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Matthew O'Brien

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THE SOCIOECONOMIC ORGANIZATION OF COMMUNAL HUNTING: AN  
ARCHAEOLOGICAL EXAMINATION OF SHOSHONE COLLECTIVE ACTION

By

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M.A., Department of Anthropology, University of Wyoming, 2006

DISSERTATION

Submitted in Partial Fulfillment of the Requirements for the Degree of

**DOCTOR OF PHILOSOPHY**

**ANTHROPOLOGY**

The University of New Mexico

Albuquerque, New Mexico

**August, 2013**

## DEDICATION

I would like to dedicate this dissertation to my wife, Jaime, and my family who have stood by me through this whole process. Even when the dissertation seemed insurmountable, your support and your love helped me to persevere.

## ACKNOWLEDGEMENTS

The research discussed within could not have been completed without the efforts and time of many contributors. First off, I would like to thank my dissertation committee for their guidance and critiques that helped shape this research project. I could not have asked for a better graduate advisor in Bruce Huckell, who provided his friendship, numerous research opportunities, and sage advice in navigating academia. Like Bruce, Jim Boone has served as a sounding board for my many issues in learning the academic ropes, and he also provided guidance in shaping the theoretical argument of this research. As an outside committee member, Ozzie Pearson's expertise in skeletal anatomy helped structure the methodological and statistical approach tied to the anatomical refit model. I would like to thank Danny Walker for sharing Eden-Farson with me and whose enthusiasm for the site and its potential was contagious. Finally, I would like to thank Mary Stiner for coming to my rescue and adding her expertise and forcing me to think outside the box.

As with all graduate experiences, professional development would be impossible without good friends and peers. I would like to thank the following people for an unquantifiable amount of friendship: Joe and Melissa Daniele, Dan Drennan, Dave Lorenzen, Caroline Gabe, John Laughlin, Thaddeus Liebert, James Mayer, Todd Surovell, Benjamin Uhler, Nicole Waguespack, and Andrew and Aurora Zink. On many occasions these people were tasked with tolerating many research ramblings, complaints about developing a workable research design, and general growing pains associated with maturing as a researcher. I would specifically like to thank Chris Merriman who has been a jack of all trades during my time at UNM. He has been a friend, a collaborator, and an editor who was always there when I needed him.

Without a doubt, my archaeological experience has had two highlights. The first was the Barger Gulch Project led by Todd Surovell and Nicole Waguespack from 2004 to 2007. Through their guidance I began to approach archaeological problems in a more analytical way without losing sight of the bigger anthropological picture. They also taught me how to infuse fun into archaeology without jeopardizing the integrity of work. These two began as advisors and bosses in 2004, but today I count them as friends.

The second milestone occurred in Rifle, Colorado where amid the doldrums of a two-month survey I met the most amazing woman. Two years later she became my wife. She is a constant reminder that the best archaeological research is meaningless without being able to share it with those that matter most. Her vitality and love have provided the motivation to finish this dissertation, so that we can embark on the next phase of our lives together.

I like to say that all the good parts of me are thanks to my family, and all deficiencies are my own. I have been so very lucky to be a part of such a wonderful family. In my sisters, I have had the best bullies willing to protect me from the beginning until today. Thanks Jiffer and Kristin. One of the best gifts from my parents, Ann and Jack, was the opportunity to pursue my passions, but in retrospect nothing compares to observing how they placed the needs and wants of loved ones above their own. Thank you for all your sacrifices.

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Abstract

This dissertation focuses on developing the means to investigate social organization of communal hunting among egalitarian groups. Communal hunting represents an alternative subsistence strategy that takes advantage of seasonal aggregation of prey species. To maximize returns from these large herds, human foraging groups opt to cooperate with additional groups that otherwise maintain their political independence during the rest of the year. Yet, what is not clear is whether these temporary large camps maintain their egalitarian ethos, giving an equal voice to all members or if the participants adopt an alternative social and political structure. This dissertation uses the case study of the Eden-Farson site to examine whether social inequality, or leadership, arises during pronghorn game drives. The site is located in southwestern Wyoming in the Green River Basin, and based on the archaeological assemblage, is associated with the Eastern Shoshone. A single radiocarbon assay places the occupation of the site at AD

1708  $\pm$  108 years, which places the site within the Proto-Historic period. The site is unique in that there are remains of over 174 pronghorn are distributed among 11 discrete house pits.

To examine the socio-economics of communal hunting at Eden-Farson, Curtis Storlie and I developed an anatomical bone refit model that can deal with large faunal assemblages. This statistical model has the flexibility to incorporate any number of dimensions as well as account for minor asymmetry that exists between an individual's left and right side bones. In a series of diagnostic tests, the multivariate model outperforms existing methodologies by identifying a greater percentage of true pairs and minimizing the number of false positives. The development of the model was then applied to the Eden-Farson site. Using five skeletal parts from the Eden-Farson sample, 63 refits were visually verified, these inter-household refits linked 10 of the 11 proveniences. This provided strong evidence that these houses were occupied at the same time, which confirms the initial interpretation that Eden-Farson represents a single occupation associated with a single mass kill event. These inter-household refits also indicate widespread food sharing regardless of distance between houses. With evidence indicating coeval occupation, it became possible to compare the proceeds of the hunt between families.

To make a comparison of house units, Thaddeus Liebert (UNM Anthropology) and I developed a food utility index (FUI) for pronghorn. Between November 2012 and February 2013, we butchered two does and one buck pronghorn. The butchery collected

the mass and processing time for meat and marrow. These values were then converted to energy (kcal) as well as return rates (kcal/hr) per anatomical unit that complements the existing FUI's of other species.

Finally, the FUI is applied to the Eden-Farson site to test whether there is a skew in the hunt proceeds. The higher ranked anatomical units were concentrated in the northwestern part of the site. When the spatial patterns of anatomical refits were factored in, House 9 has the highest average value per anatomical unit as well as possessing the third most inter-household refits. While two other proveniences had more inter-household refits, their low ranking in hunt proceeds likely reflects tolerated theft as opposed to redistribution due to payment. The existence of leadership among the otherwise egalitarian Shoshone complements what is known about their social organization of communal hunts. While the extensive refitting indicates the continued practice of food-sharing by means of reciprocity and tolerated theft, the Shoshone chose to adopt a non-egalitarian social organization during the communal hunt.

The fact the Shoshone temporarily nominate a leader is not new – there are ethnographic accounts of leadership during communal hunts and fishing as well as winter camps. The identification of leadership or non-egalitarianism in the past provides a new approach to the anthropological debate about the origins of social inequality. While many researchers point to the food production as a key agent in the evolution of institutionalized social inequality, the presence of social inequality among communal hunting suggests non-egalitarian social organization may have greater antiquity.



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## Chapter 1: Introduction

The premise of this doctoral dissertation deals with the emergence of leadership among the Shoshone of southwestern Wyoming. The Shoshone have long been labeled an egalitarian society where all resources are shared equally among the community (Hultzkrantz 1961; Malouf 1974; Shimkin 1947; Steward 1938, 1943). I argue that this equality is more of an ethos than a strict social standard based on quantitative data from contemporary foraging societies, and I intend to use an archaeological case study to identify the presence of social inequality during a communal game drive. This research centers on the Protohistoric Shoshone site of Eden-Farson, which is associated with over 174 pronghorn (*Antilocapra americana*) killed during a single drive event.

The issue of social inequality among hunter gatherers has been well established in the ethnographic literature even among groups that have been classified as egalitarian (Bachuchet 1990; Bailey 1991; Gould 1968; Gurven 2001; Hawkes et al. 2000; Hill et al. 1993; Kelly 1995; Marshall 1994; Smith et al. 2010). The incongruity of this statement is tied to how inequality is defined from an ethnographic and archaeological perspective. Therefore, the easiest approach to this topic is to first define what true egalitarianism represents, which is equal sharing of all products and proceeds among a socially defined group (Sahlins 1972). Inversely, non-egalitarian behavior would be defined as skewed distribution of resources, which is what is present in the many ethnographic studies of forager subsistence. However, recognition of individual status in archaeology is typically predicated on differences in material prestige goods. Therefore, archaeologists, such as

Evans (2004) and Renfrew and Bahn (2008), generalize that social inequality is absent in mobile foraging societies. Yet, we know from ethnographic and historic studies of foraging societies that differences in status are often based on achieved attributes among foragers. Contemporary hunter-gatherers provide a window into the existence of non-egalitarian behavior through the study of hunting. Those involved in the hunt receive elevated social status among their group, but in many situations they also receive more sought after portions of the kill. The tracking of meat distribution provides archaeology an avenue to observe social inequality among societies that do not possess material differentiation.

The justification for skewed resource distribution based on achieved status and hunting participation is valid for individual or small hunting parties, but this explanation fails to explain the presence of skewed resources among communal hunting activities.

Communal hunting represents a shift away from reliance on individual skill to the cooperation of many participants to capture numerous animals or large animals that would be too difficult to obtain individually (Arkbush 1986; Driver 1990). This can be seen in the efforts of the African Efe to trap elephants and their net hunting of small game (Bailey 1991) and Indonesian Lamalera whaling effort (Alvard 2002; Nolan 2010). Both examples exhibit a key aspect of communal hunting: the investment in technology that only has economic value when employed by multiple people. This research focuses on use of game drives for communal hunting activity, which uses stationary technology to contain and corral herd animals. While the design of game drive technology has been well documented (Arkbush 1986; Oswalt 1976), there are sparse data on the social

organization of these activities. In particular, do these drives necessitate the presence of leadership or are they undertaken under collective action (see Ostrom 1990)?

To test whether leadership existed at the Eden-Farson site, a series of inter-related questions is presented (Table 1.1). The first issue (A) deals with establishing whether the households are coeval. It is possible the households represent the reoccupation of the site over many months or years. If the houses were occupied at different times, then there should not be refits between the faunal assemblages associated with each house structure. Inversely, the presence of refits between most or all of the households would provide strong supporting evidence for the alternative hypothesis that the site represents a single occupation. If the alternative hypothesis is supported, then the proceeds of the hunt can be compared between houses.

Table 1.1: Inter-related hypotheses associated with identifying leadership at the Eden-Farson site.

<b>A) Are the households at Eden-Farson contemporaneous?</b>
<i>Hypothesis: The site represents a reoccupation of the same site</i>
Prediction: Anatomical refitting will produce no or few inter-household linkages
<i>Hypothesis: The site represents a single occupation</i>
Prediction: Anatomical refitting will link most or all of the house pits
<b>B) Can food resources shared from the game drive be quantified?</b>
<i>Hypothesis: Sharing occurred with meat that are not associated with skeletal elements</i>
Prediction: There are no quantifiable utility differences in skeletal elements among the households
<i>Hypothesis: Sharing does result in utility differences between households</i>
Prediction: Some households will possess higher utility skeletal elements than others
<b>C) Is leadership necessary?</b>
<i>Hypothesis: The Shoshone practiced collective action with all members serving a leadership role.</i>
Prediction: Variation in utility exists, but there are no discernable patterns in the hunt proceeds.
<i>Hypothesis: A single leader was responsible for the organization and facilitation of the hunt</i>
Prediction: One household exhibits preferential treatment visible through the utility of skeletal elements

To quantify differences in the proceeds from the communal hunt (Table 1.1, B), I rely on a food utility index (FUI) to distinguish between the null and alternative hypotheses. Experimental FUI have been used to interpret and predict transport and butchery decisions for various species (Binford 1978; Burger et al. 2005; Jones and Metcalfe 1988; Madrigal and Holt 2002; Metcalfe and Duncan 1994; Metcalfe and Jones 1988), but a FUI for pronghorn will allow for the comparison of households. By using skeletal elements associated with separate portions of the carcass, the FUI utilizes energy (kcal) to quantify the nutritional differences at the Eden-Farson site.

While there is little historic evidence about the Shoshone to suggest that group members practiced private ownership of material goods, theoretical arguments would suggest there would be visible differences in some resource each family receives. The use of food proceeds from communal hunts (Table 1.1, C) provides a means of isolating social inequality among the Shoshone. In zooarchaeological studies of Mississippian Chiefdoms, numerous studies provide a correlation between status and animal remains in hierarchical societies (Bogan 1983; Jackson and Scott 1995; Kelly 1997). Jackson and Scott (1995) found Mississippian Chiefdom elites at the mound sites were more often associated with skeletal elements yielding more meat and marrow compared to the villager sites. Therefore, tracking the distribution of hunting proceeds should result in unequal distribution of high quality anatomical units to those members who are instrumental to the success of the hunt. If this condition is satisfied, then the primary question of leadership can be addressed.



The social organization of the Eden-Farson site associated with a communal hunt is the primary question of this dissertation. While the theoretical hypothesis is discussed later in this chapter, the Shoshone may have used a collective action or leadership model to organize the communal activity. If leadership does exist, then a single household occupied by a leader should exhibit three independent patterns: 1) more extensive refits resulting from payments from other households; 2) refits should occur between families regardless of distance; and 3) a higher FUI value per anatomical unit should be present in its respective faunal assemblage.

This dissertation includes four manuscripts intrinsically linked to deal with the Eden-Farson site and the question of leadership. The first paper has already been accepted for publication by the *Journal of Taphonomy*; one has been submitted to the *International Journal of Osteoarchaeology* and is currently in review; and the remaining two are drafts to be submitted to other journals in the near future. Before these contributions to archaeological method and theory and the interpretation of Eden-Farson are presented, it is important to frame this discussion in the context of previously established research. Therefore, I will briefly introduce the theoretical and ethnographic support for this research, which will be followed with a discussion of pronghorn and their role in human subsistence. This will be followed by a discussion of the Eden-Farson site.

### *Theory of Leadership*

Anthropological interest into the origins of social inequality has led to archaeological studies of economic, architectural, and burial evidence. Price and Feinman (1995) argue that the discussion of social inequality in the archaeological record should focus on the institutionalized social inequality, which represents ascribed status that is expressed through architecture and material goods. Yet, my interest in inequality is more closely associated with achieved status. As I have already discussed, the idea that social inequality permeates all levels of society is not in question, but identifying it archaeologically is more difficult. Hayden (2001) has suggested that looking at the first signs of individual graves associated with prestige goods indicates the first signs of aggrandizers. Through the control of resources, Hayden calls this initial non-egalitarian societies transegalitarian. While this dissertation does not follow Hayden's theoretical approach, it is interested in the conditions under which non-egalitarian social organizations become more efficient than egalitarianism.

The concept of efficiency has gained most traction with Behavioral Ecology (BE). Under this theoretical framework, behavior is examined from an evolutionary perspective. The primary argument is that all individuals strive to extend their genetic legacies to future generations, and therefore they attempt to maximize the efficiency of their actions to reserve more energy toward reproduction (Stephens and Krebs 1985; Stephens et al. 2007). While human behavioral ecological studies have mostly examined small-scale foraging societies, E. A. Smith's (1991) study of the Inujjuamiut coastal foraging provides a thorough theoretical investigation into complex human foraging behavior. In particular, Smith examines communal hunts through the impact of group size and how

unregulated participation will lead to a decline in returns until they are on par with individual hunting returns. In essence, members of group hunts are rewarded by limiting the number of participants in order to maximize their individual return rates. From a historical perspective, Driver (1990) suggests that communal hunting provides greater efficiency than solitary hunting, yields surplus food that can be stored for lean times, and significantly reduces hunting search time. Driver also argues that the relation between prey density and hunting party size dictates the advantages of communal hunting. In both cases, observations point to social (i.e., learning opportunities for young hunters) and economic (i.e., an increase in successful procurement of game) benefits of cooperative foraging.

In theoretical biology, social foraging began to receive greater attention at the turn of the millennium (see Dall 2002; Dubois et al. 2002; Fraser et al. 2006; Giraldeau and Caraco 2000; Hamilton 2000; Hooper et al. 2010; Rands et al. 2006; Smith and Choi 2007; Wood and Ackland 2007), which led to two significant theoretical advances: kinship-sensitive group size and skewed return rate models. These models combine game theory and optimal foraging to generate new behavioral predictions. In an attempt to examine the impact of relatives on hunting practices, some models incorporate Hamilton's Rule to determine group size (Hamilton 1963). Hamilton's Rule argues that an individual's altruism is determined by the degree of relatedness of the others in a group. This concept has been included in discussions of human social organization (Trivers 1971; Volland 1998), but Giraldeau and Caraco (2000) apply Hamilton's Rule to two separate models: free entry and restricted entry. These comprehensive models build upon earlier models

used by Smith (1991), but provide more accurate predictions of single or multiple individuals' decision-making process. Based on these theoretical contributions from anthropology and biology, we can use behavioral ecology to address the question of leadership.

The initial argument for leadership was developed by Vehrencamp (1983) who argued that leadership arises through force. This hypothesis is visible in non-human social foraging studies that indicate the strongest member of the group can control access to resources, thus forcing other members to concede to their demands for larger portions of a food resource (Dubois et al. 2003; Fraser et al. 2006; Hamilton 2000; Rands et al. 2006). More recently, cooperative explanations for the presence of leadership have been developed (Hooper et al. 2010; Smith and Choi 2007). Essentially, participants are not only tasked with the cooperative venture, but they also must police the level of participation by other members as well as preventing free riders. As group size increases, the costs of monitoring become prohibitive and therefore there is mutual benefit for nominating a leader to focus on policing the event. Among traditionally egalitarian groups, this second form of leadership is more likely given the lack of resource control necessary for despotic models of leadership.

An additional explanation for leadership falls within the classification of "soft leadership" (Boone personal comm.). Soft leadership is the acceptance of a leader given their unique knowledge of a given task that increases the likelihood of group success. In essence, the leader is nominated based on their knowledge and experience, and this puts

them in an advantageous situation. Under this system, members willingly pay tribute in exchange for enhanced return rates provided by the leader's intimate knowledge and skill in organizing and performing this task. In comparison to cooperative leadership models, the leader is not tasked with monitoring and sanctioning responsibilities, but instead serves an advisory role for the communal venture.

The soft leadership and cooperative models hinge on the premise that leadership is a necessary evolution of large cooperative activities. Soft leadership argues that a single individual possesses greater knowledge of a task compared to all other members, and their participation in the hunt is essential for enhanced return rates. In the case of cooperative models, it's the increasing costs to control participation and sanction free-riders that leads to leadership in large groups. Within the field of political economy, Ostrom (1990, 1997) has argued that this is not always necessary. In her efforts to combat the accepted notion of "tragedy of the commons," Ostrom argues that in cases of common pooled resources (CPR), non-leadership strategies are equally effective. Her argument suggests monitoring can be done by each individual just as efficiently as organizations utilizing a leader. The key to successful collective action is that it requires each individual to monitor only a small portion of the group. This structure has been effective in various situations globally in the management of public fishing waters, water distribution in irrigation systems, and maintaining publically owned parks.

In the case of the Shoshone, it is plausible that either leadership or non-leadership organization could be exhibited in communal activities. The existing ethnographic

evidence indicates that five out of seven Shoshone groups nominated a leader, but Steward (1943) does not provide detailed accounts of their specific role in communal hunts. Nevertheless, the predominance of leadership roles suggests that leadership was common among the Shoshone, which would discount the possibility that it was organized under a CPR scheme. Yet, it is not possible to further eliminate the soft or cooperative leadership models without more ethnographic information.

#### *Pronghorn and their role in human subsistence*

Why hunter-gatherers pursued pronghorn and how they procured them is tied closely with their ability to coexist with other larger ungulates and their physiology, which humans exploited. While the evolution of the Antilocapridae family dates back to the Miocene, pronghorn (*Antilocapra americana*) became the sole remaining family representative at the terminus of the Pleistocene (O’Gara 2004; Walker 2000). Often called American antelope, pronghorns have no taxonomic link to antelope elsewhere. The historic range of pronghorn stretches from southern Alberta to northern Mexico and from central Oregon to the western plains of Kansas (Yoakum 2004). Pronghorn are gregarious, and herd sizes fluctuate from a low of five individuals in the spring to over 50 during the autumn and winter (O’Gara 2004). The seasonal population shifts coincide with changes in social groupings, or herds: rut, bachelor, and nursery. Wintering grounds can possess a large number of socially separate herds that total around 1,000 individuals (Lubinski and Herren 2000). In southwest Wyoming, the largest wintering ground is outside of the town of Green River. This area receives little to no winter snowfall, which leaves shrubs and forbs available for winter consumption. Overall, pronghorn seasonal

movement between spring and summer ranges typically averages over 200 km (O’Gara 2004).

While lumped with other ungulates of North America, pronghorn have a diet uniquely adapted to their grassland-desert grassland environment that allows them to coexist with grazers found in the same geographic range. Due to their small rumen, they are unable to process grasses that are low in protein and high in fiber. Instead, their diet consists of primarily forbs and shrubs, which allows them to coexist with bison and cattle. This more selective diet results in smaller body size, and only minor differences in sexual dimorphism (males avg. 40 kg and females avg. 37 kg), with the exception of the morphology of male horns (Lubinski and Herren 2000). In addition, animal size is consistent within their geographic range with the exception of the smaller Chihuahuan populations in Mexico.

Their most famous attributes are their speed and keen eyesight. Pronghorn can exceed 95 km per hour, and they can maintain this speed for extended periods. Pronghorn also have exceptional vision that allows them to detect predators 2-3 km away, but, like other ungulates, they lack the visual acuity to identify motionless nearby predators against distracting terrain. Yet, pronghorns’ innate curiosity draws them closer to objects seen at a distance. Historically, hunters have taken advantage of this curiosity by placing objects on ridges that attract the animal’s attention. Another behavior exploited by hunters is pronghorns’ reluctance to jump over low obstacles. While their gracile skeletal structure assists in their running speed and endurance, it also leads to more traumatic injuries

associated with vertical jumping. Therefore, pronghorn opt to crawl underneath fences or similar obstacles whenever possible.

While overshadowed by bison hunting in the High Plains, human exploitation of pronghorn dates back to over 10,000 years ago (Frison 2004; Hockett and Murphy 2009). Pronghorn faunal remains exist in archaeological sites that range from the southern California coast to the Mississippi River and from southern Saskatchewan to central Mexico (Yoakum 2004). According to FAUNMAP, pronghorn are found in over 2,900 archaeological and paleontological sites dating over the past 40,000 years (Walker 2000). They are present in 52 percent of 75 eastern Colorado and 67 percent of 92 Wyoming archaeofaunal assemblages (Lubinski and Herren 2000).

Despite being present in the majority of archaeological sites in the High Plains, only 12 known pronghorn bone beds exist in North America. Of these bone beds, the Trappers Point site, located near Pinedale, Wyoming, is the earliest potential case communal hunting of pronghorn, dating between 7,500 to 5,000 years old (Miller and Sanders 2000). Another early communal kill is the Laidlaw site (Alberta), which dates to 3,280 RCYBP (Brumley 1986). While taphonomic and site formation processes may have destroyed additional evidence of communal hunting of pronghorn, the existing record suggests human subsistence shifted during the Archaic Period in North America and led to greater emphasis on pronghorn procurement (Davis and Fisher 1990, 2000). Regardless of the timing of the first communal hunts of pronghorn, the archaeological evidence of game drives becomes more common between the Late Archaic through



Historic periods in the Great Basin and western Wyoming. Whether the increase in communal hunting sites is a byproduct of site formation processes, increasing human population, or a shift in subsistence strategies is not clear.

The organization of pronghorn communal hunting is best described by the ethnographic accounts from the Great Basin. These Shoshone accounts are consistent with more general accounts of pronghorn hunting (Arkbush 1986: 243-251) and game drive design (Oswalt 1976). In the Great Basin, Gosiute Shoshone families would work together seasonally for the communal hunting of pronghorn. The Gosiute evidence can be taken as a valid analogy for the Eastern Shoshone, due to the Great Basin origins of the Eastern Shoshone and the absence of horses among the Gosiute. While I acknowledge significant differences in the ecology of the Great Basin and southwestern Wyoming, ethnographic accounts of the Eastern Shoshone (Shimkin 1947; Hultzkrantz 1961, 1970) are heavily influenced by the dramatic changes to social and economic organization caused by the adoption of the horse (Kelenka 2009). Therefore using the Gosiute, who are a subset of the Shoshone, provides a better analogy of horseless pursuit of pronghorn.

The importance of the Gosiute evidence is the design and organization of the hunt (Egan 1917). Male representatives from participating villages were typically the most senior active hunters of each family. These men would gather to discuss whether a communal drive would be profitable given the size of local pronghorn herds. If they felt that a drive could be successful, they would introduce the idea to the shaman affiliated with the area of the proposed drive. If the shaman agreed, then they assume the primary leadership role

for the duration of the hunt. During this planning stage, members not included in the decision-making helped build or repair the flanking arms and corral of the animal trap. The corral was constructed of sage and whatever wood was available. Once the drive line was ready, young men were sent out to the upper end of the valley to begin the push of pronghorn toward the trap. All the other villagers were positioned along the flanks of the trap and stood within the gaps in the sagebrush clumps. Their job was to ensure that the animals continued down the V-shaped corridor. Once the animals were driven into the corral, the entrance was sealed off and the Gosiute would wait until the pronghorn exhausted themselves running around the corral. According to the Malouf (1974), celebration the night after a successful drive would result in five or six pronghorn being killed by arrows for a feast. The remaining animals would remain in the corral until they were needed, which means that it may take days to weeks to kill all corralled prey. Due to the sparse vegetation in parts of the Great Basin, the communal hunts would sometimes depress the pronghorn population from particular valleys for many years. Despite higher quality habitat for pronghorn in the Green River Basin, Shimkin (1947:268) argues that communal game drives by the Wind River Shoshone would, “would cut down the [pronghorn] population for years.”

