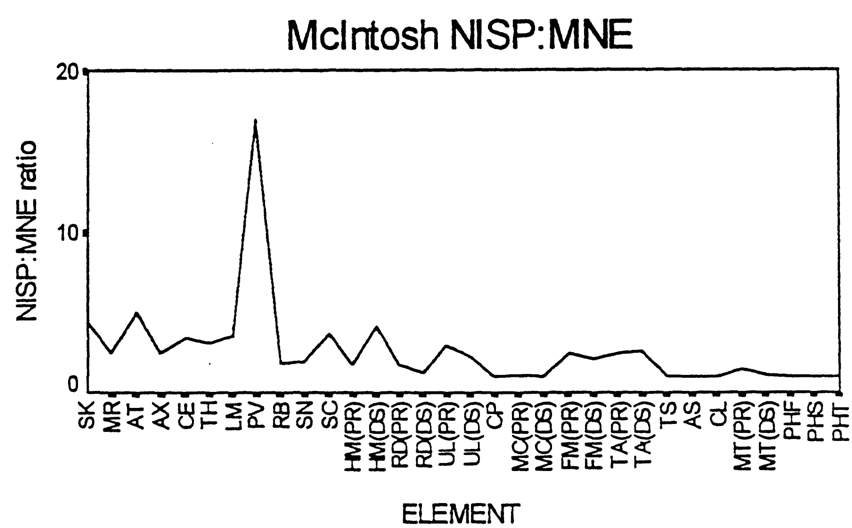

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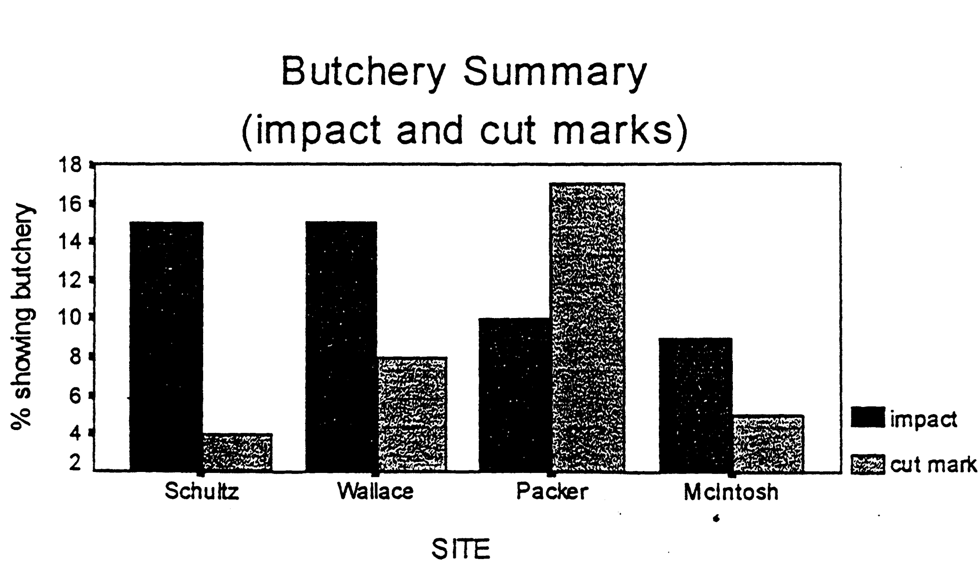

Figure 7.

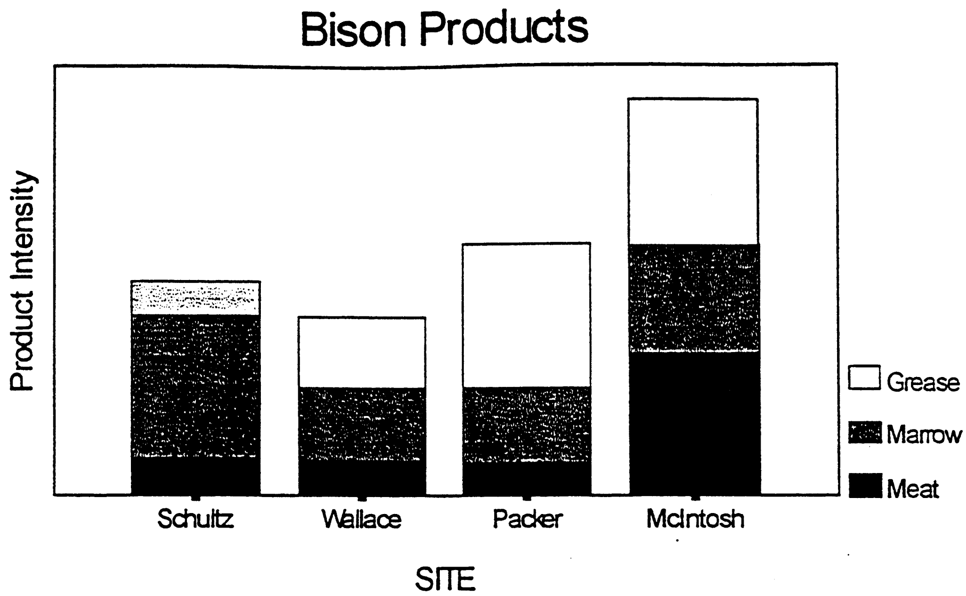
Bison Products
Product Intensity
Grease
Marrow
Meat
Schultz
Wallace
Packer
McIntosh
SITE

Figure 8.