While there are undoubtedly differences in the design of pronghorn game drives, Oswalt (1976) and Arkbush (1986) suggest the basic structure is consistent among the various groups engaged in pronghorn communal hunts. Therefore, my primary concern lies in the organization of Shoshone game drives. According to Egan (1917) and Malouf (1976), Shoshone culture operated under a loose gerontocracy, in which the oldest active male

determined the primary distribution of meat in communal hunts. Malouf (1976) and Steward (1941) suggest that Great Basin Shoshone leadership during communal hunts was divided along physical and spiritual lines. Band leaders organized labor and construction/maintenance of the game drive, a regional shaman served the spiritual function of charming “the souls of the antelope” (Malouf 1976:45). Arkbush (1984:242) argues that the presence of shaman leadership is closely tied to the use of corrals, which was most common among Great Basin pronghorn hunters. Yet, Steward (1938) also argues that the role of shamans diminishes among Northern Shoshone groups, such as the Fort Hall Bannock and Shoshone. Shamans are not mentioned in accounts of the Eastern Shoshone, and general discussions of communal hunt organization is also absent among the ethnographic accounts with the exception of horse-equipped buffalo hunts.

Hultzkrantz (1961) argued that prehistoric leadership roles arose in seasonal communal fishing activities and also gatherings at winter camping grounds. These leadership roles were fluid and dissolved when aggregated populations dispersed. What is absent from these Shoshone accounts is detail regarding actual meat distribution among participants.

### *The Eden-Farson site*

The site was initially discovered in 1967 when Jack Krmpotich came across a dense concentration of faunal and lithic artifacts exposed on the surface. The cultural material lies on the leeward side of a 10 m-high stabilized dune, and the site was rapidly buried by blowing sands (Fig. 1.1). The site consists of eleven excavated areas of which 10 were initially interpreted as house structures. Larson et al. (1969) first published on the excavations led by Frison in 1969, and Frison (1971) revisited it in 1970. Eden-Farson

has a minimum of 174 pronghorn distributed among at least 11 discrete house pits with primary distribution patterns (O'Brien *in press*). A single radiocarbon essay of cal A.D. 1708 +/- 163 places the site between the Late Prehistoric and Proto-Historic Periods. Frison determined the Shoshone cultural affiliation of the archaeological assemblage based on the presence of flat-bottomed ceramic vessels (Mulloy 1955) and the historic evidence of Shoshone occupation in the region. Later identification of several bifaces as Shoshone Knives also linked the Eden-Farson site with Shoshonean cultural affiliation (Frison 1991).

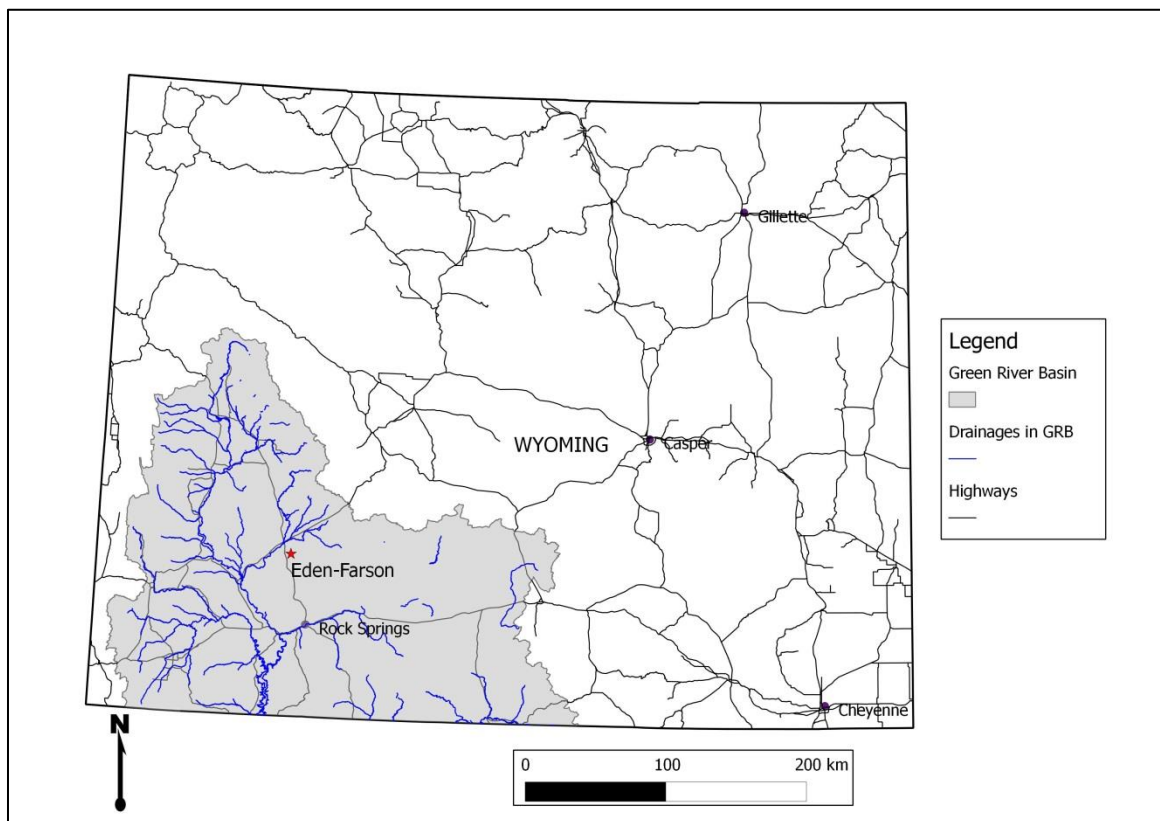


Figure 1.1: The Eden-Farson site located in the Green River Basin, Wyoming.

Bioturbation prevented identification of a single or multiple stratigraphic horizons associated with the occupation. Despite evidence of bioturbation, Frison felt the lack of

overlying cultural deposits and the distribution of cultural materials within the house pits were ample evidence of a single occupation. Initial block excavations uncovered charred juniper fragments located at the bottom of intact post holes. After recognizing that the clusters of post holes represented temporary structures during the excavation of House 1, subsequent excavations centered on considering each dwelling as a single excavation unit (Larson et al. 1969; Frison 1971). The 10 mapped structures vary from oval, averaging 4.5 m by 6 m in size, to nearly circular with a diameter of 3.6 m. Excavations revealed that each structure had distinct activity areas containing bone, stone, and fire-cracked rock from primary, or de facto, deposition.

The entire assemblage consists of an estimated 35,000 pieces of bone, over 11,000 chipped stone tools and debitage, approximately 23 ceramic vessels, and an unknown quantity of ground stone. I have completed the analysis of all provenienced bone, but I have not cataloged bones that are not affiliated with any of the households. While artifacts are found outside of the structures on the surface, the majority of the cultural material is represented within the footprint of each structure to indicate clear association of artifact frequencies with particular households. The faunal assemblage is heavily skewed toward appendicular skeletal elements, which Frison (1971) attributes to the existence of an initial processing area located off-site. Efforts to locate this processing area and the actual game drive have been unsuccessful. While the lack of a trap is a concern, Frison argues that the structure was likely constructed of sagebrush that decomposed long ago. Relying on Nimmo's (1971) tooth eruption sequences sampled from the site, Frison argues the site was occupied in the fall.

Frison's initial interpretation of a single occupation has been addressed by a series of subsequent studies of the dental remains (Lyman 1987; Lubinski 1997; Fenner 2009). In an independent analysis of the tooth eruption sequence in mandibular fragments, Lubinski (1997:253) states that "evidence bearing on the agent of mortality, number of depositional episodes, and seasonality are consistent with a mass kill rather than an accumulation of small kills or natural deaths." His interpretation is based on his calculated Fawn-Yearling-Mature (FYM) and Juvenile-Prime-Old (JPO) age profiles for Eden-Farson, which are consistent with a mass kill (see Stiner 1990 for descriptions of indices). This is also supported by the fairly uniform weathering condition of faunal elements sampled from across the site.

In contrast, Fenner (2009) argues that carbon-oxygen-strontium distance indicates multiple populations, which would indicate multiple kills. He argues that multiple kills would be represented by the following patterns in the isotopic standard deviation (ISD) of Eden-Farson: 1) the site significantly differs from Reiser Canyon (a known single kill event); 2) the site deviates from the isotope signatures from the modern local Hunting Area; and 3) the ISD is similar to a virtual assemblage that modeled an accretionary kill. First, the Eden-Farson site's ISD "is more variable than is Reiser Canyon, though not by a very large amount in carbon-oxygen distance (Fenner 2009:342)." Second, the Eden-Farson isotope signatures fall just below his virtual archaeological assemblage, which suggests a single kill event. Finally, he states that Eden-Farson's ISD is greater than the

local Hunting Area, which would also suggest separate herds and therefore multiple kill events.

The Hunt Area ISD profile used to compare the Eden-Farson signatures is problematic from a conceptual point of view, given that Eden-Farson is located on the border of two different Hunt Areas. When both Hunt Areas ISD's are compared to the Eden-Farson ISD, there are no statistical difference in the isotope results (Fenner 2009:343), which implies that the pronghorn population of Eden-Farson could be from a single herd (i.e. a single kill). It also raises concerns about the validity of using Wyoming Game and Fish Department Hunt Area boundaries, which can be defined by modern features, such as development and roads instead of pronghorn ecology (Fenner 2008:707).

Most recently, Lubinski (2013) has argued that using a single line of evidence, such as isotopic signatures, is inadequate to refute the single kill hypothesis. When all the evidence is considered, the Eden-Farson site most likely reflects a single kill event. While this argument is compelling, his argument is not without fault. In his analysis of the eruption sequences, he uses the entire assemblage to build his argument, which implies that all the households are contemporaneous. Instead, it is equally plausible that houses represent two or more separate game drives and therefore two separate pronghorn herds. His argument fails to address the question of household contemporaneity at Eden-Farson. Prior to the study of social inequality, it is critical that the temporal relationship of the houses is defined.

### *The Present Study*

The remainder of this dissertation consists of five chapters. Chapter 2 presents the manuscript, “An Alternative Bilateral Refitting Model for Zooarchaeological Assemblages,” published in the *Journal of Taphonomy* that introduces a new bilateral refitting model using pronghorn elements. This paper is significant to the study of Eden-Farson due to the inadequacies of previous refitting approaches to deal large samples of bilateral elements. The initial efforts of Todd (1983) and Lyman (2006) to develop a bilateral refit approach revealed data clustering issues when dealing with large samples. In particular, as the number of samples increases, the likelihood of overlapping specimens would result in Type I and Type II statistical errors. In conclusion, Lyman (2006) argued that any new method of refitting must address these issues. The underlying issue with the existing methods is the limited data used to quantify each specimen. Todd relied on a single measurement and Lyman used two measurements. The new method presented in Chapter 2 uses a multivariate statistical approach that has the flexibility to incorporate as many measurements as the analyst can reliably collect. In addition, this method utilizes the covariance matrix from known bilateral pairs to estimate the degree of asymmetry that exists between an individual’s left and right bones.

In Chapter 3, the multivariate refit program is applied to Eden-Farson to address household contemporaneity and social behavior. If refits can link most or all of the households, then this analysis will provide the strongest evidence that the occupation of houses were coeval. Regardless of the extent of refitting between the houses, those refits that do exist have the potential to reveal behavioral patterns. In particular, are there



patterns in the redistribution of food and do inter-household interactions favor a particular house? These questions and an evaluation of the model's effectiveness are discussed in this chapter.

Chapter 4 introduces research aimed at quantifying the food utility of pronghorn. This experimental study follows the methods employed with other food utility indices to provide a complementary dataset for cross species comparison. The authors butchered three pronghorn carcasses to determine the weights of meat and marrow from separate anatomical units. These weights were then converted to energetic values (kcal) and also return rates (kcal/hr) by recording the butchering times. This latter type of data is a useful tool for anthropologists who have examined the decision-making process of foraging societies who must decide what food items to include in their diet. In reference to the Eden-Farson site, this study provides a quantitative means to compare the amount of quality cuts per household.

The final manuscript in Chapter 5 discusses the question of whether a leader was present during the communal hunt at the Eden-Farson site. This research combines the efforts of the previous chapters to examine spatial and energetic differences that would identify leadership among the site's households. By incorporating existing theoretical arguments for the presence of leadership in large group activities or communities with the Eden-Farson faunal archaeological evidence, I propose that social inequality among the Shoshone should be visible on two conditions: 1) payment for leadership services should be linked with the meat proceeds (anatomical units) directly associated with skeletal

remains in the archaeological assemblage, and 2) leaders should be distinguishable from large families by the quality and not the quantity of the anatomical units. If the second condition is true, then leadership should be associated with the house that exhibits higher frequencies of skeletal elements associated with anatomical units yielding the highest return rates and leadership payments expressed archaeologically through anatomical refits.

## **Chapter 2: An Alternative Bilateral Refitting Model for Zooarchaeological Assemblages**

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## **Abstract**

*Since the 1980's, the development of anatomical refitting methods opened the door to interpreting the single versus multiple occupations, separate households versus distinct activity areas, and unique food sharing of archaeological sites. In particular, bilateral refitting is a useful tool to link the social concepts and theory from cultural anthropology and apply them to the static remains of the archaeological record. Recently, critiques have raised concerns about the accuracy and precision of predictions that has limited the application of bilateral refitting. Bilateral asymmetry and large sample sizes have inhibited the success of univariate and bivariate refitting schemes. This paper presents a multivariate model that renews the potential of anatomical refitting. The flexibility of this approach allows for bilateral refitting of complete and partial skeletal elements. Through a battery of trials on simulated assemblages of pronghorn (*Antilocapra americana*) humeri and empirical datasets, the results indicate significantly higher rates of successful matches and lower rates of Type I and Type II errors than existing methods.*

## **Introduction**

In the past thirty years faunal analysis has made significant strides in quantifying past social and subsistence activities. Through the use of experimental and ethnoarchaeological research, we have moved beyond pure descriptive to more behaviorally-based interpretations. Together with advances in quantitative and statistical software, anthropology has the opportunity to apply these tools toward old problems in archaeology. This paper addresses the topic of anatomical refitting of appendicular skeletal elements. We have developed a new flexible approach that bilaterally refits complete and fragmented skeletal elements.

The origins of zooarchaeological anatomical refitting dates back into the 1950s with the attempt to utilize the Lincoln Index in faunal analysis (see Adams and Konigsberg 2004; Lyman 2008a:129). New methods employed on the Horner Site provided the first well-defined and replicable means of identifying potential refits within a zooarchaeological assemblage (Todd 1983). Using a series of standardized measurements, Todd determined that the best dimension of skeletal elements to perform a univariate refitting approach. The best match was the bone that came closest to zero when a left/right bone measurement was subtracted from all the right/left bones. Enloe (1991) duplicated this methodology and articulated methods of ranking potential bilateral pairs using multiple measurements. In this case, the best match had individual measurements with differences closest to zero. While their work may have deviated in the univariate methodology, they used similar means of verifying their statistical matches (also see Waguespack 2002).

Verification procedures for bilateral refitting is best outlined by Enloe (1991:92-97) and Todd (1984), but they are summarized here. First, Enloe points out that the state of epiphyseal fusion is a clear indicator of a match. The rate of fusion within a particular element is the same for both sides of the skeleton, and therefore any statistical match of two bones with different degrees of fusion must be a false positive. The morphology of the articular surface is highly symmetrical in bilateral pairs, but it can vary due to individual stature and life history. Areas of muscle attachment provide a second means of identifying pairs. While less distinctive in young and female specimen, this attribute becomes more distinctive with age and males. Todd (1984:154) goes further to say that muscle shape and prominence provide distinctive attributes with individuals. In addition, Todd points to the shape and depth of the synovial foveae. Beyond those previously mentioned approaches, Adams and Konigsberg (2004:145) state that taphonomic variables can also be useful in identifying bilateral matches, such as degree of weathering, burning, cut marks, and animal damage. While these features have been successfully used for humans, reindeer, and bison the analyst must use their comparative collection to identify the unique attributes that distinguish individuality with their particular species.

Despite the range of applications of anatomical refitting, the existing methods lead to matching errors in large samples. Lyman (2006, 2008a, 2008b) argues that existing refitting approaches are likely to produce Type I and Type II statistical errors. In reference to bilateral refitting, Type I Statistical errors would be the inability of a model to identify a particular specimen's bilateral pair when present in the sample. Type II errors refer to the identification of a match between two different individuals. If a Type

II error occurs when the true match exists in a sample, then a Type I error also occurs. This will sometimes result in the total number of correct, Type I, and Type II errors that exceed the sample size. A model with liberal parameters (i.e. thresholds defining a match) will result in more Type II errors, but less Type I errors. If non-metric signatures are ambiguous, then the Type II errors may be accepted as true pairs. Stricter parameters will produce fewer Type II errors, but more Type I errors.

Of the two types of refitting errors, the Type II errors are more problematic within large archaeological assemblages. A model that produces numerous false positives can swamp an analyst with too many candidates and marginalize the effectiveness of any refitting scheme. Also, non-parametric variables can become ambiguous with numerous potential refit candidates. If unchecked, Type II errors can lead to misleading interpretations of the faunal assemblage. To target Type II errors, a model must be able to recognize the best match from the perspective of the left and right sides. For example, Figure 2.1 represents a sample of left and right bones separated by a hypothetical difference for a given measurement. If our goal is to find the best match for Bone A, then the easy choice is Bone B. If the process stops there, the model has likely identified a false positive. If the model also compares the best match for Bone B, we would find that Bone C is its best match. Obviously, Bone B and C is a better match, but how can a model select the appropriate match? The key is to run a model from the perspective of both sides (left and right) and choose the lower of the two probabilities. In this hypothetical case, the lowest probability between Bone B and C is still higher than the probability of Bone A and B from the perspective of Bone B. The model needs to operate along this path of logic to lower the chances of the Type II errors.

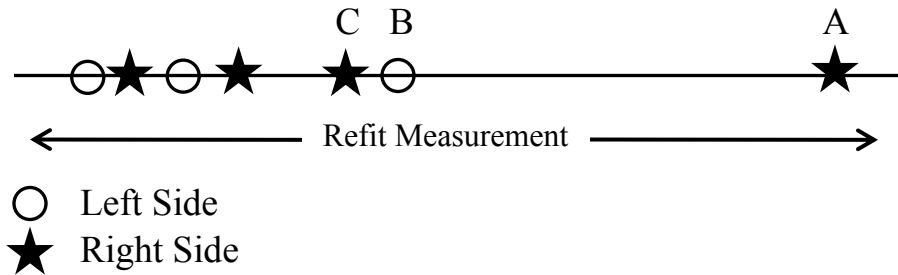


Figure 2.1: Importance of comparing left to right and right to left results

Sample size and asymmetry of bilateral pairs are the primary problems facing existing bilateral refitting schemes. Enloe (1991, 2003) and Lyman (2006, 2008a) argue that sample size must remain low to prevent clustering of data that inhibits identification of bilateral pairs. Clustering refers to the overlap in measurements from separate individuals that pose as additional potential matches for a given specimen. Larger sample sizes will result in significant overlap that prevents clear indications of actual pairs. Clustering is particularly evident when sample populations have measurements that are approximately normally distributed.

The second concern is asymmetry. It is well-established that our bones are not exactly the same bilaterally (Klingenberg et al. 2002; Leamy et al. 2001). While variation exists between bilateral pairs, the symmetry, or geometry, within a single element is consistent. Slight variation exists in the morphology of our bones and depending on the severity of asymmetry, it could lead to either Type I or Type II errors. To highlight the dilemma of asymmetry, Lyman (2006) analyzed white tailed and mule deer humeri and astragali. Unlike Todd's univariate approach, he used two measurements to identify bilateral pairs. Arguing that most studies of bilateral refitting assume bilateral symmetry, Lyman incorporated the two measurements and the Pythagorean Theorem to quantify the amount of asymmetry.



$$C = \sqrt{((AL - AR)^2 + (BL - BR)^2)}$$

The test of astragali symmetry yielded variances that ranged from 0.347 mm to 0.561 mm. So is this too much variance? Even with the inclusion of two variables, his model could not deal with the data clustering that begins to occur with 17 white tailed deer astragali. The impact of the asymmetry issue alone is not clear, but when it is combined with increased sample sizes bilateral refitting is severely inhibited.

The range of anthropological applications suggests that we continue to pursue a methodology that can narrow down the potential bilateral refitting. Todd's (1984) interest was to understand the temporal relationship of multiple bone deposits. Bilateral refitting has also been used to address food sharing (Lyman 2008b; Waguespack 2002) and socioeconomic organization (Enloe 1991, 2003; Enloe and David 1992). While using different methods, Lyman (2006) and Adams and Konigsberg (2004) used bilateral refitting to approximate Lincoln Index MNI values. Bilateral refitting is time consuming and is limited to sites with ideal faunal preservation, but the successful identification provides a rare glimpse into past events that other streams of evidence cannot provide. This paper presents a new multivariate approach that increases the frequency of positive matches and minimizes the number of Type I and Type II errors relative to existing methods.

## **Methodology**

To develop a new method of anatomical refitting, our model takes full advantage of the multivariate nature of measurements included to increase statistical power. To deal with the asymmetry problem, the approach also incorporates the variance existing between two known pairs into determining pairs within the test sample. We will first

outline the basic structure of the statistical methodology and then introduce the comparative and test assemblages used to test the model.

### *Refit Model*

In order to identify bilateral pairs in the presence of substantial data clustering, it is necessary to increase the number of measurement dimensions, or variables, per skeletal element. For this paper, we chose to use the measurements used by Todd (1983, 1987), Enloe (1991, 2003) and Waguespack (2002). Additional measurements are also possible, including those derived from the use of 3D laser scanning. The improvement in accuracy depends on the covariance structure of the measured variables; more independence among variables implies more information gained from each variable, and hence, more accuracy gained for the purpose of matching. The amount of accuracy gained by adding a variable is also dependent on how highly correlated the corresponding measurements (left and right) are within an individual. If a given measurement taken from a left and right bone has a high amount of variability, then it will provide little additional help in identifying the correct match. Let  $\mathbf{x}_i, i = 1, \dots, m$ , be the vector of measurements made on the  $i$ -th left skeletal element in the sample,  $\mathbf{x}_i = [x_{1,i}, x_{1,i}, \dots, x_{p,i}]'$ , where  $p$  is the number of separate measurements made on each skeletal element. Similarly let  $\mathbf{y}_j, j = 1, \dots, n$  denote the vector of measurements made on the  $j$ -th right skeletal element in the sample. To calculate the probability of a refit, we make use of a multivariate normal model for the difference  $\mathbf{d}$  between two corresponding ( $i \leftrightarrow j$ ) right and left measurements,  $\mathbf{x}_i$  and  $\mathbf{y}_j$ , respectively. Namely, for a corresponding pair ( $i \leftrightarrow j$ ), we assume

$$\mathbf{d} = (\mathbf{x}_i - \mathbf{y}_j) \sim N(\mathbf{0}, \mathbf{\Sigma}),$$

where  $N(\boldsymbol{\mu}, \boldsymbol{\Sigma})$  represents the multivariate normal distribution with mean vector  $\boldsymbol{\mu}$ , and covariance matrix  $\boldsymbol{\Sigma}$ . Our model assumes that in nature, left and right bones will average no difference, but that does not suggest there is no difference between a given pair of bones, because there is a covariance in our model. This is to say that we would not expect a measurement on a left skeletal element to be greater than the same measurement on the corresponding right skeletal element (i.e., on average over many pairs), and vice versa. Under this model, we can calculate the probability that  $i \leftrightarrow k$  given that  $i \leftrightarrow j$ , for some  $j = 1, \dots, n$ . That is, if we assume that there **is** a refit for the  $i$ -th left skeletal element in our sample, then we can calculate the probability that it corresponds to a particular ( $k$ -th) right skeletal element. Let  $\mathbf{d}_{ij} = \mathbf{x}_i - \mathbf{y}_j$ , and we can write this conditional refit probability  $\lambda_{ik}$  formally as

$$\begin{aligned}
 \lambda_{ik} &= \Pr(i \leftrightarrow k | i \leftrightarrow j, \text{ for some } j = 1, \dots, n) \\
 &= \Pr(\mathbf{d} = \mathbf{d}_{ik} | \mathbf{d} = \mathbf{d}_{ij}, \text{ for some } j = 1, \dots, n) \\
 &= \frac{\phi(\mathbf{d}_{ik}; \mathbf{0}, \boldsymbol{\Sigma})}{\sum_{j=1}^n \phi(\mathbf{d}_{ij}; \mathbf{0}, \boldsymbol{\Sigma})},
 \end{aligned}
 \tag{1}$$

where  $\phi(\mathbf{d}; \boldsymbol{\mu}, \boldsymbol{\Sigma})$  is the multivariate normal density function (Johnson and Wichern 2003:143 [4-11]),

$$\phi(\mathbf{d}; \boldsymbol{\mu}, \boldsymbol{\Sigma}) = \frac{1}{(2\pi)^{p/2} |\boldsymbol{\Sigma}|^{1/2}} \exp \left\{ -\frac{1}{2} (\mathbf{d} - \boldsymbol{\mu})' \boldsymbol{\Sigma}^{-1} (\mathbf{d} - \boldsymbol{\mu}) \right\}.
 \tag{2}$$

See the Appendix for a formal derivation of (1). The Refit Probability  $\lambda_{ik}$  provides a measure of the likelihood of  $i$  (a particular left sided bone) matching  $k$  (a particular right sided bone) according to the observed measurements. We can also calculate the conditional refit probability  $\rho_{jl}$  for a particular right bone  $j$  to a particular left bone  $l$ ,

given that there is a match for the  $j$ -th right bone in the sample. This is just the mirror image of the calculation given in (1), namely

$$\begin{aligned}\rho_{jl} &= \Pr(j \leftrightarrow l | j \leftrightarrow i, \text{ for some } i = 1, \dots, m) \\ &= \Pr(\mathbf{d} = \mathbf{d}_{lj} | \mathbf{d} = \mathbf{d}_{ip} \text{ for some } i = 1, \dots, m) \\ &= \frac{\phi(\mathbf{d}_{lj}; \mathbf{0}, \mathbf{\Sigma})}{\sum_{i=1}^n \phi(\mathbf{d}_{ip}; \mathbf{0}, \mathbf{\Sigma})},\end{aligned}$$

In order to calculate  $\lambda_{jk}$  and  $\rho_{jl}$  on a test sample of unknown individuals, we need to specify the unknown covariance matrix  $\mathbf{\Sigma}$ . This can be done by substituting in the maximum likelihood estimates based on a sample of  $\mathbf{d}_{ij}$  from which the  $i \leftrightarrow j$  relationships are known (i.e. the comparative sample).

The exponent of the numerator in equation (2) is the Mahalanobis Distance between  $\mathbf{x}_i$  and  $\mathbf{y}_k$ . Generally, the Mahalanobis Distance can be seen as a multivariate Euclidean Distance weighted by the sample variance-covariance matrix (for actual formula see Johnson and Wichern 2003: 127). This effectively quantifies the amount of asymmetry between  $\mathbf{x}_i$  and  $\mathbf{y}_k$ . In a perfectly symmetrical sample, for  $i \leftrightarrow k$  the difference  $\mathbf{d}_{ik} = \mathbf{x}_i - \mathbf{y}_k$  would be equal to zero, which means that the Mahalanobis Distance would equal zero. For the purposes of bilateral refitting,  $\phi(\mathbf{d}; \mathbf{0}, \mathbf{\Sigma})$  represents the coefficient of asymmetry within a given skeletal element within a single species. For any given test sample, the  $\phi(\mathbf{d}; \mathbf{0}, \mathbf{\Sigma})$  will be unique, depending on the vector of measurements taken and the species.

Based on the multivariate density function and our refit probability function, we built a working model using R version 2.9 (see **Appendix B.1** for code), which is open-source statistical software (<http://cran.r-project.org/>). Two probability matrices are constructed: one matching from the perspective of the sample of left bones,  $\{\lambda_{jk}, i =$

$1, \dots, m, k = 1, \dots, m\}$ , and the second from the perspective of right bones, and  $\{\rho_{jl}, j = 1, \dots, n, l = 1, \dots, n\}$ . The results are then tabulated into two matrices: a minimum probability matrix  $P_{\min}$ , whose  $i$ -th row,  $j$ -th column is  $P_{\min,ij} = \min(\lambda_{ij}, \rho_{ji})$  and a maximum probability matrix,  $P_{\max}$  whose  $i$ -th row,  $j$ -th column is  $P_{\max,ij} = \max(\lambda_{ij}, \rho_{ji})$ . The minimum probability matrix ( $P_{\min}$ ) will yield the more cautious results by reflecting the lower of two probabilities to minimize Type II errors. The maximum probability matrix ( $P_{\max}$ ) reports the higher of the results to maximize the number of positive matches and minimize the number of Type I errors. The drawback of the second matrix is that it will likely cause more false positive results. In practice, these measures should be used as a lower and upper bound, respectively, on the likelihood of a match between skeletal elements  $i$  and  $j$ . Any pairs  $(i,j)$  that have a high enough value (above some threshold  $T$ ) for  $P_{\min,ij}$  and/or  $P_{\max,ij}$  could be chosen as candidates for further analysis. The actual value of  $T$  used should be determined by the analyst who needs to consider the comparative sample size, the condition of the archaeological assemblage, the sample size, and the number of measurements.

### *Data Selection*

The refit model requires two independent samples to operate. The first sample is a comparative sample of known individuals that can be used to establish the covariance matrix. The second sample of individuals is a test sample on which to evaluate potential matches. In this presentation, the relationships in the test sample are also known so that we can evaluate the success of the proposed approach. In practice the relationships in the test sample would not be known of course, and hence the need for the proposed approach.

The species used for the three diagnostic tests is pronghorn (*Antilocapra americana*). This study uses eight post-cranial remains from the University of Wyoming's Zooarchaeological Laboratory and nine individuals housed at the University of New Mexico's Museum of Southwest Biology. Each measurement was taken three separate times using digital calipers accurate to +/- 0.3 mm. The averages of those three measurements were taken as the estimated length, which lowers the influence of intra-observer error. The proposed method will be most effective when the measurements from the sample approximately follow a multivariate normal distribution. Based on bivariate plots, histograms per variable, and quantile-quantile plots, the comparative sample measurements can be treated as a multivariate normal distribution in this case. In other samples, this assumption should be verified, and the data should be transformed to normality if necessary (Johnson and Wichern 2003:192-200). In total, Todd established six separate measurements (i.e.,  $p = 6$ ) for this portion of the skeleton (**Table 2.1**) (1983, 1987). Each distal humerus was measured 18 times to approximate size and minimize the intra-observer error. **Table 2.2** presents the comparative sample. For complete bones, analysts following Todd's methods can collect up to 15 different measurements from each specimen, but this is time consuming and often not practical given the problems of weathering and post-depositional processes that break down zooarchaeological assemblages.

Table 2.1: Definition of distal humerus measurements defined by Todd (1983)

Measurements	Definition
HM6	Greatest Breadth of the Distal End
HM7	Breadth of Distal Articular Surface
HM8	Least Breadth of Olecrannon Fossa
HM11	Greatest Depth of Medial Distal End
HM14	Least Depth of Medial Distal End
HM15	Depth of Olecrannon Fossa

Table 2.2: Comparative Sample of pronghorn humeri from the University of New Mexico's Southwest Biology Museum (MSB) and the University of Wyoming's Frison Institute (UW)

Catalog Number	SIDE	HM6	HM7	HM8	HM11	HM14	HM15	Source
21271L	LEFT	34.73	33.03	15.02	30.48	23.38	7.65	MSB
40082L	LEFT	29.37	30.22	13.36	26.80	19.86	6.53	MSB
42162L	LEFT	37.27	36.84	14.15	32.13	26.65	8.54	MSB
42174L	LEFT	36.32	35.40	11.77	30.31	23.71	8.13	MSB
53505L	LEFT	33.47	34.24	14.05	28.98	23.76	7.36	MSB
8255B	LEFT	35.77	36.37	14.46	30.00	23.83	8.04	UW
8263B	LEFT	35.31	34.39	11.63	30.67	24.97	9.30	UW
8363B	LEFT	40.48	41.28	15.91	33.02	25.85	9.41	UW
8403B	LEFT	36.71	36.81	13.25	31.63	25.52	8.83	UW
8409B	LEFT	36.06	36.43	13.56	30.57	24.04	9.23	UW
86329L	LEFT	35.86	36.87	15.93	31.67	24.20	8.12	MSB
87751L	LEFT	35.13	34.70	12.93	29.35	22.86	8.02	MSB
87752L	LEFT	34.74	35.56	15.40	29.90	22.39	7.88	MSB
87753L	LEFT	34.98	34.11	15.20	30.30	23.49	7.62	MSB
9271B	LEFT	37.58	38.16	14.41	31.77	24.84	7.90	UW
9981B	LEFT	37.74	37.28	14.17	31.30	26.00	8.95	UW
9982B	LEFT	34.82	34.81	15.29	30.77	23.31	8.24	UW
21271R	RIGHT	34.36	33.90	15.35	29.94	23.67	7.62	MSB
40082R	RIGHT	29.66	30.75	13.96	26.85	20.28	6.56	MSB
42162R	RIGHT	36.69	37.08	14.08	32.05	26.60	8.56	MSB
42174R	RIGHT	36.65	34.91	12.02	29.77	23.87	8.38	MSB
53505R	RIGHT	33.39	33.89	13.88	28.82	24.10	7.48	MSB
8255B	RIGHT	35.57	35.50	13.96	30.27	24.24	8.01	UW
8263B	RIGHT	36.39	36.11	11.64	30.48	25.36	9.30	UW
8363B	RIGHT	40.37	40.90	15.46	33.16	26.22	9.90	UW
8403B	RIGHT	36.30	36.63	13.01	31.91	25.79	9.16	UW
8409B	RIGHT	36.52	36.27	13.25	30.32	24.17	8.90	UW
86329R	RIGHT	35.88	36.65	15.15	31.80	24.17	8.32	MSB
87751R	RIGHT	35.02	34.46	13.21	29.39	22.76	7.95	MSB
87752R	RIGHT	35.16	35.36	15.42	29.51	22.82	7.75	MSB
87753R	RIGHT	35.35	35.02	15.21	30.12	23.62	7.83	MSB
9271B	RIGHT	37.96	38.28	14.58	31.41	24.62	7.69	UW
9981B	RIGHT	37.57	37.02	13.98	31.22	25.61	9.19	UW
9982B	RIGHT	34.85	34.59	15.17	30.65	23.14	8.05	UW

Our goal of this research is to identify the effectiveness of this approach with larger samples and varying numbers of measurements. Simulated assemblages provide the necessary flexibility to test the model to cope with different conditions. The model will then be applied to empirical data to verify the results from the simulated assemblages. In order to test the model against large sample sizes, a simulated assemblage of humeri was randomly generated using a multivariate normal distribution with parameters obtained from the MLE estimates of the comparative sample. Specifically, we assume that the vector  $\mathbf{z} = [\mathbf{x}_i, \mathbf{y}_j]$ , of 12 measurements from a corresponding pair of bones (six measurements on left bone and right bone, respectively) follows a multivariate normal distribution, i.e.,  $\mathbf{z} \sim \mathcal{N}(\boldsymbol{\mu}_z, \boldsymbol{\Sigma}_z)$ , where

$$\boldsymbol{\mu}_z = \begin{bmatrix} \mu_x \\ \mu_y \end{bmatrix}, \boldsymbol{\Sigma}_z = \begin{bmatrix} \Sigma_x & \Sigma_{xy} \\ \Sigma'_{xy} & \Sigma_y \end{bmatrix}. \quad (3)$$

It is assumed that the distribution of  $\mathbf{x}_i$  is the same as that of  $\mathbf{y}_j$ , i.e., there is no systematic difference between left bones and right bones as mentioned earlier. Therefore, the model in Equation (3) is restricted such that  $\mu_x = \mu_y$  and  $\Sigma_x = \Sigma_y$ . The resulting MLEs under this model using the comparative sample are provided in Table 2. Notice the positive values in the  $\Sigma_{xy}$  matrix. The primarily positive covariances, especially on the diagonal of the  $\Sigma_{xy}$  matrix are what yield the discernment power of the proposed method.

Given the model in Equation (3), we can generate a test sample to evaluate the proposed method with the `mvrnorm` function in R. Specifically, using the  $\boldsymbol{\mu}_z$  and  $\boldsymbol{\Sigma}_z$  in **Table 2.3**, the command

```
test.sample <- mvrnorm(n, mu.z, Sigma.z)
```



will generate a  $n \times 12$  matrix, each row of which is a sample of corresponding left and right bones (the first six measurements of each row correspond to a the left bone, and the last six to the right bone, of the same individual).

Table 2.3: The comparative sample variance and covariance matrix for left (x) and right (y) humeri

$\Sigma x$						$\Sigma xy$					
4.78	4.56	0.31	2.75	2.8	1.35	4.69	4.4	0.19	2.83	2.76	1.42
4.56	4.85	0.64	2.73	2.66	1.26	4.59	4.65	0.44	2.85	2.59	1.35
0.31	0.64	1.43	0.43	-0.05	-0.16	0.39	0.75	1.37	0.59	0.05	-0.09
2.75	2.73	0.43	1.94	1.84	0.82	2.67	2.63	0.3	1.9	1.74	0.83
2.8	2.66	-0.05	1.84	2.32	0.93	2.76	2.67	-0.19	1.89	2.25	0.98
1.35	1.26	-0.16	0.82	0.93	0.59	1.28	1.18	-0.23	0.77	0.85	0.57
<hr/>						<hr/>					
4.69	4.59	0.39	2.67	2.76	1.28	4.78	4.56	0.3	2.76	2.78	1.35
4.4	4.65	0.75	2.63	2.67	1.18	4.56	4.84	0.64	2.73	2.65	1.26
0.19	0.44	1.37	0.3	-0.19	-0.23	0.3	0.64	1.43	0.43	-0.06	-0.17
2.83	2.85	0.59	1.9	1.89	0.77	2.76	2.73	0.43	1.99	1.84	0.83
2.76	2.59	0.05	1.74	2.25	0.85	2.78	2.65	-0.06	1.84	2.3	0.93
1.42	1.35	-0.09	0.83	0.98	0.57	1.35	1.26	-0.17	0.83	0.93	0.6
$\Sigma xy$						$\Sigma y$					

A sample of the generated measurements is provided in **Table 4.4**. A total of fifteen simulated pronghorn humerus test samples were used for this analysis that ranged from  $n = 10$  to 50 individuals. While it is possible to examine the impact of larger sample sizes, the majority of archaeological assemblages likely fall within this range of individuals. The refitting model was run under a series of different tests. An arbitrary threshold of ( $T \geq 0.85$ ) was selected to determine a match. Since this method should be used to pare

down the number of individual specimen that needs physical inspection, we have chosen a value lower than normally used in statistical tests. The actual threshold value used in a particular analysis should be set in accordance with the number of matches that can feasibly be followed up with further non-parametric analyses. For the purposes of this methodological paper, a probability equal to or greater than the threshold was determined a match. In circumstances that more than one match exceeded the threshold; the highest probability was chosen to be the correct match. In the unusual case that there is an equal probability of the correct match, the correct match prevailed. The summary tables for each diagnostic test provide the number of correct matches (C), Type I errors (T I), Type II errors (T II), and their respective percentages. If the model makes an incorrect match with the true match in the sample, then Type I and Type II errors occur. In these circumstances, the total of correct, Type I, and Type II can exceed the number of individuals. In practice, all specimens that exceed the threshold should be inspected for non-parametric attributes to identify the best fit.

Table 4.4: An example of simulated pronghorn humerus sample for trial one for sample size of 10 individuals

Individual	SIDE	HM6	HM7	HM8	HM11	HM14	HM15
1	LEFT	35.51	35.89	15.18	29.66	23.30	7.79
2	LEFT	32.15	31.58	13.32	27.76	22.20	7.96
3	LEFT	33.67	35.17	14.69	30.12	22.92	7.88
4	LEFT	36.91	36.48	11.78	30.03	23.66	8.57
5	LEFT	34.73	34.53	14.03	28.91	22.51	7.36
6	LEFT	37.20	38.34	14.94	30.80	24.09	8.79
7	LEFT	35.88	36.94	15.30	30.90	24.28	7.57
8	LEFT	35.21	35.46	14.96	29.88	23.32	7.89
9	LEFT	32.26	31.57	11.72	27.78	22.53	7.56
10	LEFT	37.82	37.83	15.53	31.63	24.62	9.12
1	RIGHT	35.94	36.18	15.19	30.14	23.97	7.91
2	RIGHT	31.88	31.68	13.64	28.07	22.30	7.82
3	RIGHT	33.50	34.93	15.13	29.96	22.07	7.82
4	RIGHT	36.81	36.05	12.38	29.84	23.23	8.50

5	RIGHT	34.48	34.51	14.10	29.30	23.06	7.63
6	RIGHT	37.41	38.16	14.62	31.03	24.16	9.13
7	RIGHT	35.59	36.35	15.09	31.41	24.55	7.76
8	RIGHT	35.32	35.36	15.19	30.25	23.50	7.90
9	RIGHT	32.68	32.47	12.33	27.59	22.38	7.24
10	RIGHT	37.64	37.50	15.39	31.81	24.64	9.25

The first test of the model examined the impact of increasing sample sizes on the reliability of matching an individual specimen's bilateral elements. All tests were run with the six variables available for the distal humerus. Random sample sizes of 10, 20, 30, 40, and 50 individuals were generated for three separate trials to approximate the model's effectiveness. For comparative purposes, we also used the same data with Lyman's approach. HM11 and HM14 were the two measurements used for Lyman's (2006) bivariate model based on bilateral correlation values (**Table 2.5**). The conservative matching statistic (c) was 0.36 and the liberal value was 0.52. Both values and their associated results are presented. The second series of tests examined the impact of reducing the number of variables used to distinguish pairs. We used the three trials of 20 individuals from the previous test. The bilateral correlations derived from the comparative sample were used to decide which measurements were removed first. From five down two variables, each of the following measurements was removed in this order: HM8, HM7, HM15, and HM6. The third test for the model was to generate hypothesized archaeological assemblages with uneven preservation or presence of an individual specimen's bilateral pair. The goal is to test the accuracy of the model when there is no match for a portion of the specimen. In particular, how does uneven representation of lefts, rights, and true pairs impact the effectiveness of  $P_{min}$  and  $P_{max}$ . Since the entire test sample is random, there was no need to randomize the selection process for this test.

Humeri were arbitrarily removed from a randomly generated complete pairs sample to create the wanted quantity of left and right bones. The first two trials examined whether the model could identify the correct match when all the true matches for the left bones existed within the sample of right bones. The third and fourth trials tested the models success when only a portion of the left and right bones were true matches. For example, the third trial had 15 lefts and 25 rights, but only 10 of those left bones had a true match.

Table 2.5: Correlation coefficients for distal humerus

Measurement	r
HM6-HM6	0.984
HM7-HM7	0.965
HM8-HM8	0.964
HM11-HM11	0.985
HM14-HM14	0.987
HM15-HM15	0.967

While the simulated assemblages indicate the impact of sample size and the number of variables, these tests do not actually incorporate existing empirical datasets to verify its success. The final test looks at various comparative samples provided by published data on various species. The criteria for selecting datasets requires two criteria: 1) multiple measurements on bones from known individuals, and 2) a large enough sample size to partition the data into the comparative sample for running the model and a separate test sample. A series of histograms, qq plots, and pairwise plots indicate that each dataset adheres to a multivariate normal distribution. These datasets were randomly sub-divided into comparative samples and test samples three different times. The data incorporated into the empirical test included Todd's (1983:311) comparative sample of bison (*Bison bison*) femura, Klein's (per. comm.) comparative sample of grysbok (*Raphicerus melanotis*) metapodials that were collected in 1984 from the South African

Museum, and Lyman's (2006) analysis of deer (*Odocoileus sp.*) astragali and distal humeri. Todd's dataset has only 20 individuals that have the majority of measurements, which restricted the comparative sample to only 12 individuals. The measurements utilized from Todd's data included FM12, FM13, FM14, FM15, FM17, FM18, and FM19 (see Todd 1983 for descriptions). From Klein's unpublished data containing 27 individuals we used five variables: the mediolateral and the anteroposterior diameter of the proximal end, mediolateral and the anteroposterior diameter of the distal end, and the minimum shaft diameter. The model incorporated 15 of the 27 individuals into the comparative sample and the remaining 12 individuals were used in the test sample. Lyman's (2006:1258) data represents a large dataset (60 individuals using the astragalus and 48 individuals using the distal humerus) with a limited number of variables (2). To power the model, 30 individuals were used in the comparative sample. The test sample for the deer astragalus was 30 individuals and 18 individuals for the distal humerus. Each dataset poses a unique test of the model's flexibility.

## Results

The test results of varying sample sizes show  $P_{\min}$  identifies a match on average 50 percent of the time (**Table 2.6**). Using  $P_{\max}$ , the average rate of identifying a pair increases to 86 percent with even numbers of left and right bones. To see the impact of sample size more clearly, a pair of plots shows the decline of correct matches as the sample size increases (**Fig. 2.2**).  $P_{\min}$  has an almost linear inverse relationship with sample size, which adheres to Lyman's (2006, 2008a) and Enloe's (1991, 2003) predictions. Whereas the success rate of identifying the correct match occurs over 80 percent of the time with samples of 10 individuals, this percentage drops to an average of

34 percent with samples of 50 individuals. The impact of sample size is less severe in the  $P_{max}$ , which correctly matched individuals 96 percent of the time with 10 individuals, and remained successful over 80 percent of the time with 50 individuals. Of possibly greater importance,  $P_{min}$  is more successful at minimizing Type II errors than  $P_{max}$ . Regardless of sample size, the average of Type II errors in  $P_{min}$  remains below 3 percent.  $P_{max}$  is less accurate at minimizing false positives, but the average rate is 6.4 percent.

Table 2.6: Results from various sample sizes with the accepted matching probability threshold set at 0.85

Individuals	Trials	$P_{min}$						$P_{max}$					
		C	T I	T II	%C	%T I	%T II	C	T I	T II	%C	%T I	%T II
10	1	7	3	0	70.0%	30.0%	0.0%	9	1	0	90.0%	10.0%	0.0%
	2	9	1	0	90.0%	10.0%	0.0%	10	0	0	100.0%	0.0%	0.0%
	3	8	2	1	80.0%	20.0%	10.0%	10	0	0	100.0%	0.0%	0.0%
20	1	16	4	0	80.0%	20.0%	0.0%	20	0	0	100.0%	0.0%	0.0%
	2	13	7	1	65.0%	35.0%	5.0%	17	3	2	85.0%	15.0%	10.0%
	3	14	6	0	70.0%	30.0%	0.0%	20	0	0	100.0%	0.0%	0.0%
30	1	18	12	1	60.0%	40.0%	3.3%	25	5	5	83.3%	16.7%	16.7%
	2	14	16	1	46.7%	53.3%	3.3%	28	2	2	93.3%	6.7%	6.7%
	3	15	15	1	50.0%	50.0%	3.3%	25	5	1	83.3%	16.7%	3.3%
40	1	22	18	0	55.0%	45.0%	0.0%	37	3	3	92.5%	7.5%	7.5%
	2	13	27	1	32.5%	67.5%	2.5%	26	14	4	65.0%	35.0%	10.0%
	3	21	19	0	52.5%	47.5%	0.0%	39	1	1	97.5%	2.5%	2.5%
50	1	23	27	3	46.0%	54.0%	6.0%	43	7	2	86.0%	14.0%	4.0%
	2	17	42	1	34.0%	84.0%	2.0%	42	8	4	84.0%	16.0%	8.0%
	3	15	35	1	30.0%	70.0%	2.0%	36	14	5	72.0%	28.0%	10.0%
450		225	234	11	50.0%	52.0%	2.4%	387	63	29	86.0%	14.0%	6.4%

C: The highest refit probability occurred between a single individual's left and right humeri

T I: Type I Error - The refit model failed to identify a match within the given sample

T II: Type II Error - The highest refit probability occurred between different individuals

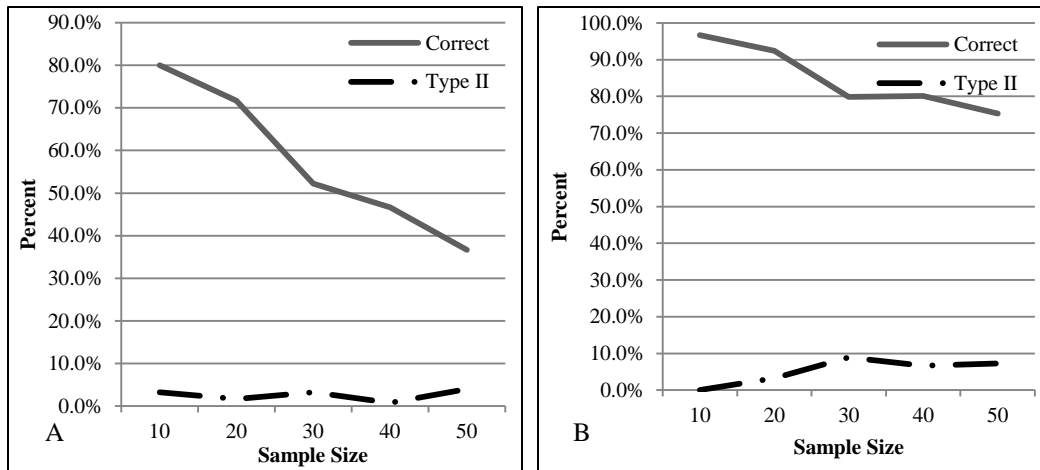


Figure 2.2: Graphs show the average percentage of refit success rates and Type II errors for A)  $P_{\min}$  and B)  $P_{\max}$

The results from Lyman's model fits with his assumption of increasing sample sizes. As sample size increases, the number of correct matches declines rapidly and the frequency of Type II errors increases significantly (**Table 2.7**). This confirms Lyman's (2006) concerns with his approach to bilateral refitting in larger samples. **Figure 2.3** shows the inverse relationship of correct matches in relation to sample size and the positive relationship between false positives and the increase in individuals within a sample. The percentage of Type II errors exceeds the percentage of correct matches when the number of individuals exceeds 28 individuals. Using the conservative threshold, correct matches occur at slightly under 30 percent, while Type II errors occur 45 percent of the time. The liberal threshold increases the likelihood of a correct match, but results in a marked increase in the number of false positives.

Table 2.7: Refitting results using Lyman (2006) model against the first trial of each random sample

Individuals	Conservative (C) of 0.36						Liberal (C) of 0.52					
	C	T I	T II	%C	%T I	%T II	C	T I	T II	%C	%T I	%T II
10	3	7	5	30.0%	70.0%	50.0%	3	7	6	30.0%	70.0%	60.0%
	2	8	2	20.0%	80.0%	20.0%	4	6	2	40.0%	60.0%	20.0%
	5	5	2	50.0%	50.0%	20.0%	5	5	4	50.0%	50.0%	40.0%
20	12	8	4	60.0%	40.0%	20.0%	12	8	7	60.0%	40.0%	35.0%
	8	12	6	40.0%	60.0%	30.0%	10	10	8	50.0%	50.0%	40.0%
	11	9	4	55.0%	45.0%	20.0%	14	6	4	70.0%	30.0%	20.0%
30	11	19	7	36.7%	63.3%	23.3%	13	17	12	43.3%	56.7%	40.0%
	8	22	15	26.7%	73.3%	50.0%	9	21	19	30.0%	70.0%	63.3%
	8	22	11	26.7%	73.3%	36.7%	11	19	14	36.7%	63.3%	46.7%
40	11	29	19	27.5%	72.5%	47.5%	16	24	22	40.0%	60.0%	55.0%
	11	29	19	27.5%	72.5%	47.5%	14	26	22	35.0%	65.0%	55.0%
	10	30	22	25.0%	75.0%	55.0%	12	28	26	30.0%	70.0%	65.0%
50	13	37	24	26.0%	74.0%	48.0%	15	35	31	30.0%	70.0%	62.0%
	9	41	29	18.0%	82.0%	58.0%	13	37	33	26.0%	74.0%	66.0%
	11	39	34	22.0%	78.0%	68.0%	12	38	37	24.0%	76.0%	74.0%
Total	133	317	203	29.6%	70.4%	45.1%	163	287	247	36.2%	63.8%	54.9%

C: The highest refit probability occurred between a single individual's left and right humeri

T I: Type I Error - The refit model failed to identify a match within the given sample

T II: Type II Error - The highest refit probability occurred between different individuals

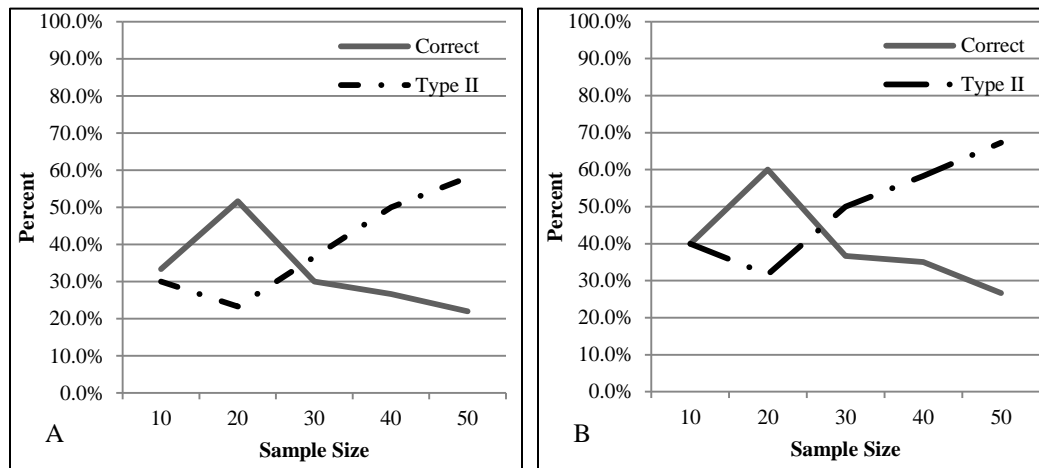


Figure 2.3: Graphs show the average percentage of refit success and Type II errors for Lyman's method: A) Conservative Threshold Value of 0.36 and B) Liberal Threshold Value of 0.52.

On average, the results from the second test of the model fall in line with logical expectations (**Table 2.8**). As the number of variables decrease, the effectiveness of



identifying matches decreases. With normally distributed data, the reduction in variables results in less effective identification of correct matches. The  $P_{min}$  matrix prevents an associated increase in false positives as the number of variables decreases.  $P_{max}$  is less successful at minimizing Type II errors, but identifies correct matches with greater frequency. Through the combination of both matrices, the model is capable of identifying true matches with fewer variables, and it still maintains high levels of confidence in accuracy of these matches. This is particularly important given the variability in the preservation of skeletal elements that may limit the number of variables to two or three. Despite the rise in the frequency of Type II errors, they still fall well below the results from Lyman's model for a sample of 20 individuals.

Table 2.8: Summary tables showing the impact of reduced measurements on the simulated assemblages of 20 individuals

Trail	Variables	$P_{min}$						$P_{max}$					
		C	T I	T II	%C	%T I	%T II	C	T I	T II	%C	%T I	%T II
1	6	16	4	0	80.0%	20.0%	0.0%	20	0	0	100.0%	0.0%	0.0%
	5	8	12	0	40.0%	60.0%	0.0%	16	4	0	80.0%	20.0%	0.0%
	4	4	16	0	20.0%	80.0%	0.0%	11	9	3	55.0%	45.0%	15.0%
	3	1	19	0	5.0%	95.0%	0.0%	6	14	2	30.0%	70.0%	10.0%
2	6	12	7	1	60.0%	35.0%	5.0%	17	3	2	85.0%	15.0%	10.0%
	5	3	17	1	15.0%	85.0%	5.0%	10	10	8	50.0%	50.0%	40.0%
	4	1	19	0	5.0%	95.0%	0.0%	10	10	1	50.0%	50.0%	5.0%
	3	0	20	0	0.0%	100.0%	0.0%	4	16	1	20.0%	80.0%	5.0%
3	6	14	6	0	70.0%	30.0%	0.0%	20	0	0	100.0%	0.0%	0.0%
	5	10	10	0	50.0%	50.0%	0.0%	14	6	1	70.0%	30.0%	5.0%
	4	4	16	0	20.0%	80.0%	0.0%	13	7	1	65.0%	35.0%	5.0%
	3	1	19	0	5.0%	95.0%	0.0%	6	14	4	30.0%	70.0%	20.0%

C: The highest refit probability occurred between a single individual's left and right humeri

T I: Type I Error - The refit model failed to identify a match within the given sample

T II: Type II Error - The highest refit probability occurred between different individuals

**Table 2.9** provides the difference in the number of left to right humeri and the results of the test. Overall, the  $P_{\min}$  predicts correct matches in slightly less than 60 percent of the individuals and limits the number of Type II errors occur approximately 7.9 percent of the time.  $P_{\max}$  maintains a success rate exceeding 65 percent, but the likelihood of Type II errors increases to 20 percent. The uneven distribution of lefts and rights had a mixed impact on the model's ability to predict pairs. In some cases the matching success rates stay about the same as in the even distribution of sided element trials, but most saw a decline in the number of successful matches.  $P_{\min}$  still produced percentages of Type II errors that were less than 10 percent. Another important result is the jump in the number of Type II errors when using  $P_{\max}$  to identify matches in uneven samples.

Table 2.9: Uneven representation of sided elements using simulated assemblages

				$P_{\min}$						$P_{\max}$					
Left	Right	True	Trial	C	T I	T II	%C	%T I	%T II	C	T I	T II	%C	%T I	%T II
10	20	10	1	8	2	0	80.0%	20.0%	0.0%	9	1	1	90.0%	10.0%	10.0%
			2	6	4	0	60.0%	40.0%	0.0%	9	1	1	90.0%	10.0%	10.0%
			3	8	2	0	80.0%	20.0%	0.0%	8	2	2	80.0%	20.0%	20.0%
20	40	20	1	11	9	2	55.0%	45.0%	10.0%	17	3	3	85.0%	15.0%	15.0%
			2	7	13	1	35.0%	65.0%	5.0%	14	6	3	70.0%	30.0%	15.0%
			3	13	7	3	65.0%	35.0%	15.0%	18	2	2	90.0%	10.0%	10.0%
15	25	10	1	5	5	1	50.0%	50.0%	6.7%	10	0	4	100.0%	0.0%	26.7%
			2	10	0	2	100.0%	0.0%	13.3%	10	0	3	100.0%	0.0%	20.0%
			3	8	2	0	80.0%	20.0%	0.0%	9	1	2	90.0%	10.0%	13.3%
20	40	10	1	4	6	5	40.0%	60.0%	25.0%	8	2	8	80.0%	20.0%	40.0%
			2	4	6	1	40.0%	60.0%	5.0%	9	1	8	90.0%	10.0%	40.0%
			3	6	4	4	60.0%	40.0%	20.0%	8	2	11	80.0%	20.0%	55.0%
				90	60	19	60.0%	40.0%	7.9%	129	21	48	65.2%	10.6%	20.0%

C: Correct - The highest refit probability occurred between a single individual's left and right humeri

T I: Type I Error - The refit model failed to identify a match within the given sample

T II: Type II Error - The highest refit probability occurred between different individuals

The empirical data sets have similar refitting successes as their simulated assemblage equivalents (**Table 2.10**). The model maintains high success rates of identifying matches

and minimizes false positives. In the small samples of Todd's and Klein's data,  $P_{\min}$  was successful in refitting over 65 percent of true matches and  $P_{\max}$  correctly matched 90 percent of the samples. The frequency of Type II errors remains low in both matrices. The refit success using Lyman's data were significantly lower using only two measurements on larger samples.  $P_{\min}$  refit only 12.5 percent correctly with Type II errors occurring less than 1 percent of the time.  $P_{\max}$  nearly triples the number of correct matches (33%) with Type II errors (5.5%) at acceptable levels. The results from Lyman's data were comparable to the simulated assemblages using four variables. These results indicate that larger comparative samples increase the predictive power of the model.

Table 2.10: Summary refit results from empirical samples of bison (Todd 1983) femura, grysbok (Klein per comm) metapodials, and deer (Lyman 2006) humeri and astragali.

Species	Element	Trials	Sample Size	Minimum Probability Matrix						Maximum Probability Matrix					
				C	T I	T II	%C	%T I	% T II	C	T I	T II	%C	%T I	% T II
Bison	FM	1	8	6	2	0	75.0%	25.0%	0.0%	7	1	0	87.5%	12.5%	0.0%
		2	8	7	1	0	87.5%	12.5%	0.0%	8	0	0	100.0%	0.0%	0.0%
		3	8	7	1	0	87.5%	12.5%	0.0%	7	1	1	87.5%	12.5%	12.5%
Grysbok	MP	1	12	8	4	2	66.7%	33.3%	16.7%	12	0	0	100.0%	0.0%	0.0%
		2	12	8	4	0	66.7%	33.3%	0.0%	11	1	0	91.7%	8.3%	0.0%
		3	12	4	8	1	33.3%	66.7%	8.3%	9	3	3	75.0%	25.0%	25.0%
Deer	HM	1	18	2	16	0	11.1%	88.9%	0.0%	4	14	0	22.2%	77.8%	0.0%
		2	18	3	15	0	16.7%	83.3%	0.0%	7	11	0	38.9%	61.1%	0.0%
		3	18	0	18	0	0.0%	100.0%	0.0%	5	13	0	27.8%	72.2%	0.0%
Deer	AS	1	30	6	24	0	20.0%	80.0%	0.0%	11	19	1	36.7%	63.3%	3.3%
		2	30	3	27	0	10.0%	90.0%	0.0%	13	17	4	43.3%	56.7%	13.3%
		3	30	4	26	1	13.3%	86.7%	3.3%	8	22	3	26.7%	73.3%	10.0%

C: Correct - The highest refit probability occurred between a single individual's left and right humeri

T I: Type I Error - The refit model failed to identify a match within the given sample

T II: Type II Error - The highest refit probability occurred between different individuals

## Discussion

The results of this analysis indicate that it is possible to identify individuals within large samples if the analysis uses additional metric dimensions. The importance of using multiple measurements decreases the frequency of Type II errors and increases the likelihood of correct pairings. Through a combination of  $P_{min}$  and  $P_{max}$ , it is possible to increase the number of matches while targeting both Type I and Type II errors. In many cases of Type I errors in  $P_{min}$ , the true match fell below the probability threshold, which was then properly identified in  $P_{max}$ . Yet in uneven samples,  $P_{max}$  often forced incorrect matches. The results of the uneven trials indicate the importance of using both matrices together to verify potential matches. Despite the model's success in identifying bilateral pairs, results from actual empirical studies still need to be physically verified to confirm matches. For additional confidence, analysts should also consult other zooarchaeologists to confirm identified matches.

A primary issue with archaeological assemblages is the degree of weathering that limits the number of accurate measurements that can be captured per specimen. The diagnostic tests indicate that fewer variables decrease the model's ability to distinguish pairs, but the probability of Type II errors remains low. This is an important aspect of the model.

When identifying matches with heavily weathered assemblages, the chances of a match will be contingent on the number of measurements that can be reliably recorded. The four empirical tests of the model indicate results that conform to the diagnostic tests, which verify the use of normally distributed simulated assemblages. The combined results of the simulated and empirical samples indicate that the model is most successful when: 1) the comparative sample is large, 2) the number of measurements is large, and 3)

the number of individuals in the test sample is small. Even when these conditions are not met, the model is still successful at minimizing false positives.

In comparison with Lyman's bilateral refitting model, our approach provides improved rates of pair identification and reduced frequencies of Type II errors regardless of the number of individuals or variables. Overall, the conditional probability of the model generating a Type II error for a given specimen within even samples is 1.2 percent using  $P_{\min}$  and 5.9 percent in  $P_{\max}$ . The probability of a match being correct is 95.3 percent using  $P_{\min}$ . In the case of  $P_{\max}$ , the analyst can still be certain that a match generated by the model is an actual pair 93 percent of the time when its actual match is present in the sample. For a given specimen in an uneven sample, the analyst can be confident that a predicted match using  $P_{\min}$  is from a single individual 99 percent of the time. This confidence in a predicting a correct match drops when using  $P_{\max}$  to 83 percent. Using Lyman's conservative approach, the probability of a identifying a match is 74 percent, but any identified match has a 60 percent chance of being a false positive. The even sample test results improve with the liberal approach, which leads to a 91 percent probability of a match, but there is still a 60.2 percent chance of a false positive.

## **Conclusions**

The time investment involved with bilateral refitting is prohibitive with most faunal assemblages. In large assemblages, the total number of measurements needed for this approach can be excessive. Conservatively, this model should be reserved for archaeological sites that have well preserved faunal remains and/or well-preserved spatial context. In these circumstances, the spatial distribution of individual animal remains across a site can provide a unique view into site formation, spatially segregated activities,

and/or the social interaction between different households. Analysts examining spatially segregated faunal assemblages within a site, or closely linked sites, could use bilateral refitting to identify whether individual animals were dismembered in a single location or processed in a series of stages located in different portions of a campsite. Researchers can also use bilateral refitting to identify single versus multiple occupations at a site. In a similar vein, the successful application of bilateral refitting can also help address identifying mass kill versus accretionary kill events. Finally, the application of bilateral refitting can be used to identify directional trends of past sharing behavior, which can be used in conjunction with Behavioral Ecological models (i.e. Waguespack 2002) to better understand transitions in social interaction over time.

The strength of this model lies in its flexibility to incorporate as many variables that can be reliably collected by the faunal analyst. As long as two or more measurements can be recorded, the model is superior to existing approaches. It can be used in traditional analyses using digital calipers as well as more recently accepted use of 3D scanned images. This allows the model to be applied to existing faunal data as well as newly compiled data. Unlike many other advances in methodology or analysis, this model requires no investment in cost-prohibitive software or hardware.

Previous attempts to identify bilateral pairs raised concerns that large sample sizes lead to statistical Type I and Type II errors (Enloe 2003; Lyman 2006, 2008). Overlapping is common in skeletal measurements because of bone sizes are generally normally distributed. Our model presents an alternative approach to identifying bilateral pairs within the appendicular skeleton that increases the frequency of correct matches and limits the number of false positives. As the sample size increases, the conservative model

( $P_{min}$ ) results in lower percentage of correct matches and Type II errors, while increasing the frequency of Type I errors. The  $P_{max}$  increases the likelihood of a correct match, but it also results in a higher number of Type II errors. While the  $P_{max}$  matrix may prove more advantageous on species with reliable non-parametric variables for verification, using the combination of  $P_{min}$  and  $P_{max}$  can provide the respective lower and upper boundaries of likely matches that can minimize the number of specimen that need physical inspection.

### **Chapter 3: Evaluating the Contemporaneity of Households at the Eden-Farson Site**

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## Abstract

*Archaeologists often rely on absolute dating methods, but the standard deviations associated with these approaches often leave us wondering what to make of spatially related archaeological units, such as adjacent sites, clusters of features, or regional scale investigations. This issue is particularly relevant to the Shoshone Protohistoric site of Eden-Farson located in southwest Wyoming. The campsite consists of at least eleven discrete excavation units which is associated with a successful communal game drive of over 156 pronghorn. Yet the sheer number of pronghorn and the ambiguous nature of the near-surface cultural deposits have left researchers debating whether or not it represents a single occupation associated with a single successful game drive. Using a multivariate refit model, I have performed a bilateral refit analysis to identify links between the excavation units. Strong evidence for contemporaneity of Eden-Farson excavation units comes from 38 linkages between ten of the eleven proveniences. Coeval occupation of the separate houses also allows for an analysis of food sharing behaviors. With the last game drive occurring in the 1870's, the Eden-Farson site provides a rare opportunity to examine the social organization of communal hunting.*

## Introduction

Anatomical refitting fills a critical role in understanding the temporal relationship of spatially discrete archaeological units. Refitting also provides a glimpse into behavioral and natural processes which can be interpreted based on spatial relationships. Refitting is most commonly associated with mechanical refitting as done by ceramic, lithic, and faunal analysts. However, faunal analysts have additional means of refitting, which rely on the generalized morphology of skeletal elements (Hofman, 1981; Hofman and Enloe, 1992; Lyman, 2008a).

Anatomical refitting consists of three basic types: conjoined refitting, articular refitting, and bilateral refitting (Enloe, 1991; Todd, 1983). Conjoined refitting refers to the reassembling of bone fragments and is similar to lithic refitting of debitage and tool fragments, which requires physically piecing together separate fragments from the assemblage. Articular refitting deals with elements that are linked anatomically together (i.e. humerus to radius, or atlas to axis), and uses measurements of adjoining epiphyses that should be more similar within a single individual than between individuals (Todd 1983). Finally, bilateral refitting consists of matching bones from a single individual with a corresponding left and right side. Underlying the latter two methods is the need for visual inspection (with small assemblages it could be considered an additional method of its own). Using bilateral refitting, this paper addresses the issue of contemporaneity of cultural deposits at the Eden-Farson site.

## Background

The Eden-Farson site is a Protohistoric site dating to A.D. 1708 +/- 163, excavated by the Wyoming Archaeological Society in 1968 and 1969 under the direction of Frison (Fig. 3.1). The spatial layout of the site shows eleven discrete concentrations of excavated cultural material, which can be identified as ten living structures (“houses”) and an initial excavation block. Frison (1971; 1991) determined the Shoshone cultural site affiliation based on the presence of flat-bottomed ceramic vessels (Mulloy, 1955) and the historic evidence of Shoshone occupation in the region. Later, he identified several bifaces as Shoshone Knives, which also linked the Eden-Farson site with the Shoshone (Frison, 1991).

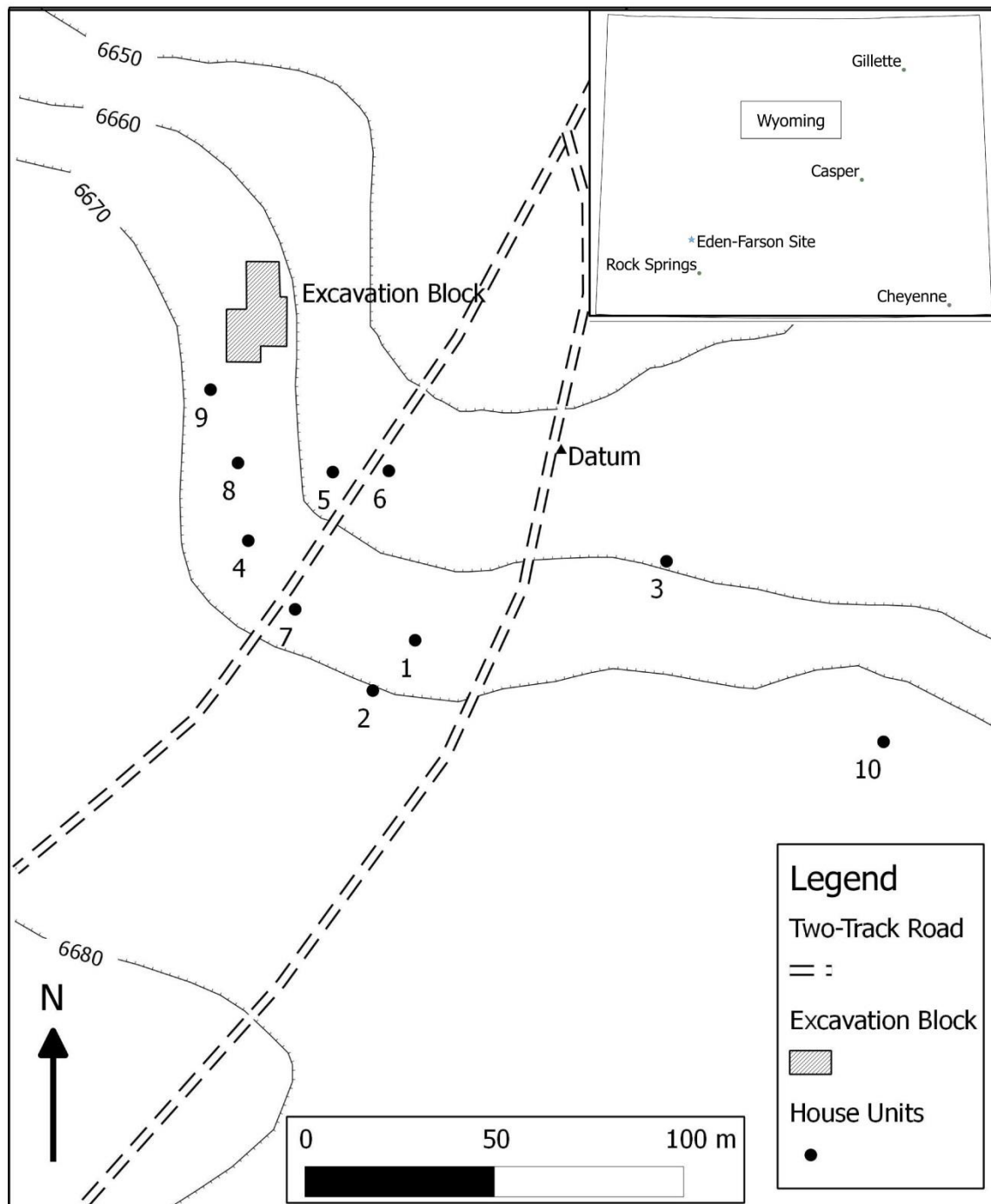


Figure 3.1: Site map indicating spatial distribution of households at Eden-Farson site, in southwest Wyoming.

The site consists of over 30,000 faunal, more than 11,000 chipped stone, and numerous ceramic and groundstone artifacts mixed with cultural features such as postholes, storage

pits, fire-cracked rock, and hearths. Cultural material was found and can still be found on the surface outside the excavated structures and the initial excavation block, but at much lower densities (Lubinski, 1997). The initial approach was stripping 7.6 cm levels from an excavation grid of 28 1.5 m by 3 m units (Larson et al., 1969). Although Larson et al. (1969) state that hearths were located within the initial excavation block, the rapid and coarse excavation techniques failed to map the provenance of artifacts and features. Therefore, it is possible that the initial excavation block represents one or more households.

Beginning with the excavations at House 1 and 2, excavation strategies shifted away from the grid when the field crew realized that the suspected rodent holes turned out to be a series of postholes (Larson et al., 1969). All subsequent concentrations of cultural material turned out to be separate households which were excavated as individual units (Frison, 1971). The shape of these living structures varied between oval and round and ranged in size from approximately 4.0 m to 7.0 m in maximum dimension. Excavation methods did not record the piece-plot locations of artifacts and features within the structures, but Frison does provide detailed sketch maps of three of the ten living structures (Fig. 3.2a & 3.2b). While there is a significant degree of variability in the quality and detail of the house pit maps, each one possesses redundant attributes: a hearth, postholes, a lithic workshop area, and faunal remains. This discrete discard of cultural material within the house pits reflects patterns of minimal camp cleaning associated with short-term foraging camps (O'Connell, 1987; O'Connell et al., 1991).

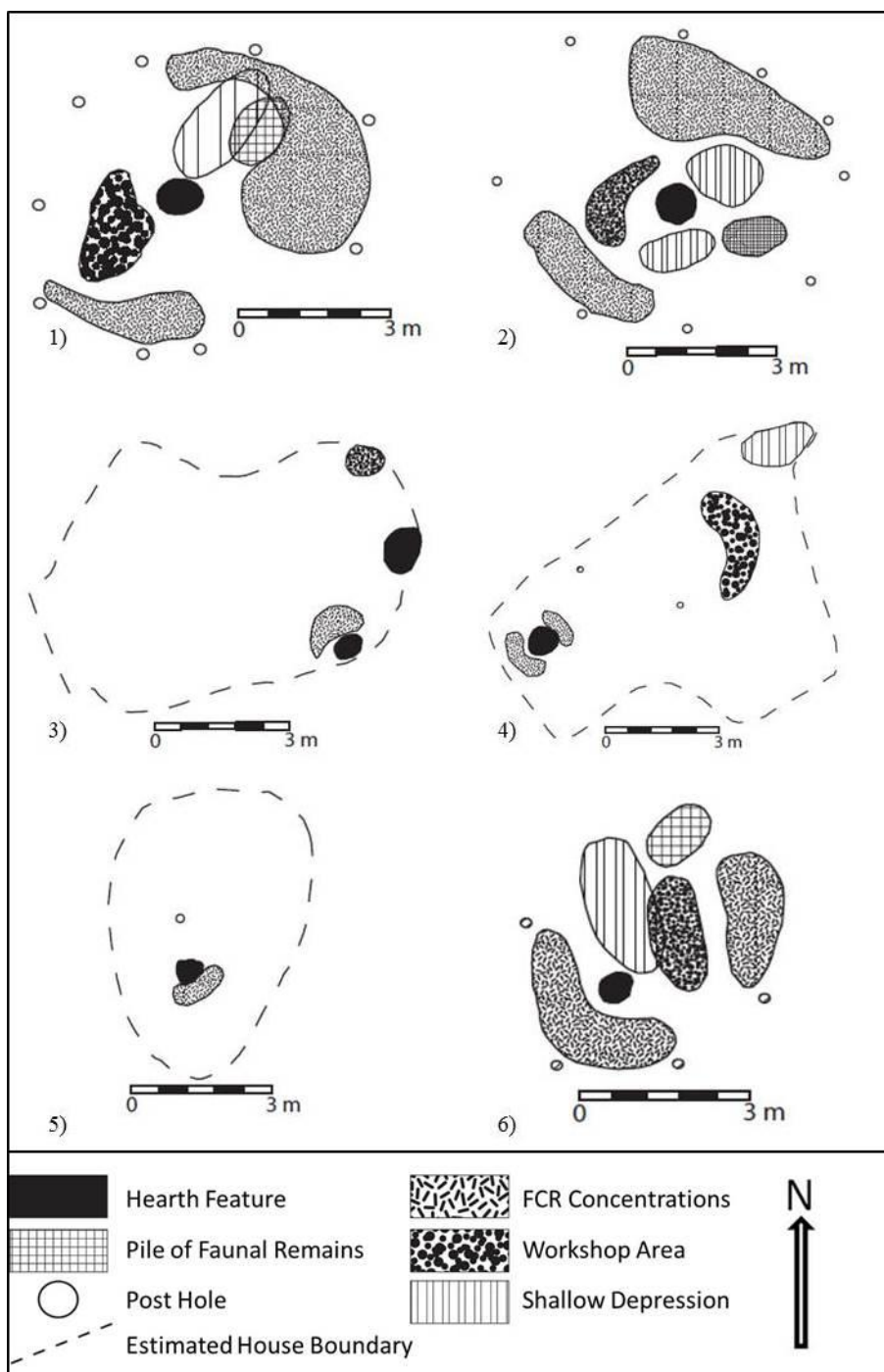


Figure 3.2a. Plan view maps of Eden-Farson's Houses 1-6 (1-6). Maps 1, 2, & 6 are redrawn with permission of author from Frison 1971: 260. Maps 2, 4, & 5 are redrawn with permission from Wyoming Archaeological Society archive; unpublished.

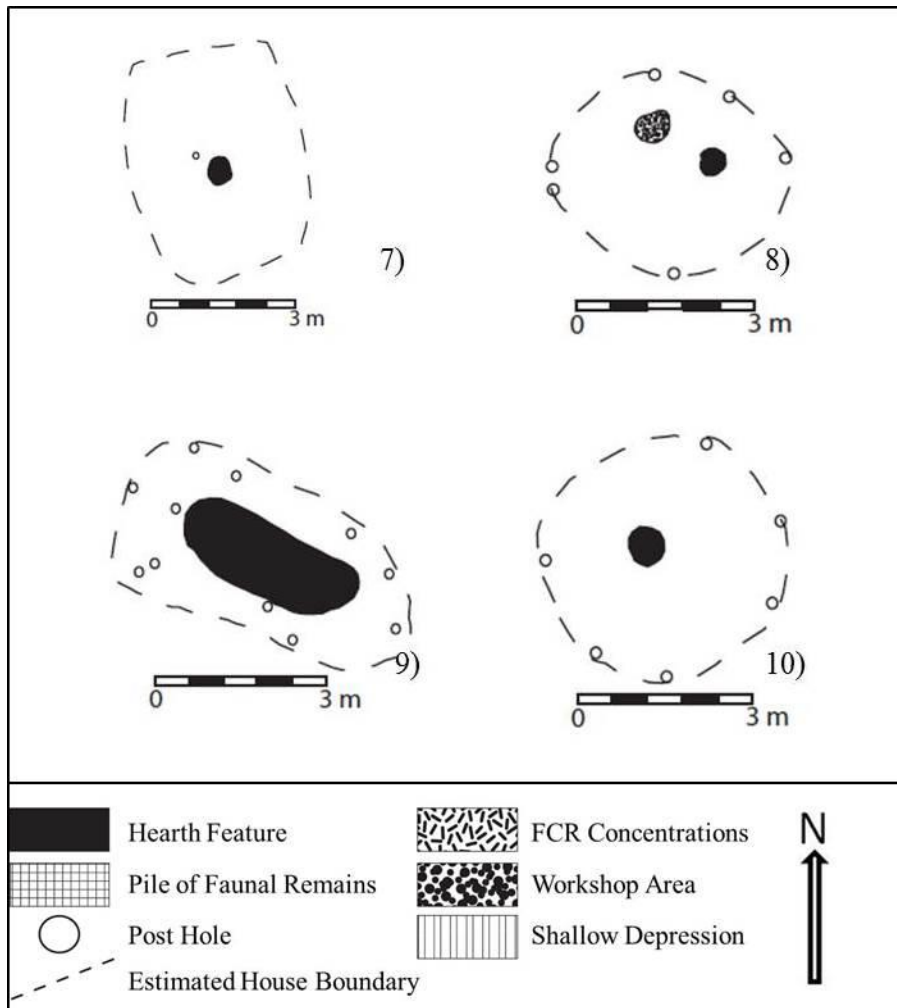


Figure 3.2b. Plan view maps of Eden-Farson's Houses 7-10 (A-D). Redrawn with permission from Wyoming Archaeological Society archive: unpublished.

The faunal assemblage from Eden-Farson consists of over 156 pronghorn distributed unevenly between the excavated living structures, the surface, and the initial excavation block. Frison's (1971) initial assessment suggests that a minimum of 212 individual pronghorn were present at Eden-Farson, but details of how this number was calculated are not clear. In a subsequent analysis of the dentition, Lubinski (1997) used the 4th premolar mandibular socket to tally a MNE of 303 and a skeletal part-specific MNI of

156 based on left mandibular fragments. Regardless of the estimate of MNI, Eden-Farson remains the largest pronghorn kill site in North America.

### *Debating Single vs. Multiple Kill Events*

The primary concern with Eden-Farson is how the site has been, and should be, interpreted. Frison argued the site was a Shoshone fall campsite associated with a single communal game drive. He based this interpretation on Shoshone diagnostic artifacts recovered from multiple living structures and Nimmo's (1971) age profiles based on a sample of mandibular fragments. Using the tooth eruption and wear patterns from 79 mandibles, Nimmo developed an age cohort profile showing no evidence of attritional kills. Instead, the profile showed age patterns more similar to those of catastrophic kills, which Nimmo interpreted as a mass kill. While Frison argues that all the cultural material comes from the same stratigraphic horizon, he admits that the stratigraphy at Eden-Farson was heavily bioturbated, which obscured any geological support for a single kill event.

Lubinski (1997) reanalyzed the Eden-Farson assemblage to address the single communal kill interpretation. While Nimmo's (1971) analysis was insightful, Lubinski felt an expanded analysis of the Eden-Farson mandibular dental remains would shed more light on the question of single vs. multiple kill events. His age groupings were broken down into Fawn-Yearling-Mature (FYM) and Juvenile-Prime-Old (JPO), and the annual cohort grouping based on time of death (see Stiner, 1990 for JPO; Lubinski, 1997 for FYM). While the JPO profile reflected an attritional kill profile, the FYM and the annual age



cohorts approximated expectations of a mass kill. Combined with the nearly uniform weathering patterns across all proveniences, he concluded Eden-Farson most closely resembled a mass kill event. The single kill hypothesis was then questioned by an isotopic analysis of the dental remains (Fenner, 2008, 2009). Like the tooth eruption sequences, Fenner found ambiguity in the isotopic signatures from Eden-Farson. As a result, Fenner (2008:343) states "Eden-Farson's pronghorn formation history is currently indeterminate." Most recently, Lubinski (*in press*) has argued multiple lines of evidence indicate that Eden-Farson is most likely a human-caused single deposit of pronghorn associated with a single kill event.

All previous studies of Eden-Farson agree with the interpretation that the campsite was associated with a successful communal game drive, but debate revolves around the question of whether the site represents a single or multiple kill events. Analyses addressing this debate have used the entire faunal assemblage regardless of provenience, which raises concerns that all of these separate deposits are contemporaneous. This is concerning given that two catastrophic kill events occurring over a short time span could mimic signatures attributed to a single kill in the absence of concrete geologic and stratigraphic evidence. As such, I use the faunal materials from the Eden-Farson site to perform an anatomical refit analysis to address contemporaneity of the house pits.

Anatomical refits between the households will provide evidence that these excavated house units are contemporaneous and will strengthen the existing single kill hypothesis.

Using refits to argue household contemporaneity relies on the assumption that all the meat was processed at the same time and that none was stored in abandoned houses for later consumption. My assertion that refits reflect contemporaneity is supported by

Frison's (1971) initial interpretation of the site. Based on cut mark frequencies, the degree of green bone breakage for marrow, and the use of ceramic vessels to extract bone grease, he proposes camp members ate the marrow and bone grease after the hunt and they dried the meat to make pemmican. His analysis of butchery patterns at Houses 6 and 9 is consistent with my own observations of the frequency and location of cut marks from the other proveniences, which suggests similar carcass processing was employed across the site. Processing and distribution of pronghorn shortly after the hunt is also consistent with numerous ethnographic accounts of game drives (Egan, 1917; Hill, 1938; Hoebel, 1978; Malouf, 1974; Smith, 1974).

## Methodology

### *Anatomical Refitting*

While many materials have been used for refitting, bone is unique in that the meat and marrow associated with it rapidly spoils (Field et al., 2003). The economic value of bone is tied to the meat, marrow, and bone grease attached to it which begins to lose economic utility within weeks of procurement. As a result, a refit between skeletal elements provides a stronger temporal link between artifact concentrations than other archaeological materials. Faunal refitting has been used to determine whether artifact concentrations are coeval at many archaeological sites (Todd, 1983, 1987; Lyman, 2006, 2008b; Enloe, 2004, 2005; Enloe and David 1992; Waguespack, 2002). The work at the Pincevent and Palangana sites also used linkages to examine the social implications of refits between artifact concentrations and households.

Bilateral refitting has been used for decades to identify coeval deposition of faunal remains, but the first standardized methodology was established by Todd (1983). By using a comparative assemblage, Todd identified a single measurement providing the highest correlation between known matches and then applied it to the test sample from the Horner site. This same approach was then replicated with minor alterations by Enloe (1991, 2003) and Waguespack (2002). To improve this existing method, Lyman (2006) introduced a bivariate approach using two measurements from appendicular skeletal elements.

Lyman's (2006, 2008a, 2008b) bivariate approach highlighted the potential issue with existing bilateral refitting approaches. First, data clustering, or the overlap of similarly-sized elements from different individuals, led Lyman (2006) to conclude bilateral refitting becomes increasingly unreliable beyond 15 individuals. Data clustering in larger sample sizes results in an increase in the frequency of Type I and Type II statistical errors. Type I errors refer to the inability to identify true refits existing within a sample, and Type II errors are potential refits that are not true matches. An additional concern is the inability of previous methods to deal with bilateral asymmetry. While it is well established within biology that vertebrates possess bilateral symmetry, there are varying degrees of asymmetry between an individual's left and right sided elements (Klingenberg et al., 2002; Leamy et al., 2001). Therefore, metrically-based methods serve as a means of narrowing the range of possible matches, but they still require visual inspection. For the purposes of this paper, refits identified by statistical methods are termed “potential” refits or matches. Those potential refits that are visually examined and determined to be a match will be referred to as “actual” refits.

### *The Multivariate Model*

The large number of pronghorn represented at Eden-Farson represents the type of challenge by which existing refit approaches are unable to cope. As such, O'Brien and Storlie (2011) developed a multivariate bilateral refit program to better deal with large sample sizes. The basic model relies on the established concept of appendicular bone symmetry between the left and right sides of the skeleton (Lyman, 2006). Simply put, the model assumes that an individual's left bone is more similar to its corresponding right bone than the right bones of other individuals.

To predict bilateral refits the model relies on the multivariate model,

$$d = (x_1 - y_1) \sim N(\mu, \Sigma), \quad (1)$$

where  $N(\mu, \Sigma)$  is the multivariate normal distribution,  $\mu$  is the mean vector, and  $\Sigma$  is the covariance matrix. While variation will exist between an individual's left and right element, the model assumes that within the population, left or right bones will not always be larger. If true, then the variation between lefts and rights will approach zero as the sample size approaches the actual population. Therefore,  $N(\mu, \Sigma)$  can be expressed as  $N(0, \Sigma)$  to reflect their assumption that the mean difference between the population of left and right bones would be zero. Next, the model calculates the probability that  $i \leftrightarrow k$  given that  $i \leftrightarrow j$ , for some  $j = 1, \dots, n$ . More simply, the model assumes that a match does exist for each bone ( $i$ ) within the sample ( $j$ ), and it predicts the probability that the  $i$ -th left specimen in the sample matches a particular right bone ( $k$ -th). The model performs this probabilistic calculation for all right bones in the sample ( $j$ ). The formal conditional refit probability for the model is

$$\begin{aligned}
\lambda_{ik} &= \Pr(i \leftrightarrow k | i \leftrightarrow j, \text{ for some } j = 1, \dots, n) \\
&= \Pr(d = d_{ik} | d = d_{ij}, \text{ for some } j = 1, \dots, n) \quad (2) \\
&= \frac{\phi(d_{ik}; 0, \Sigma)}{\sum_{j=1}^n \phi(d_{ij}; 0, \Sigma)},
\end{aligned}$$

where  $\phi(d_{ik}; 0, \Sigma)$  is the altered form of the multivariate density function (Johnson and Wichern, 2003:143),

$$\phi(d_{ik}; 0, \Sigma) = \frac{1}{(2\pi)^{p/2} |\Sigma|^{1/2}} \exp \left\{ -\frac{1}{2} (d - \mu)' \Sigma^{-1} (d - \mu) \right\}. \quad (3)$$

The multivariate density function is altered for the purposes of the model by substituting the right bone dimensions for  $\mu$ . In addition, the covariance matrix for the sample of unknown paired elements is undefined, and therefore we substitute the covariance matrix from a comparative sample (i.e. a sample of known bilateral pairs).

The multivariate model generates probability matrices from the perspective of all left and all right elements. Each potential match has a refit probability based on its multivariate density value relative to the sum total of all other densities derived from all potential matches. O'Brien and Storlie (2011) define two matrices  $P_{\text{MIN}}$  and  $P_{\text{MAX}}$  to reflect the conservative and liberal probabilities of a match, respectively. These matrices differ in reporting the lowest probability ( $P_{\text{MIN}}$ ) from left to right and right to left bone comparisons, while the  $P_{\text{MAX}}$  reports the higher probability. The matrices function as a

means to reduce the number of specimens that need visual verification, which will reduce the analytical time spent identifying potential matches in a large assemblage.

The multivariate method deals with the two issues plaguing previous methods: data clustering and asymmetry. This method employs a flexible design allowing for some or all of the dimensions collected by Todd (1983) or any other system of attaining quantifiable dimensions. Their diagnostic tests show that the number of dimensions measured is positively correlated with the statistical power of the model; i.e. the more measurements used, the more powerful the statistical method. Therefore, comparing potential matches in five dimensions will result in greater separation between actual pairings from the cluster than two measurements. Regarding asymmetry, the model uses a variance-covariance matrix derived from the comparative sample and its associated maximum likelihood estimates to provide a unique expected degree of asymmetry for any skeletal element sample. The coefficient of asymmetry sets the tolerance of variation for comparisons in the test sample.

O'Brien and Storlie (2011) ran a series of diagnostic tests on the model and Lyman's (2006) bivariate approach. These tests show accuracy improvements in identifying the correct pair within simulated assemblages and comparative collections over the bivariate method. In smaller samples, the model was successful at minimizing Type I and Type II statistical errors. The model was also successful in identifying pairs in larger samples, but the frequency of Type II errors, or false positives, increased. Like the other statistical approaches, the model is best suited to narrow the number of visual comparisons as opposed to a final step in the identification of bilateral refits.

### *Eden-Farson Refitting Sample*

To accomplish bilateral refitting, I collected similar measurements from both a comparative sample of pronghorn and the Eden-Farson archaeological assemblage<sup>1</sup>. This research focuses on the refit results from the astragalus, distal humerus, distal radius, proximal radius, and distal tibia. Other viable bilateral skeletal elements were excluded due to small sample sizes or poor overall condition. The measurements used to quantify the dimensions of the pronghorn skeletal parts follow Enloe (1991) and are outlined in Table 3.S1. All dimensions from the comparative and test samples were taken three separate times and then averaged to give an estimated value for each dimension. The analysis only included archaeological specimens intact enough to reliably provide each measurement. Therefore, the number of total refits reflects the minimum number of refits for each skeletal part.

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<sup>1</sup> The comparative assemblage was collected from the University of Wyoming's Comparative Osteological Museum and the University of New Mexico's Museum of Southwest Biology Mammal Collections.

Table 3.S1: The dimensions measured for the refit model. All dimensions were taken from Enloe (1991) with the exception of tibia dimensions with asterisks.

Skeletal Part	Distal Epiphysis of Humerus	Proximal Epiphysis of Radius
Dimensions	<i>Greatest Breadth of Distal End</i>	<i>Greatest Breadth</i>
	<i>Breadth of Distal Articular End</i>	<i>Greatest Breadth of Articular Surface</i>
	<i>Least Breadth of Olecranon Fossa</i>	<i>Greatest Depth of Medial End</i>
	<i>Greatest Depth of Medial Distal End</i>	<i>Greatest Depth of Lateral End</i>
	<i>Least Depth of Distal Medial end</i>	
	<i>Depth of Olecranon Fossa</i>	
Skeletal Part	Distal Epiphysis of Radius	Distal Epiphysis of Tibia
Dimensions	<i>Greatest Breadth</i>	<i>Greatest Breadth</i>
	<i>Greatest Breadth of Articular Surface</i>	<i>Greatest Depth</i>
	<i>Greatest Depth</i>	<i>Breadth of Distal Articular Surface</i>
	<i>Greatest Breadth of Articular Surface with Radial Carpal</i>	<i>Maximum Depth of the Lateral Groove*</i>
		<i>Articular Depth of Medial Groove*</i>
		<i>Articular Depth of Lateral Groove*</i>
Skeletal Part	Astragalus	
Dimensions	<i>Greatest Lateral Length</i>	
	<i>Greatest Breadth</i>	
	<i>Breadth of Distal Articular Surface</i>	

The model was run for each element and the output was analyzed to identify bilateral comparisons with the highest probability of refitting. The exact probability value used to define a potential refit varied due to the number of dimensions measured for the skeletal parts. With the exception of humeri, I visually inspected the top three ranked potential matches from the  $P_{\text{MIN}}$  and  $P_{\text{MAX}}$  matrices with probability values greater than 20 percent. To visually verify the predicted pairings, calipers were used to confirm the dimensions of each specimen. Next, the morphology of the articular surfaces between individuals is distinct in many cases reflecting differences in growth and development and thus was



visually inspected. While this second step is subjective, only the use of 3D scanning can accurately capture the dimensions of the articular surface. All potential refits were analyzed by the author to identify actual bilateral refits. To test for author bias, the potential humeri refits were visually verified independently by two other zooarchaeologists.

## Results

The use of the bilateral refit program to identify contemporaneity of houses at Eden-Farson is part of a larger faunal analysis project. To date, my analysis includes all 31,638 faunal remains with provenience as well as 2,286 bones from the non-provenienced assemblage and the entire assemblage of maxillary fragments to establish an independent minimum number of individuals (MNI) from previous studies (Frison, 1971; Lubinski, 1997). The skeletal part specific MNI is based on the 4<sup>th</sup> premolar socket on the right side of the maxillary element. Table 3.1 provides the NISP and MNI for each house and initial excavation unit. While a sizeable assemblage is present at each area of the site, there is substantial variability in the number of individuals represented. The largest assemblages according to NISP are House 2, 5, 9, and the excavation block, but the areas with the largest number of individuals include House 6 (MNI=35), House 2 (MNI=34), House 9 (MNI=20), and the excavation block (MNI=18).

Table 3.1: Eden-Farson NISP and MNI per provenience. MNI based on the 4<sup>th</sup> premolar socket on the right side of the maxilla.

House	1	2	3	4	5	6	7	8	9	10	EX BLK	Total
NISP	1723	3503	1021	1456	6241	2723	1643	1111	5003	517	6868	31809
MNI-Maxilla	7	34	4	7	11	35	1	7	20	7	18	151

### *Provenience of Refits*

The number of skeletal parts (NSP) within the comparative sample ranges from 18 to 21 individuals depending on the skeletal element. In total, 188 skeletal elements were examined with equal numbers of left and right bones. The Eden-Farson sample consists of 527 NSP's with 264 left and 263 right specimens (Table 3.2). Those houses with the largest samples for refitting closely mirror the household-level MNI's. Although there are multiple instances of null sample sizes, each house is represented in four of the five skeletal parts used in this analysis.

Table 3.2: The NISP and the Number of Skeletal Parts (NSP) used in the refit model for each provenience.

House	Astragalus		Humerus		NISP	Radius		Tibia		Totals	
	NISP	NSP	NISP	NSP		Dist. NSP	Prox. ISP	NISP	NSP	NISP	NSP
1	20	11/7	53	2/4	34	0/0	5/2	62	3/3	169	37
2	11	1/9	101	16/12	61	1/8	0/7	154	16/15	327	85
3	8	2/5	29	1/3	23	4/6	1/3	37	8/4	97	37
4	13	7/4	48	2/1	59	4/2	1/4	80	8/8	200	41
5	14	8/1	133	12/13	164	0/1	1/0	232	17/12	543	65
6	18	8/7	192	10/8	186	3/8	10/4	248	16/19	644	93
7	6	0/2	49	1/1	62	3/2	0/0	62	0/4	179	13
8	5	1/3	39	2/0	21	0/1	1/0	136	2/0	201	10
9	6	4/2	199	5/10	71	2/4	4/5	48	8/9	324	53
10	3	2/1	42	1/0	28	0/1	1/2	43	2/1	116	11
Ex. Block	20	2/7	121	1/4	131	1/2	7/3	199	7/9	471	43
No Prov.	24	14/8	80	0/2	709	10/0	5/0	60	0/0	873	39
Totals	148	60/56	1086	53/58	1549	28/35	36/30	1361	87/84	4144	527

NSP: Left/Right specimens used in the refit model

Across all elements, the multivariate refit model produced 63 actual bilateral matches: 9 astragali, 17 humeri, 3 distal radii, 5 proximal radii, and 29 tibiae refits. The entire sample indicates faunal refits between 10 of the 11 areas. Nearly 40 percent (25 of 63) of the linkages occurred within a single excavation unit, but the majority occurred between

households and the initial excavation block (Table 3.3). Almost all individual houses have multiple refits with other houses; House 7 has but one refit to House 6. With 17 refits the humerus has the highest percentage of refits of all the skeletal parts, which includes 11 (65%) intra-household linkages. The remaining six refits link Houses 1 and 2 (N=2), Houses 2 and 6 (N=2), Houses 2 and 9 (N=1), and Houses 8 and 9 (N=1).

Table 3.3: Number of faunal refits by provenience unit.

House	1	2	3	4	5	6	7	8	9	10	Ex Blk	No Prov
1	0	2	0	0	0	2	0	0	2	0	0	0
2		7	1	1	2	3	0	1	2	0	2	1
3			0	0	1	1	0	0	2	0	0	1
4				0	0	2	0	0	1	0	2	0
5					5	0	0	1	2	0	1	0
6						8	1	2	0	0	1	0
7							0	0	0	0	0	0
8								0	1	0	0	0
9									2	0	1	0
10										1	0	0
Ex Blk											1	0
No Prov												0

Refitting linked most of the households at Eden-Farson with the exception of House 10. On average, the excavated areas are separated by 55 m from all other proveniences when excluding House 10 (Fig. 3.3). House 3 is closest to House 10, which lies 68 m away to the southeast. While the lack of refits may reflect a behavioral or temporal issue, it is likely due to House 10's small sample size. When the sample size contributing to the refit model is compared to the number of refits per excavation unit, there exists a strong correlation [*Spearman's rho* (9) = 0.895,  $p < 0.001$ ]. This supports the interpretation that the number of refits is dependent on the number of bones included in the refit model.

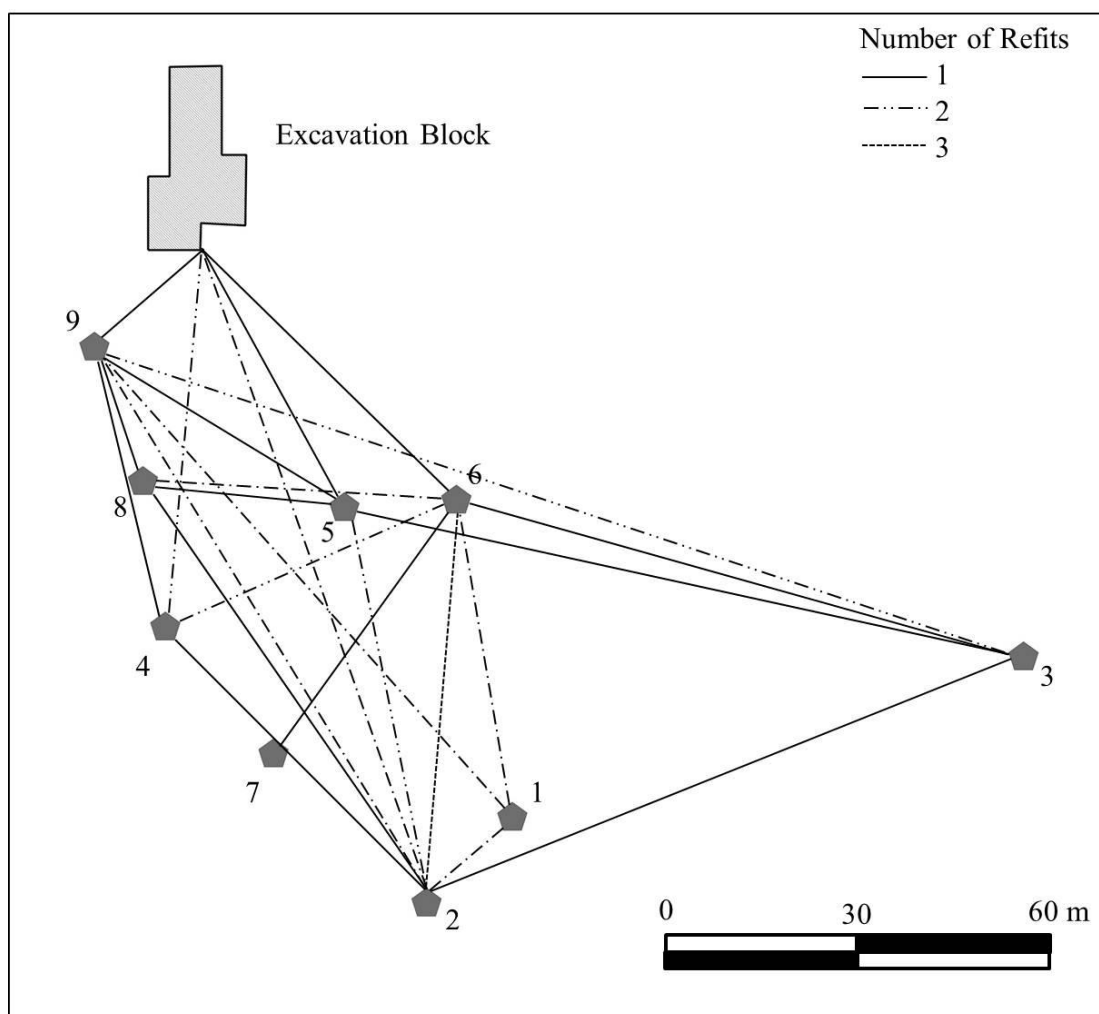


Figure 3.3: Map of refits between houses and excavation block excluding House 10.

### *Behavioral Interpretations of Refits*

The identification of bilateral refits between Eden-Farson households permits an examination of behavioral trends. The site boasts multiple refits between houses, but what is less clear is whether certain parts are shared more often than others and with whom. First, I tested to see whether social practices led to increased sharing of fore or hind limbs. If food sharing favored the redistribution of better cuts of meat, then ungulate food utility indices indicate the hind-limb should be shared more frequently (Jones and

Metcalf, 1988; Madrigal and Holt, 2002; Metcalfe and Jones, 1988). Of the 63 refits, 25 are between fore-limb elements of which 52 percent (N=13) of the refits are between houses (Table 3.4). The 38 hind quarter refits have 13 (34%) within and 25 (66%) between household linkages. Despite the higher percentage of inter-household refits among hind limb bones, a chi square and G test show no statistical difference in the representation of fore and hind limbs among refits within and between houses [ $\chi^2 (1, 63) = 1.198, p = 0.274$ ;  $G (1, 63) = 0.518, p = 0.4717$ ]. Based on these results, there is no evidence residents chose to share fore-limbs with any greater frequency than hind-limbs, or vice versa.

Table 3.4: Refits comparing within and between household by element.

Provenance	Humeri	Prox. Radi	Dist Radi	Fore-Limb	Astragali	Tibiae	Hind-Limb	Total
Within	11	1	0	12	1	12	13	25
Between	6	4	3	13	8	17	25	38
Total	17	5	3	25	9	29	38	63

Social practices may favor the sharing of larger pronghorn carcasses over smaller ones, which can be tested by using measurements from the refit sample as a proxy for overall size. I used the distal humerus maximum breadth and the distal tibia maximum breadth as proxies for pronghorn size and compared these values across refits found intra-household (within) and inter-household (between) linkages. A comparison of size shows no difference among those bones associated with inter-household and intra-household refits [ $t (15) = 2.131, p = 0.248$ ] among humeri and there are similar non-significant results from the tibia sample [ $t (33) = 2.035, p = 0.136$ ]. This suggests that carcass size did not influence whether occupants shared or not.

Although the statistical analyses above point to an absence of preferential treatment of high utility hind limbs or larger carcasses, the frequency of refits per household suggests that some houses were more active than others. Houses 2 (N=14), 6 (N=12), 9 (N=11), and the excavation block (N=8) had the most inter-household refits. Yet, do more refits indicate differences in status among the households?

Using only those elements of a sufficient quantity from the entire assemblage (including those without provenance), the proxies for pronghorn size are the astragalus maximum length, the distal humerus maximum breadth, and distal tibia maximum breadth. The ANOVA for the astragali shows significant size differences between houses [ $F(11,115) = 2.96, p = 0.002$ ], but a Tukey Test indicates these differences are driven by the excavation block that is statistically smaller than all the houses except House 7, 8, and 10. The same pattern is mirrored for tibia size where the difference is driven by smaller mean distal tibia breadth of House 10 and the following areas: Houses 2, 3, 4, 5, 6, and 9 [ $F(11,194) = 2.13, p = 0.020$ ]. The ANOVA for humeri shows no significant differences between the houses, excavation block, and non-provenienced samples [ $F(11, 123) = 1.60, p = 0.106$ ]. In summary, there is no statistical evidence from the bone size among all three skeletal parts that supports the hypothesis that one house received larger pronghorn than others.

### *Model Effectiveness*

The Eden-Farson site represents the first application of the multivariate refit model on a large archaeological assemblage. The model succeeds in its primary goal of minimizing the number of specimens to be visually compared. In total, the use of both matrices

predicts 192 matches, but the  $P_{\text{MIN}}$  predictions are also present among the  $P_{\text{MAX}}$  matrices. As such, 164 comparisons required physical verification, but this is many fewer than the number of visual inspections needed in the absence of the model. If all possible specimens for all the bones were visually compared, this would require a total of 15,802 comparisons.

In their diagnostic tests, O'Brien and Storlie (2011) used an arbitrary probability of 0.845 to test whether the model could successfully identify true pairs in blind tests. Using this same probability threshold for the Eden-Farson assemblage, all values equal to or greater than 0.845 were summed for all the skeletal parts as were all cases where the actual refit was included in the pool of potential refits (Table 3.5). The counts under the heading "Potential" represent all refits that equaled or exceeded 0.845 and "Verified" are the number of observations that were actual refits within the specific skeletal part potential refit subsample. The  $P_{\text{MIN}}$  matrix predicted a total of 28 refits and resulted in 13 (46.4%) actual refits, which is close to the expected value given previously published diagnostic tests (O'Brien and Storlie, 2011).  $P_{\text{MAX}}$  predicted 164 matches needing verification, but only 32 (19.5%) proved to be actual refits. These lower than expected values likely reflect variability in the number of dimensions measured and sample size. Those samples with more measurements produced much higher percentages of actual refits than those samples with few dimensions. Yet, regardless of sample size and dimensions measured, these results indicate that relying on the probability thresholds to identify refits without visual verification will often result in Type II errors.

Table 3.5: The number of potential refits that were visually verified refits using arbitrary probability threshold of  $p = 0.845$  for  $P_{MIN}$  and  $P_{MAX}$  matrices.

Element	Left/Right	Dimensions	$P_{MIN}$			$P_{MAX}$		
			Potential	Verified	% Accurate	Potential	Verified	% Accurate
Astragals	60/56	3	2	1	50.0%	32	5	15.6%
Humerus	53/58	6	14	9	64.3%	43	14	32.6%
RD Dist	28/35	3	1	0	0.0%	11	1	9.1%
RD Prox	36/30	3	7	1	14.3%	49	5	10.2%
Tibia	87/84	6	4	2	50.0%	29	7	24.1%
Total			28	13	46.4%	164	32	19.5%

Potential: The number of potential refits exceeding 0.845 probability; Verified: Those potential refits that were visually verified; % Accurate: the percentage of Correct divided by Predict.

## Discussion

### *Eden-Farson Site*

The Eden-Farson site represents a unique archaeological assemblage due to its size, preservation, and the primary discard patterns. The site provides a better understanding of the social behaviors and organization associated with prehistoric communal game drives which no longer take place in foraging societies. Frison's (1971) initially hypothesized the houses were coeval, and this bilateral refit analysis of pronghorn elements provides additional support for contemporaneity. The 39 inter-household refits link all of the houses and the initial excavation block with the exception of the small sample from House 10.

The social implications of refits suggest widespread sharing of carcasses at the Eden-Farson site. Despite the large number of pronghorn killed, the presence of carcass sharing is common among the Shoshone and other accounts associated with communal game drives (Arkbush, 1986; Driver, 1990; Egan, 1917; Hultzkrantz, 1961, 1970; Malouf,



1974; Murphy and Murphy, 1960; Russell, 1970; Shimkin, 1947; Steward, 1938, 1943).

In particular, the Gosuite of the Great Basin employed a slow culling process where only a few animals were killed within the trap and shared with all participants (Egan, 1917).

This would continue for days until all the pronghorn were killed and processed. After this, the camp would be abandoned. This pattern of distribution is mirrored at the Eden-Farson site.

There is no evidence of preferential treatment of the carcasses or certain members of the hunt. Comparisons of fore-limb and hind-limb refit distribution show no evidence that either portion were treated differently. The skeletal elements associated with intra and inter-household refits also show insignificant size differences between carcasses kept within the house and those shared with neighbors. Refits indicate that some houses were more active than others, but the more active houses did not receive larger pronghorn. Overall, the refit analysis reflects the egalitarian tradition observed ethnographically.

### *The Multivariate Model*

While the model successfully narrows the number of potential refits for any given skeletal part, its calculated probabilities are poorly suited for determining actual refits when sample sizes are large and the measurements are few. Inaccuracy of the refit probabilities within this study likely resulted from three things: 1) non-normal data distributions, 2) sample size, and 3) measurement error. Non-normal distributions are a common issue in statistics, and while data transformations can approximate normality, it is rarely perfect. As for sample size, the model is capable of finding potential matches, but very large assemblages will lead to more errors. One solution is to increase the

number of measurements used, which will help isolate potential bilateral pairs. Finally, measurement error is an ongoing concern in archaeology (Lyman and VanPool, 2009), and these errors become more compounded in larger faunal assemblages. 3D scanning technology has the potential to increase the number of measurements per element and simultaneously reduce measurement error. Yet, the use of calipers remains the most cost effective means of quantifying the size and morphology of objects.

## Conclusion

The Eden-Farson site represents the largest known pronghorn kill site in North America, but it has been marred by doubts of its status as a single or multiple occupation campsite. The results of this study in combination with the existing dental evidence (Lubinski, 1997, 2013; Nimmo, 1971) provide support for Frison's (1971) initial hypothesis that the accumulation of archaeological material occurred during a single occupation. In terms of behavioral implications, the Shoshone at Eden-Farson appear to have practiced egalitarian reciprocity among the separate house pits despite the large number of pronghorn. The comparative analyses do not support propositions that different households, anatomical portions, or large prey were preferentially treated by the occupants.

The refit analysis also provides the first archaeological application of the multivariate refit approach developed by O'Brien and Storlie (2011). The results of the case study point to two conclusions: 1) the model is successful in identifying potential bilateral pairs regardless of sample sizes and 2) using the probability values without visual verification

leads to unreliable results. This case study suggests that the model is best suited as a means of reducing the number of specimens for visual verification. It will be up to the discretion of the analyst to decide when this method is necessary over other refitting methods, but its flexibility to address bilateral asymmetry and its ability to cope with large sample sizes make it a valuable contribution to anatomical refitting.

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**Chapter 4: Pronghorn – the Other Plains Meat: The Development of a Pronghorn  
Food Utility Index through Experimental Means**

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## Abstract

*Processual archaeology marked a high point in the development of new tools to aid in interpreting the archaeological record. One of these tools was the quantification of meat and marrow from experimentally butchered animals. The mass or caloric values per anatomical unit, called Food Utility Indices (FUI), provided a basis of economic hypotheses of human behavior. In particular, FUI have been used to address factors such as butchery, transport, and social inequality through skeletal remains. This paper presents an experimentally-derived FUI for pronghorn (*Antilocapra americana*) to provide an analytical tool for zooarchaeologists working on the Great Plains to the Great Basin. We collected and butchered three pronghorn between October 2012 and February 2013. The butchered anatomical units were weighed to provide the mass and butchering was timed to yield processing times. The mass was then converted to energy (kcal) and with the addition of the processing times, we provide the energetic return rates (kcal/hr). Based on these results, we are able to rank the economic value of each anatomical unit. We then compared these economic values to three pronghorn communal kill sites. The results of this study indicate a preferential bias toward appendicular elements for marrow processing. This study contributes to the investigation of human subsistence on pronghorn and to the growing literature detailing the importance of this species to North American human prehistory.*

## Introduction

Archaeological research into the role of the North American pronghorn (*Antilocapra americana*) in forager subsistence has received significant attention for over the past two decades (Byers and Hill 2009; Davis et al. 2000; Fenner 2008, 2009; Fisher and Frison 2000; Frison 2000; Hockett and Murphy 2009; Lubinski 1997, 1999, 2000, 2011; Lubinski and O'Brien 2001; Miller and Sanders 2000). Archaeologically, pronghorn have been overshadowed by American Bison (*Bison spp.*) kill sites, but archaeological evidence indicates that human predation of pronghorn dates back to the Paleoindian period (Frison 2004; Hackett and Murphy 2009; Wilmson and Roberts 1978). Although it is unclear whether human demographics, pronghorn hunting intensification, or site formation processes are the cause, game drive sites become common in the Archaic period and escalate in the Late Prehistoric and Proto-Historic periods in southwest Wyoming and the Great Basin (Miller and Sanders 2000; Hackett and Murphy 2009). The escalation of pronghorn hunting intensity is associated with the practice of communal game drives. Given the archaeological significance of this mode of procurement to forager subsistence, archaeological efforts have aimed to isolate the technology, strategy, and organization of communal hunting activities.

One question that persists is how to explain the presence or absence of certain skeletal elements at sites associated with communal game drives. Are the skeletal frequencies a result of post-depositional, behavioral, or post-occupational carnivore scavenging factors? Previous efforts to determine how bone densities and carnivores alter the faunal assemblage have been addressed (Blumenshine and Marean 1993; Lyman 1992; 1994),

but there has been an absence of a formal examination into how behavioral factors might differ from these other taphonomic agents. This paper introduces a pronghorn food utility index (FUI) to predict expected frequencies of pronghorn skeletal elements in archaeological assemblages based on nutritional factors. The FUI will provide baseline predictions of what should be most common skeletal elements in archaeological assemblages, and we then compare these predictions with the taphonomic factor of bone density (Lyman 1992). Next, we examine three archaeological sites associated with communal pronghorn hunting that span the Late Prehistoric to the Historic in western Wyoming and southern Montana.

## Background

Beginning with Binford's (1978) initial efforts to quantify the distribution of nutritional contributions for different portions of sheep and caribou, experimental studies have produced similar FUI for bison (Emerson 1990), caribou (Jones and Metcalfe 1988; Metcalfe and Jones 1988), gazelle (Bar-Oz and Munro 2007), horse (Outram and Rowley-Conwy 1998), toothed whale (Savelle and Friesen 1996), white-tailed deer (Madrigal and Holt 2002), and wild boar (Rowley-Conwy et al. 2002). Through calculations of meat and marrow weights directly associated with bone, these indices have proved valuable for interpreting subsistence behavior in the past.

Food utility indices are used in anthropological research to test whether individual or an aggregated archaeological faunal assemblage reflects optimal foraging behavior. Through experimental butcheries, the weights of meat for each portion of the carcass, or

anatomical unit, are quantified. The weights provide a means of ranking the utility of anatomical units to test whether the behavior of an individual or the bones from an archaeological site adhere to optimal foraging behavior. One specific behavior that interested archaeologists is carcass transport. Simply stated, if the entire carcass is too heavy to return to camp, then what skeletal elements will be butchered (Burger et al. 2005) and which parts are most likely to be taken (Metcalf and Barlowe 1988)? FUI provide a means of predicting what parts of a carcass are worth the butcher's time to remove and transport back to camp based on caloric return. In this study, the average dressed weight of the pronghorn carcasses was 30.5 kg after evisceration. Over short distances, an entire carcass of this weight can be carried by one or two hunters with ease, but the energetic costs rise as distance increases. Therefore, pronghorn killed far from camp are more likely to be field processed to eliminate weight from low utility skeletal elements. The number of pronghorn killed during a hunt is another factor influencing whether the carcass is field processed or returned to camp whole.

Beyond transport decisions, meat sharing commonly adheres to standard divisions of the carcass, which tends to tie the participant's role and the anatomical unit received. Those that play a more crucial role often get higher ranked anatomical units (Alvard 2002; Alvard and Nolin 2002; Bachuchet 1990; Bailey 1991; Kitanashi 1998, 2000). Often it is the successful hunter who receives the prime cuts of meat prior to sharing the rest of the carcass with others. Utility indices provide a means of quantifying differences in carcass portions, which have been used to identify social inequality among archaeological bone assemblages (Bogan 1983; Jackson and Scott 1995; Kelly 1997). Through the



combination of these indices and spatial analysis, the identification of social differentiation becomes possible in archaeological sites with discrete faunal remains associated with separate households.

Beyond the taphonomic factors of bone density and carnivores scavenging, previously defined FUI's overlook the significance of non-nutritional animal byproducts and concerns over inter-species comparisons. While meat is often the primary resource for prehistoric peoples, animals also provide tendons for bindings, bones for tool production, brains for tanning leather, and hides for clothing and shelter. These goods are intrinsic to human material culture and therefore likely influence choices people make when transporting carcass or carcass parts back to camp.

From a methodological standpoint, FUI indices do not account for different strategies in processing carcasses and suffer from issues of replicability. For example, the standard experimental approach to recording processing times ignores the impact of cooking or boiling of the anatomical units prior to defleshing (Stiner personal comm.). While cooking of meat prior to defleshing would likely reduce processing times, it becomes problematic quantifying the time and energy expended to build and maintain the fire. In addition, FUI results often cannot be replicated by other researchers due to a number of variables that often cannot be controlled. Carcass size, season of the kill, weathering and other conditions during the butchery, butcher experience, qualities of the butcher's tools (stone vs. steel knives), and prioritizing quality of cuts over processing time (or vice versa) can vary significantly between one experimental study and the next. The

quantification of utility using a single currency and experimental methods raise concerns over comparisons of nutritional values between species. While these issues are real, we believe that each study provides an accurate estimate of nutritional value for anatomical units within a specific species and that cross-species comparisons can be successfully done along the most basic units.

## Methods

Given the existing FUI's that have been published, this paper aims to produce results allowing for comparative analysis. In particular, this paper relied on Madrigal and Holt's (2002) white-tailed deer investigation to provide a methodology easily replicated. Their deer FUI published the results of two does and one buck obtained in the fall and winter seasons. As with any experimental study, variation in methodology is inevitable and therefore we will be explicit about deviations from their approach. In addition, the processing times address only the time it takes to remove meat from raw portions of the carcass, which omits the impact of cooking the meat on the bone.

Our sample consists of three pronghorn killed between October 2012 and January 2013. All carcasses were field dressed and butchered by the second author. Carcass 1 was a mature male approximately three to four years old that weighed 32.65 kg after evisceration. It was killed southeast of Poudre Center, Colorado, on October 4<sup>th</sup>, 2012 and donated by Joseph Mark Liebert (CID 185818572). The kill shot entered the right flank at the 4<sup>th</sup> rib and punctured both lungs before exiting through the 8<sup>th</sup> rib on the left flank

nicking the ventral side of the thoracic vertebrae. The animal was immediately field dressed and transported to Colorado Springs for butchery the next day.

Carcasses 2 and 3 were two does donated (Permit # 55099) by the New Mexico Department of Game and Fish during a pronghorn herd relocation project (January 11<sup>th</sup> to 15<sup>th</sup>, 2013). In an effort to bolster the population of pronghorn in the Ft. Stanton, New Mexico, area, the NMDGF organized a pronghorn trap east of Cimarron, New Mexico on the UU Bar Ranch. While these operations typically result in 10 percent morality rates (per. comm. with Game Warden Ty Jackson), only two does out of over 150 trapped pronghorn had to be put down during this operation from breaking or dislocating limbs. These injuries occur most often during the process of loading the animals into the transport trailers. Carcass 2 was a 2-3 year old pregnant doe who snapped her right metacarpal diaphysis and Carcass 3 was a 2-3 year old doe who dislocated her right hind limb between the astragalus and tibia. The dressed weights of these specimens were 30.22 kg and 29.95 kg, respectively. These animals were eviscerated adjacent to the trap and transported to Ocate, New Mexico, for butchery.

All animals were hung by their hind limbs and butchered using a steel knife by the second author, who is an experienced hunting guide. After the removal of the hide and evisceration of the carcass, the typical pattern of dismemberment was as follows: removal of the fore limbs, removal of backstraps and tenderloins, removal of hind limbs, and finally separation of the axial skeleton. Muscle tissue was detached whole and associated with the primary skeletal element to which it attaches. All meat removed was

then weighed using two digital scales that provided capacities of 200 g and 75kg with 0.01 g and 10 g accuracy, respectively. Efforts were made to remove all usable meat from the bones, but small pieces of muscle were often still attached to the vertebrae and cranium. In reference to the rib flanks, the meat weights include the intercostal as well as exterior muscle tissue. The reported values reflect the weight of each axial skeletal section as well as the averaged muscle weight for each paired element.

To collect the marrow, long bones were smashed using large hammer stones and a stone anvil to fracture the diaphysis in multiple places. The marrow was then extracted with a metal rod and weighed. Due to damage to the marrow during extraction, undamaged portions of the marrow were selected for calculation of dry marrow weight. Following McCullough and Ullrey (1983), the wet marrow subsamples were weighed and then placed in an oven at 93 degrees Celsius until the mass of the samples remained constant. To approximate the dry marrow weight for each skeletal element, the quotient of the dry divided by wet weights for the subsample was multiplied times the total wet weight. Following Madrigal and Holt (2002) and Bar-Oz and Munro (2007), the mass was then multiplied by 0.93 to account for the non-fat cell proportion of typical bone marrow composition. The final reported value reflects the average of the paired bilateral elements.

Behavioral ecology subsistence models have placed an emphasis on reporting all nutrition in the form of kilocalories, or Calories, and recording the butchery times to calculate a kilocalorie per hour post-encounter return rate. Since the goal is to focus on variation in the amount of meat per animal, times were recorded for each part of the

butchery and averaged for a composite time used for all three specimens. Although there has been no quantification of the kilocaloric return of pronghorn muscle and marrow, Bar-Oz and Munro (2007) argue most tropical and temperate ungulates share similar levels of nutritional returns. The energetic returns for muscle tissue are also supported by a University of Wyoming Department of Agriculture report comparing the nutritional returns of pronghorn, mule deer, elk, bison, and cattle (Medeiros et al. 2002). In that study, pronghorn and deer are nearly similar in the levels of kilocalories, fat, and protein. As such, rates of 6.09 kcal per gram for muscle tissue and 9.37 kcal per gram are used in this paper.

## Results

### The Meat Index

The ranking of skeletal part mass was consistent across all three specimens with the thoracic section providing the most meat and the cranium yielding the least (Table 4.1). Kilocalories for the cranium include the tongue and meat stretching from the maxilla to occipital bone, but do not include the brain. Absent from this analysis are the metapodials and podials where no edible tissue is externally attached. One area of significant difference among the carcasses is the amount of meat associated with the cervical vertebrae—the male has over twice the meat of the females. Since our efforts were to mimic the previous study of Madrigal and Holt (2002), both backstraps were entirely attributed to the thoracic vertebrae. Backstraps run the length of the thoracic and the anterior half of the lumbar vertebrae, which means mass of the thoracic portion is overinflated and the lumbar section underrepresented. Without the backstraps, the

thoracic vertebrae would yield an average of 0.684 kg of meat, placing this portion 6<sup>th</sup> among the other skeletal portions. This reflects the relative significance of the backstrap for pronghorn, which suggests this should always be a primary choice cut.

Table 4.1: Distribution of muscle meat (g) per anatomical unit

Anatomical Unit	Time (sec)	Carcass 1	Carcass 2	Carcass 3	Avg Meat (g)
		Meat (g)	Meat (g)	Meat (g)	
Cranium	1392.5	420	280	310	337
Cervical	430.5	2073	1010	893	1325
Thoracic	627	2951	2680	2941	2857
Lumbar	228.5	523	330	420	424
Innominate	439.5	1070	1030	1082	1061
Ribs	457	676	881	783	780
Scapula	425	631	650	784	688
Humerus	323.5	704	570	386	553
Radiulna	134	281	270	334	295
Femur	342	2317	2850	2534	2567
Tibia	224	541	280	483	435
Totals	5023.5	12187	10831	10950	11323

Although the conversion from mass to energy yielded identical rankings, factoring in processing time led to a significant alteration of the ordering of skeletal sections (Table 4.2; Fig. 4.1). The highest ranked anatomical units are the thorax and femur and the lowest caloric benefits are from the lower limbs and cranium when the brain is excluded. In particular, the long processing time to remove the backstraps and tenderloins causes the kcal/hr to fall below that of the femur. While this change in ranking might suggest the backstraps and tenderloins are difficult to remove, the actual explanation has to do with the meat quality and quantity. It is possible to cut the anterior end of the backstrap and rip it back quickly, dramatically reducing the processing time at the expense of damaging the section of meat. Given the significant nutritional benefit associated with this cut, we

chose to carefully remove the backstrap meat at the 1<sup>st</sup> thoracic vertebra to maximize the yield. The same consideration was given to the tenderloins, also considered the premier cut of most ungulates.

Table 4.2: The Kcal and Kcal/hr return rates for each specimen

An. Unit	Time (sec)	Carcass 1	Carcass 2	Carcass 3	Carcass 1	Carcass 2	Carcass 3	Averages	
		Kcal	Kcal	Kcal	Kcal/Hr	Kcal/Hr	Kcal/Hr	Kcal	Kcal/Hr
Cranium	1393	2558	1705	1888	6613	4408	4881	2050	5301
Cervical	431	12625	6151	5438	105571	51436	45478	8071	67495
Thoracic	627	17972	16321	17911	103186	93710	102836	17401	99911
Lumbar	229	3185	2010	2558	50181	31663	40298	2584	40714
Innominate	440	6516	6273	6589	53376	51380	53974	6459	52910
Ribs	457	4117	5365	4768	32430	42265	37563	4750	37420
Scapula	425	3843	3959	4775	32551	33531	40443	4192	35508
Humerus	324	4287	3471	2351	47711	38630	26160	3370	37500
Radiulna	134	1711	1644	2034	45975	44175	54646	1797	48266
Femur	342	14111	17357	15432	148532	182700	162443	15633	164558
Tibia	224	3295	1705	2941	52950	27405	47274	2647	42543
Totals	5024	74219	65961	66686	679076	601303	615997	68955	632125



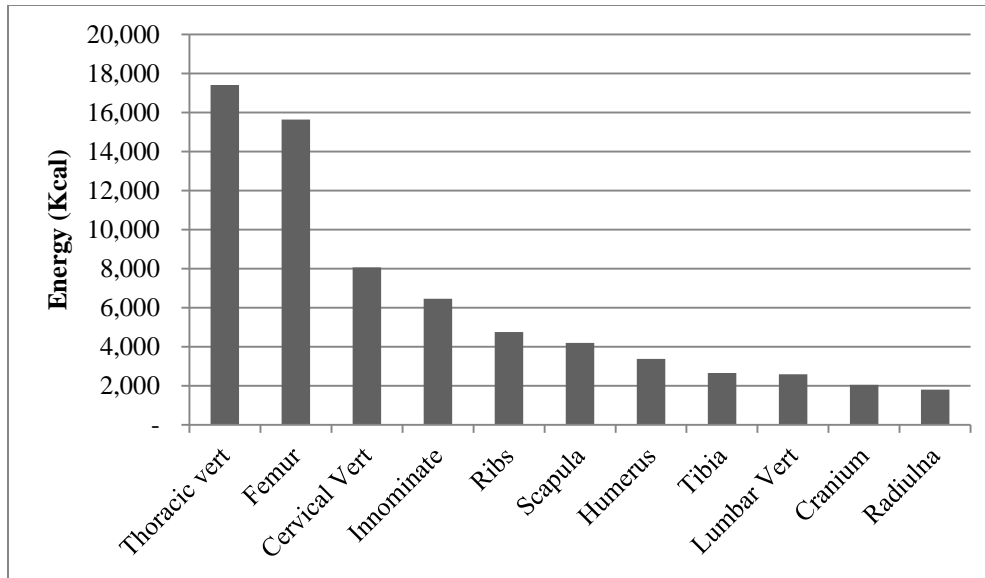


Figure 4.1: The average Kcal meat returns per anatomical unit

The basic pattern from the kcal and kcal/hr ranking indicates that the femur is the most valuable, followed by the axial skeleton. The thoracic and cervical vertebrae both produce significant contributions as well as the innominate and ribs, but the cranial and lumbar portions are lower ranked. Despite the small amount of meat associated with the radius-ulna and tibia, they outrank the scapula and humerus when processing time is factored. This result is significant because these elements often are seen as providing little energetic benefit when processing time is not considered. Regardless of how these portions are quantified, the cranium is consistently the lowest ranked.

### The Marrow Index

The following analysis of the marrow quantities deals with the appendicular long bones of pronghorn. Although the weight of marrow pales in comparison to the muscle, its high fat content makes marrow a valuable contribution to forager diets (Bar-Oz and Munro 2007; Speth and Speilmann 1983). The wet and dry weights are consistent among all

three specimens, but the amount of marrow is higher with the male Carcass 1 (Table 4.3). While this difference might be accounted for by sexual dimorphism, Carcass 1 was the only individual obtained in the fall when marrow content is highest. The variation in marrow quantities is also complicated by the pregnancy of female Carcass 2, which lowered the percentage of marrow fat content in each long bone. Bar-Oz and Munro's (2007) examination of marrow in African gazelles (*Gazella gazella*) shows that there is significant variation in the marrow fat content that is correlated with season of the year. Gazelles had the lowest percentage of marrow fat toward the end of the dry season and peaks during better forage conditions during the wet season. Given our limited sample size of pronghorn, we are unable to isolate whether the sex or seasonality accounts for the difference in marrow content, but it is likely a combination of both these factors.

Table 4.3: Distribution of pronghorn marrow (g) per anatomical unit

An. Unit	Time (sec)	Carcass 1		Carcass 2		Carcass 3	
		Wet (g)	Dry (g)	Wet (g)	Dry (g)	Wet (g)	Dry (g)
Humerus	275	13.4	11.3	11.9	8.2	12.7	10.16
Radius	182	8	7.3	5.7	5	7.4	6.8
Metacarpal	171	4.8	4.3	4.4	3.8	4.2	3.9
Femur	295	20	16.5	19.3	14.2	16.9	13.8
Tibia	331	21.1	18.7	20.2	15.5	18.9	16.2
Metatarsal	181	5.5	4.8	5.7	4.7	5	4.4
Totals	1435	72.8	62.9	67.2	51.4	65.1	55.26

As with other ungulates, meat mass and kilocalorie ranking from most to least for the appendicular long bones is: tibia, femur, humerus, radius, metatarsal, and metacarpal (Table 4.4; Fig. 4.2). The kcal/hr ranking for marrow also follows this pattern with the exception of Carcass 2 that has the greatest marrow yield from the femur. As with the meat index, the hind limb possess much more marrow than their fore limb counterparts.

Table 4.4: The Kcal and Kcal/hr pronghorn return rates for marrow extraction

	Carcass 1	Carcass 2	Carcass 3	Carcass 1	Carcass 2	Carcass 3	Averages	
An. Unit	Kcal	Kcal	Kcal	Kcal/Hr	Kcal/Hr	Kcal/Hr	Kcal	Kcal/Hr
Humerus	105.9	76.8	95.2	1386.1	1005.8	1246.2	92.6	1212.7
Radius	68.4	46.9	63.7	1353.0	926.7	1260.3	59.7	1180.0
Metacarpal	40.3	35.6	36.5	848.2	749.6	769.3	37.5	789.1
Femur	154.6	133.1	129.3	1886.7	1623.7	1578.0	139.0	1696.1
Tibia	175.2	145.2	151.8	1905.7	1579.6	1650.9	157.4	1712.1
Metatarsal	45.0	44.0	41.2	894.6	875.9	820.0	43.4	863.5
Totals	589.4	481.6	517.8	8274.3	6761.3	7324.8	529.6	7453.5

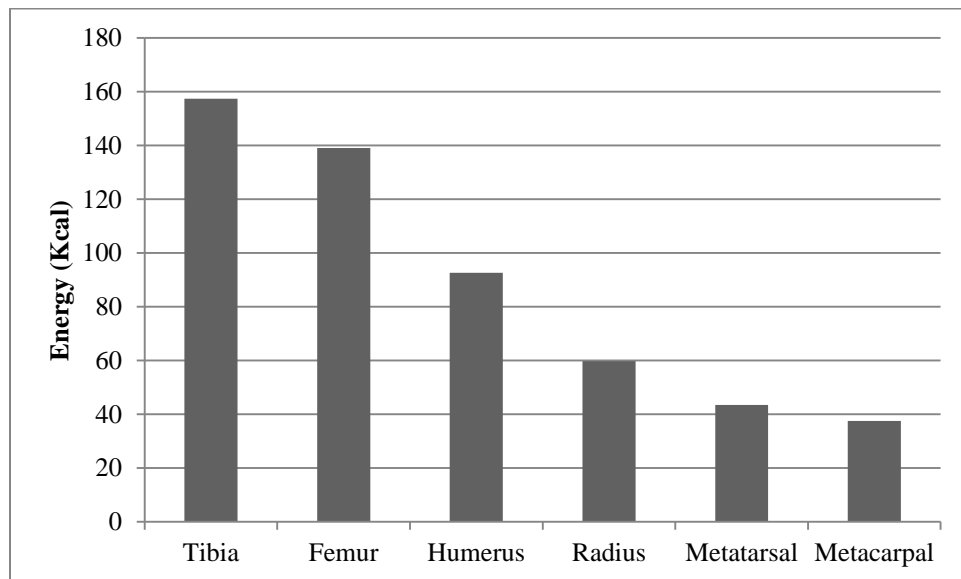


Figure 4.2: The average Kcal returns for marrow per unit.

## Discussion

The pronghorn FUI for meat predicts that hunters will focus butchery efforts on the hind limb and axial skeleton before dealing with the fore limb. When marrow is considered, the experimental results further suggest hunters will prioritize the hind limb over the fore limb. While variation exists among the three carcasses, the small sample size prevents us from determining whether differences in sex, seasonality, or other factors are behind this variation, although seasonality probably plays the biggest role. These results are

important for archaeological studies, but how do they compare to the FUI for other ungulates? In addition, how do the rankings of elements differ from predictions of density-dependent attrition?

A common justification for the generation of additional food utility indices is the distinctive physiology of various species. Yet, Madrigal and Holt (2002:749) argued meat distribution from caribou and white tailed deer is well correlated, and the same can be said of pronghorn and deer. If all ungulates share similar physiology, then there should be no difference between our results and those on deer and caribou (see Jones and Metcalfe 1988). Despite the statistical support for similarities, we believe this obscures true variation in the gross weight of meat. If the weights of all anatomical units are converted to a percentage of the total meat mass and then compared to the average contribution of each anatomical unit across all three species, then distinctions become apparent (Fig. 4.3). For example, caribou have a greater amount of meat on their lower limbs than either deer or pronghorn; deer yield more meat on their cervical vertebrae and ribs; and pronghorn carry more weight on their thoracic vertebrae. This simple comparison provides justification for the continued quantification of additional species regardless of their perceived similarities to existing indices created for similar species.

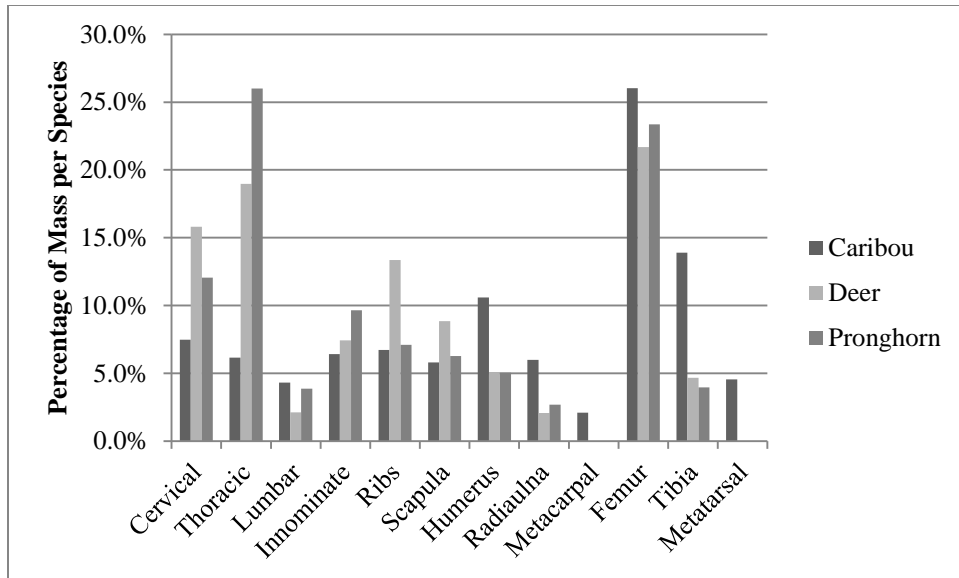


Figure 4.3: The percentage of meat by mass for caribou, white-tailed deer, and pronghorn.

The development of a pronghorn FUI provides predictions in stark contrast to Lyman's (1992) density-dependent attrition hypotheses, which provided archaeologists with two distinct patterns for comparing their faunal assemblages (Fig. 4.4). While it is unlikely any archaeological site will reflect one pattern over the other, sites should fall somewhere within the continuum, possibly reflecting greater influences of taphonomic pressures or processing behavior. If we use the highest density value for each element correlating to those anatomical units used for this analysis, then radioulnae ( $0.57 \text{ g/cm}^3$ ) and metapodials ( $0.57 \text{ g/cm}^3$ ) should be the most common in a heavily weathered assemblage. Also, the femora and vertebrae should be nearly absent from this same environment with the exception of the atlas, which happens to carry the most meat. The distinction is less clear when marrow is concerned. In general, Lyman argues that the appendicular skeleton is more resistant to weathering, which means a site with many long bones relative to axial elements could be the product of either attrition or marrow-seeking behavior. This

overlap in diagnostic signatures can be alleviated by quantification of green versus dry bone breakage and the stage of weathering.

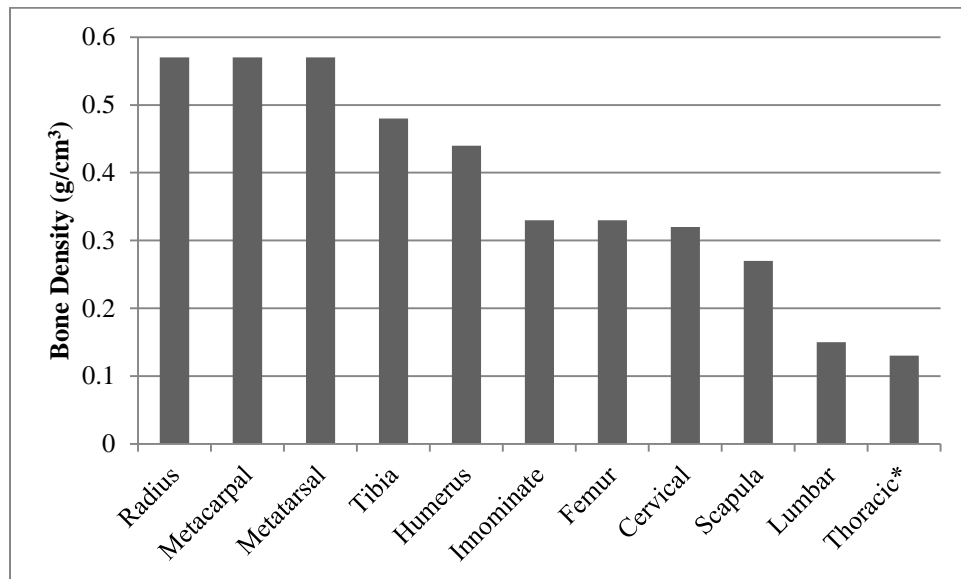


Figure 4.4: Bone Density values for pronghorn (Lyman 1992). \* The thoracic value estimated by the average maximum value of lumbar and cervical vertebrae excluding the atlas and axis

### Archaeological Application

We have introduced the pronghorn FUI as a tool for interpreting the presence of subsistence-related decision-making behavior within archaeological faunal assemblages. Based on our results, we would predict that a forager faced with transport and processing decisions preventing full carcass transport to camp would chose to collect meat from the axial skeleton and the hind limbs. The hunter's preferences would shift toward collection of appendicular anatomical units if fatty marrow is more important. Although this decision-making process was likely prevalent in the past, few known sites have preserved pronghorn assemblages that could test such transport hypotheses. The exception to this is communal game drive events that occurred in western North America. We now discuss three site assemblages associated with communal pronghorn drives to test whether the

differences in the amount of food between anatomical units influenced what was transported to camp. These sites include the Late Prehistoric to Historic sites of Boars Tusk, Eden-Farson and Lost Terrace. Lost Terrace represents the oldest assemblage at 1,200 uncalibrated years BP. Eden-Farson has a single assay of  $230 \pm 100$  uncalibrated years BP and Boars Tusk dates to  $100 \pm 80$  uncalibrated years BP. Each of these sites represents occupations intent on extracting meat and marrow from pronghorn, which is evident in the absence of a single long bone.

The Lost Terrace site lies on the north bank of the Missouri River in central Montana, and has been interpreted to be a winter camp site associated with either a traditional communal game drive with a corral or the ambush of pronghorn crossing the river (Davis et al. 2000). The site was initially excavated in 1975 and resvisited between 1985 and 1986. The site boasts a large assemblage of faunal, lithic, and hearth features primarily located within a large midden. Despite erosion that likely removed nearly 50 percent of the site, a minimum of 83 post-natal and 22 fetal pronghorn were recovered. It is the published data on the 83 post-natal pronghorn killed during the late winter early spring that are used in this discussion.

The Eden-Farson site represents a campsite associated with a communal drive located in the Green River Basin of southwest Wyoming (Frison 1971). The site lies on the leeward side of a north-south trending dune, which provided shelter for the occupants and rapid burial for the preservation of the faunal material. Although no drive trap was identified, the dental evidence points to demographic patterns associated with a catastrophic kill event in the fall. In total, the site has an estimated 154 to 212 pronghorn distributed

among at least ten house pit structures, an excavation block, and the surface (Lubinski 1997; Frison 1971, 2000).

The final site is the Boars Tusk site, also located in the Green River Basin of southwest Wyoming (Fisher and Frison 2000). Its status as a communal kill site is debatable given the small assemblage and the lack of a trap, but a recent isotopic analysis suggests that all the pronghorn were likely from the same herd (Fenner 2009), supporting the interpretation that these animals were killed together in a single hunt. In addition, there are at least an additional eight features that were not excavated, suggesting the archaeological evidence is likely a small sample of the total assemblage. There are at least nine pronghorn distributed among five excavated features (Lubinski 1997).

Using the existing published data and additional data in the possession of the first author, we tallied the MAU for the primary skeletal elements and correlated those values with our FUI anatomical units (Table 4.5). For each element, we used the highest MNE for any portion of a particular element. In each case, the frequencies of archaeological elements are examined in relation to their kcal returns.



Table 4.5: The Minimum Number of Individuals (MNI) for three pronghorn communal kill sites

Site	Boars Tusk	Eden-Farson	Lost Terrace
Estimated Age	100 BP	230 BP	1,200 BP
An. Unit	MNI	MNI	MNI
Cranium	4	174	46
Cervical	4	26	24
Thoracic	3	49	0
Lumbar	3	8	0
Rib	5	5	15
Scapula	2	84	25
Humerus	4	101	27
Radiulna	2	80	45
Femur	6	107	42
Tibia	3	124	45
Metatarsal	2	57	79
Metacarpal	1	48	80
Pelvis	2	19	5

There appears to be little correlation between the Lost Terrace pronghorn assemblage and the meat Kcal,  $F(1, 9) = 2.27$ ,  $R^2 = 20.1\%$ ,  $p = 0.166$ ; the same is true for the marrow Kcal values,  $F(1, 4) = 2.89$ ,  $R^2 = 41.9\%$ ,  $p = 0.165$ . In both analyses, the high counts of metapodials far exceed FUI expectations and more closely fit attritional predictions. The axial skeleton is also poorly represented within the Lost Terrace assemblage, which is further support for bone density-related attrition. While this may be the case, the impact of active erosional forces represents another factor that likely altered the frequency distribution of faunal elements. Unless pronghorn processing occurred identically in all places across the site, the erosional loss of half the site might have removed areas associated with the processing of specific elements. Support for this interpretation comes from the “very good to excellent” preservation of the bone reported by Davis et al. (2000: 61).

The Eden-Farson assemblage provides another case where the archaeological anatomical units do not correlate with Kcal,  $F(1,11) = 0.06$ ,  $R^2 = 0.5\%$ ,  $p = 0.815$ . These regression results are driven by the large quantities of cranial remains and the relatively small number of axial units. The elemental breakdown of the assemblage also does not cleanly support attrition either, given the low numbers of metapodial and radioulna specimens. As with Lost Terrace, the preservation of the faunal assemblage at Eden-Farson is mostly excellent, and although carnivore damage is present, it is not frequent on the faunal remains. Frison (1971) observed an absence of axial remains during the initial excavations and subsequent analysis of House Pits 6 and 9, and suggested that there must have been a processing area where trapped pronghorn were initially butchered. The complete analysis of the remaining proveniences by the first author supports this claim (unpublished data in possession of the first author). Given the difficulty of removing all the meat from the axial skeleton and the large number of pronghorn killed at the site, the occupants may have chosen to pull the backstraps, tenderloins, and appendicular skeleton and abandon the axial material at the processing area. Support for this argument comes from the close correlation of marrow Kcal to limb bone counts,  $F(1, 4) = 38.24$ ,  $R^2 = 90.5\%$ ,  $p = 0.003$ . Even if this argument is accepted, the high counts of cranial remains represented by maxilla fragments suggest non-dietary factors are involved with some of the decisions to transport skeletal material to camp.

At Boars Tusk, there also appears to be a correlation between meat Kcal and bone frequencies,  $F(1, 11) = 3.84$ ,  $R^2 = 25.9\%$ ,  $p = 0.076$ , but it is not significant due to the outlying observation of thoracic vertebrae. The marrow and bone frequencies also appear

correlated, but this too is not statistically significant,  $F(4, 1) = 4.65$ ,  $R^2 = 53.8\%$ ,  $p = 0.097$ . The small assemblage from this site makes interpreting these results speculative at best. While the assemblage MNI of anatomical units is likely a combination of attrition, carnivore damage, and behavior, the distinction between the FUI and Lyman's (1992) bone density data makes it possible to identify what process or factor was more dominant. It is possible that bone-density attrition is the primary factor, but we would expect the radiulna and metapodials to be most prevalent. This is not the case. The Boars Tusk site has more femur and axial anatomical units than the more dense units. On the other hand, the low count of thoracic vertebrae may mirror the pattern observed at Eden-Farson where the occupants preferred to abandon the vertebrae and transport only the backstraps and tenderloins. While this assertion cannot be proven, the removal of the thoracic vertebrae leads to a closer correlation between the FUI and the Boars Tusk assemblage,  $F(1,10) = 9.98$ ,  $R^2 = 50.0\%$ ,  $p = 0.010$ .

One common trend among all three sites is the few axial remains relative to appendicular elements. This pattern is consistent with those reported by Madrigal and Holt (2002) for Late Archaic Eastern Woodland sites utilizing white tailed deer (*Odocoileus virginianus*). Our evidence also supports their argument for incongruities between element frequencies and the respective utility to be impacted by cultural and natural forces. Based on density values for pronghorn osseous material, we should expect to see more limb than body bones. In each case, the bones are in good to excellent condition regardless of element, suggesting that bone density is not directly affecting the representation of pronghorn remains. While undoubtedly weathering has played some role in each site, other factors

are likely involved. In the case of Lost Terrace, erosion has removed half the site, which likely skewed the bone frequencies. Transport decisions at Eden-Farson and possibly Boars Tusk likely inflated the appendicular and depressed the axial elements counts. Regardless, the marrow content in the appendicular elements likely played an influential role in the determining what elements to transport to camp. Extraneous factors like the odor of decomposing carcasses and the unwanted attention these animal remains would attract may have led to a concerted effort to process much of the carcasses away from the residential area. If true, then hunters would chose to transport only marrow and grease-rich bones to camp.

## Conclusions

The development of a pronghorn utility index provides a useful tool for zooarchaeologists dealing with archaeological sites in the western portion of North America. While pronghorn rarely rank at the top of Diet Breadth Models, their presence in the diets of foragers for over 10,000 years suggests they were a valuable food source. Pronghorn were used for their meat and marrow as well as non-food byproducts, and intense butchering occurred regardless of the number killed at communal hunts.

The goal of this study was to produce results similar to those of Madrigal and Holt (2002) and provide comparable datasets. As such, this study provides raw weights of meat and marrow per anatomical unit, and their conversion to kilocalories of these weights and Kcal/hr return rates. We agree with Madrigal and Holt (2002) that processing times and calculated kcal/hr return rates are essential for comparing plant and animal food resources, but we raise concerns about replicating comparable processing times between

different studies. Various factors can alter the processing times between butchers, which can significantly change return rate values and skew comparisons across species. In addition, our approach ignores the impact that other forms of preparation, such as cooking or boiling of meat and bone could have altered the processing times.

This study relies on a sample of three pronghorn to derive utility values, which is on par with previous studies of other species. Nevertheless, this limited sample has left many questions unanswered regarding the variation in individual nutritional returns. Additional samples are necessary to determine whether pronghorn share similar seasonal fluctuations in muscle and fat content for marrow. Also, inclusion of more specimens could examine the impact of sexual dimorphism. Any future analyses of pronghorn FUI should address one or both of these research questions.

While indices such as ours are not without fault, their application to archaeological problems has provided zooarchaeologists the ability to move beyond purely descriptive narratives of the taxonomy toward questions of human behavior. As the briefly introduced archaeological faunal assemblages have shown, the use of these utility models is not an “be all and end all” tool, but part of the larger picture of interpreting site history within the context of multiple lines of evidence. Given the sometimes massive amounts of data archaeologists must sort through to build a narrative, utility models provide a simple means of explaining a portion of the evidence. This allows the researcher to focus on the anomalies or other aspects of the data. It is in this light that food utility indices advance the interests of archaeological research.



**Chapter 5: Social Implications of Bones: Identifying Leadership among the  
Shoshone Protohistoric Site of Eden-Farson**

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## Abstract

In archaeology, we commonly associate social inequality with the institutionalized form seen through material goods and architecture. Yet, ethnographically we know social inequality permeates all forms of society including egalitarian groups. This paper presents an archaeological analysis of the Protohistoric Shoshone campsite of Eden-Farson (48SW304) in southwest Wyoming associated with a successful communal pronghorn game drive. Using the faunal remains and their spatial association with discrete house structures, I examine the existence of social inequality among an otherwise egalitarian society. Through the comparative analysis of the skeletal anatomical units present, it is possible to identify the uneven distribution of hunt proceeds among houses. Furthermore, the use of anatomical refits allows for examination of food distribution patterns. The results of this study not only indicate social inequality, but also evidence for the existence of leadership. These findings point to a greater understanding of the social organization of communal hunting among the Shoshone, and its broader application to similar subsistence practices elsewhere.



## Introduction

Communal hunting is a specialized form of subsistence that takes advantage of temporary aggregations of prey through the cooperation of multiple independent families or communities. These hunting parties take advantage of the large group size to build or use technology that maximizes the total number of animals captured. Communal hunting is ubiquitous in forager prehistory and dates to the North American Paleoindian period. Success hinges on the implementation of various technologies that take advantage of heterogeneous clumps of food resources such as game drives, nets, fishing weirs, and fishing/whaling boats. This study focuses on the use of game drives; the strategy of driving large numbers of prey through v-shaped drive lines and toward arroyos, cliffs, corrals, hunting blinds, or sand dunes.

Communal hunting is almost universal among human foragers, and has sometimes been regarded as the principal selective factor behind the evolution of human sociality (Boyd and Richerson 1985). Also nearly as universal among foraging societies is the existence of inequality in the distribution of hunted resources (Bliege Bird and Bird 1997; Hawkes and Bliege Bird 2002; Gurven et al. 2001; Hill et al. 1993; Kaplan et al. 2000; Kelly 1995; Sahlins 1972; Service 1966; Smith et al. 2010; Winterhalder 1997). Inequality is often tempered with the redistribution of resources in foraging societies (Winterhalder 1997). The most common method is reciprocity, which occurs when an individual is willing to donate resources to another under the implicit agreement that when the roles are reversed the individual will repay the debt. This mechanism of redistribution is often cited as a means to alleviate shortfalls in the food supply (Winterhalder 1997). Tolerated

theft—the taking of someone’s resources without prior permission—is another form of redistribution often associated with subsistence shortfalls by one or more members of a group. This transaction is considered tolerated since the resource is worth more to the thief than the owner, which often leads to the owner relinquishing control of the resource to avoid conflict.

At the most basic level, the spatial distribution of food among families can be seen as social inequality. In essence, meat can be assumed to represent a currency to measure status among foraging groups. In the case of the Shoshone, the successful hunter is given the animal hide and a cut of meat of his choosing prior to sharing with the group (Steward 1938). Among African foraging groups, the most highly ranked portions of the carcass are the hindlimbs, the vertebral column, and the head, and these highly ranked anatomical units often go to the hunter or owner of the weapon (Bahuchet 1990; Bailey 1990; Kitanashi 1998, 2000; Marshall 1994).

The top choices of the hindlimb and vertebral column correlate closely with the rankings of anatomical units by caloric returns (Binford 1978; Emerson 1990; Jones and Metcalfe 1988; Madrigal and Holt 2002; Metcalfe and Jones 1988; O’Brien and Liebert Chapter 4). Undoubtedly, social, ideological, and non-nutritional factors influence the rankings of carcass portions, but these appear to be secondary in the limited ethnographic record of meat distribution. If we assume that the quantity of meat per anatomical unit dictates what is most sought after, then we can then apply these predictions to the archaeological record by associating skeletal remains to cuts of meat, or anatomical units.

To assume that meat can serve as a social currency assumes that different prey and different portions of particular prey have different prestige. This premise has not been tested in the case of forager archaeology, but zooarchaeological studies by Bogan (1983) and Jackson and Scott (1995) found that the distribution of meat is well correlated with social status among Mississippian chiefdoms. Bogan (1983) showed that elite residences possessed more highly ranked prey choices than the villager sites, and Jackson and Scott (1995) used the skeletal frequencies linked to portions of deer meat to identify social distinctions between elite and non-elite residences. While there are significant differences in the organization of sedentary food producers and foragers, the key point is that some carcass parts are ranked more highly than others and these highly ranked anatomical units are correlated with high status residences. This suggests that meat distribution is a plausible means of gauging social rank in the absence of material markers in egalitarian societies.

While individual hunting relies on individual skill to determine who kills prey, communal hunting hinges on the cooperation and organization of large numbers of people. Those with leadership roles during these game drives are likely to be rewarded for their efforts. Among egalitarian groups, these leaders are likely elected by the members of hunt and not through despotic means (see Vehrencamp 1983). In this paper, I refer to leaders as one (or more) individuals who serve a central role in the execution of the communal hunt. Leaders increase the efficiency of game drives and increase the return rates for all participants. These leaders likely receive payment for their efforts in the form of social

currencies, but it is also possible payment may be more tangible (see Alvard 2002; Alvard and Nolin 2002; Nolin 2010; Sosis 1997).

My primary interest is to use an archaeological example to test whether social inequality during communal hunts can be identified among an egalitarian group. I use the case study of the Protohistoric site of Eden-Farson (AD 1350 to AD 1750), located on the High Plains of southwestern Wyoming, because of its affiliation with the Shoshone—a traditional hunter-gatherer egalitarian culture. The excellent preservation of the faunal skeletal material and clear association of these remains with eleven house structures allows for the analysis of food resources obtained from a successful pronghorn game drive. I aim to quantify the distribution of food resources through the faunal remains and examine spatial patterns of this material between houses.

### **The Shoshone**

Since the initial studies by Julian Steward (1938), the Shoshone have long been viewed as an archetype for egalitarianism. The composition of Great Basin Shoshone groups is centered on the nuclear family that often includes unmarried extended family members. The actual number of families that constitute a village varies depending on the carrying capacity of the local environment. Among the Shoshone-Bannock of Idaho, the group size ranged from 8-15 members (Heaton 2005: 22). The group size of the Tukuddika Shoshone, who lived in the mountains of northeast Utah, typically had three to four family bands (Hultzkrantz 1974:202). Among the Shoshone in the Yellowstone region,

Russell (1970:26) observed Shoshone group sizes of 21 to 23 individuals, which included multiple nuclear families.

Beyond group size estimates, the Shoshone social structure remained diffuse and atomistic; prior to the horse there was no centralized power structure (Murphy and Murphy 1960: 333). Each band was represented by a senior active male and these leaders served as representatives of the group and inherited the social and political responsibilities associated with this title (Steward 1938). What leaders lacked were social means of control to maintain economic privilege and power. This was due to the established practice of widespread sharing among members of a camp and the fluid group membership that made aggrandizement by individuals unsustainable. When leaders attempted to circumscribe power or neglect the wants of the group, members would defect.

On a seasonal basis, leadership became more visible and structured among the many Northern Shoshone groups that aggregated to pursue salmon along the major rivers of northwest Wyoming and central and southern Idaho (Hultzkrantz 1961; Shimkin 1947). These leaders helped organize fishing activities, but their power diminished when these large groups disbanded. In Wyoming, Hultzkrantz's (1961) interviews of Wind River Shoshone elders also indicate that leadership tasks were common in the aggregated winter camps. While he did not elaborate on the need for leadership, Hultzkrantz implied a leader was needed to organize the large population. Accounts of leadership do exist among the Fort Hall Shoshone of Idaho and the Great Basin Shoshone of Grouse Creek

and Promotory Point (Steward 1943). Detailed accounts of communal hunting among the Goshute of the Great Basin describe how male representatives for families would seek out a local shaman to lead their proposed game drive (Arkbush 1986; Egan 1917; Malouf 1974). Absent from the ethnographies is discussion of the social organization of Eastern Shoshone game drives.

### *Theories of Leadership*

Although there are no descriptions of Eastern Shoshone game drive social organization, theoretical arguments provide an alternative means of hypothesizing how large communal tasks are structured. Given that individuals in egalitarian societies maintain the power to exercise autonomy when conditions are no longer beneficial, the rise of leadership must rest on the motives of the followers. Cooperative models of leadership suggest that in the absence of leadership, all members of the group share the responsibility of monitoring group participation and sanctioning free-riders (Hooper et al. 2010; Smith and Choi 2007). If each member is responsible for monitoring all other members, then these costs rise with each additional individual added to the group. Eventually these costs will negate a member's energetic returns unless group size is restricted. An elected leader assumes the responsibilities of restricting group access, monitoring members, and sanctioning free-riders on behalf of the group for a fee, or tribute. Since the followers in the group reserve the right to defect, then the size of the tribute must satisfy both the leader and the group members. In essence, the tribute represents a mutually beneficial contract.

Participants may also elect a leader if one individual possesses greater knowledge and experience in the operation of communal hunts (Boone personal comm.). These individuals will tend to be a senior member of the group who played a central role in previous the past. Under this “soft” leadership scenario, the leader helps to manage the timing and location of a potential hunt, design and building of game drives, and the labor organization of the hunt. These services rendered lead to greater forager efficiencies by providing higher returns and lower costs. Given their unique status among the group, these leaders can demand a payment for their services.

The theoretical models for cooperative leadership are useful for justifying the utility of leadership, but how and in what currency these payments are received can only be addressed by the ethnographic record. Like the social organization of Eastern Shoshone game drives, descriptions of payments to Shoshone leaders are unavailable or do not exist. Accounts of payments are even scarce among other non-Shoshone groups practicing pronghorn communal drives. Among the Utes, once the animals were contained in the corral, the males would enter with clubs and kill the animals. After the animals were killed, the leader received donated meat and/or pronghorn from other hunters if he had not killed many prey (Smith 1974). After a successful hunt, hunt leaders among the Cheyenne received all the tongues of the prey and the choice of two pronghorn carcasses (Hoebel 1960). This same pattern also occurred among the Navajo (Hill 1938: 155). While these represent tribute to the hunt leader, only the Cheyenne and Navajo cases suggest there might be archaeologically visible evidence of leadership based on the faunal materials.

### **The Eden-Farson Site**

Eden-Farson lies on the leeward side of a 10 m-high stabilized dune east of the Big Sandy River in southwestern Wyoming. Discovered in 1967, the bulk of the excavations occurred in 1969, but the site was later revisited in 1970 (Fig. 5.1). Eden-Farson is a Proto-historic campsite associated with a successful pronghorn game drive. Although the remnants of the game drive, Frison (1971) has argued that the sage brush structure has long since deteriorated, but it is also possible that the trap utilized the many active dunes within the local area. He has also argued that the campsite and trap were accompanied by game processing area, but attempts to relocate processing site have also been unsuccessful. Eden-Farson is affiliated with the Shoshone based on presence of flat-bottomed ceramic vessels (Mulloy 1955) and the historic range of Shoshone occupation in the region. Later, Frison (1991) classified several bifaces as Shoshone Knives that further strengthened Eden-Farson's association with Shoshonean culture.



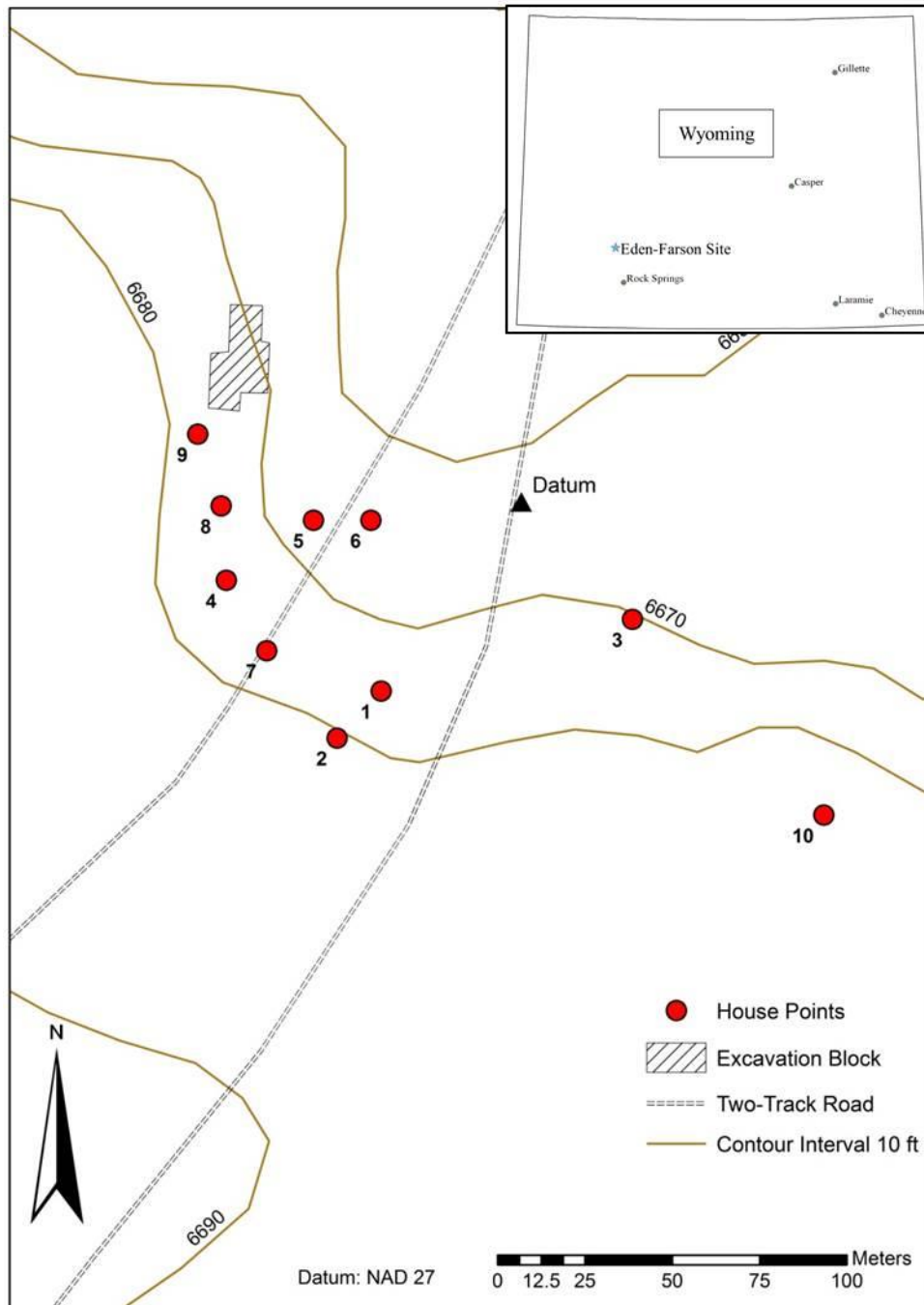


Figure 5.1: Site map indicating spatial distribution of households at Eden Farson site, in southwest Wyoming (O'Brien *in review*)

An ongoing debate over whether the site represents single or multiple occupations has persisted since its initial publication. Whether the cultural material was associated with a

single stratigraphic horizon was obscured by extensive bioturbation. Despite this, Frison (1971) felt that Eden-Farson was a single occupation based on Nimmo's (1971) interpretation of tooth eruption sequences, the lack of overlying cultural deposits, and the distribution and similarity of cultural materials within the house structures. After recognizing that the clusters of post holes represented temporary structures, field crews dug each dwelling as a single excavation unit (Larson et al. 1969; Frison 1971). The 10 excavated structures, referred to as houses following Frison's interpretation, vary from oval, 4.5 m by 6 m, to nearly circular with a diameter of 3.6 m. Each of the excavated areas has a similar distribution of bone, stone, and fire-cracked rock from primary, or de facto, deposition. Despite some concerns regarding contemporaneity of the households raised by Fenner (2009), Frison's initial interpretation of a single occupation is supported by 38 inter-household refits of pronghorn elements, linking 10 of the 11 excavated structures (O'Brien Chapter 3). When this is combined with Lubinski's (1997; 2013) demographic profiles based on dental eruption sequences, it becomes clear Eden-Farson represents a single occupation associated with a single mass kill event.

One remaining point of contention is the interpretation of the initial excavation block as either a refuse pit or an additional house. From a spatial perspective, O'Connell (1987) observed that in long-term occupations, foragers typically place refuse pits far from the area of habitation to avoid the smells, debris, and carnivore intrusion into their workspace. The excavation block is within 40 m of Houses 8 and 9. This places it in closer proximity to those houses than that of the other houses. The initial excavation of the block also mentions the presence of hearths and distributions of non-faunal artifacts

mirroring those found in house units. Larson et al. (1969) also note postholes were initially thought to be rodent holes, and this initial interpretation was not corrected until they were investigated during the excavation of House 1. Therefore, the existing evidence favors an interpretation of the block as an additional house unit, and for the purposes of this analysis, it is treated as such.

### *Archaeological Evidence of Social Inequality*

To address social inequality at Eden-Farson, I argue the requisite initial capital investment and the organization requirements of communal hunting leads to unequal distribution of hunt proceeds. In essence, those hunters playing a more central role in the hunt will be rewarded with better cuts of meat. Theoretical predictions suggest that those in charge of game drives would restrict group size, manage the construction of the drive lines and corral, and direct the participants during the drive. In the one detailed account of game drive execution, Egan (1917) described how a regional shaman served this role among the Goshute. Steward's (1943) informants indicated that five of seven Shoshone-Bannock groups in the Great Basin and Southern Idaho also shared this social organization of communal hunts. Regardless of who led these historic game drives, there is ample evidence to suggest leadership was present.

Mapping the provenience of skeletal materials associated with the residence of an individual and their family would reveal patterns of hunt proceeds distribution. In the case of Jackson and Scott (1995), the location of the elites was easily demarcated by the

architecture and prestige goods, but those attributes are absent in egalitarian societies. In addition, comparing contemporaneous households requires controlling for differences in family size and the length of occupation. Ethnographically, extra food is given to those families with more mouths to feed (Bleige Bird and Bird 1997; Winterhalder 1997), and those residing at camp longer are likely to consume more meat. Yet, the redistribution of additional meat does not imply these large or long-residing families should get the better cuts of meat. Therefore, I would argue that a leader's residence should exhibit a pattern of average greater energetic returns per anatomical unit. Archaeologically speaking, these skeletal elements associated with particular anatomical units should be highly correlated with the residence of a leader. When the faunal assemblages are tallied across houses, the leader's house should yield the highest kcal per anatomical unit (kcal/au).

In order to identify social inequality among coeval houses at Eden-Farson, only meat and marrow-bearing bones were examined. In addition, some skeletal elements were combined to fit with the FUI (food utility indices) anatomical units established by O'Brien and Liebert (Chapter 4) of skull, cervical vertebrae, thoracic vertebrae, lumbar vertebrae, innominate, scapula, humerus, radioulna, metacarpal, femur, tibia, and metatarsal. Although rib fragments are numerous, most were too highly fractured to accurately tally the number of rib flanks present in each house. Therefore, ribs were removed from the analysis. MNEs (minimum number of elements) for axial remains were based on the count of identical whole or fragmented specimens of the same numbered vertebrae. For appendicular units per household, the MNE represents the highest count from either the proximal or distal portion for each side. With only 14 proximal and distal

femurs, the MNE was based on presence of the linea aspera ridge on the caudal surface of the diaphysis.

Skeletal element counts (Table 5.1) show a clear disparity in representation across the excavation units. House 6 (18.8%), House 2 (16.4%), and House 5 (11.5%) have the highest percentage of elements tallied for the site, while House 3 (5.5%), House 7 (3.2%), and House 10 (2.9%) have the fewest units. When the MNEs from Eden-Farson are converted to kilocalories using the appropriate anatomical unit, a greater degree of disparity between the proveniences is seen (Table 5.2). From an energy standpoint, the top yields were House 6 (1,110,701 Kcal), House 9 (692,703 Kcal), the excavation block (653,156 Kcal), House 2 (621,585 Kcal), and House 5 (600,253 Kcal). A Kruskal-Wallis non-parametric test indicates the differences in the kilocalories per anatomical unit for each house is significant ( $H = 26.3$ ,  $df = 10$ ,  $p = 0.004$ ). When the houses are compared using Kcal/au, House 6 falls into the middle and House 9 ranks first (Fig. 5.2). This pattern indicates that the residents of House 9 received better cuts of meat than those of House 6, but the reason for the high ranking of House 9 is subtle. House 9 does not have the highest frequencies of femurs or thoracic vertebrae, but it does rank in upper third of all highly ranked sections. Perhaps more importantly, House 9 has very few metapodials relative to all anatomical units, suggesting that its residents did not need the lowest ranked skeletal elements for subsistence. Interestingly, the top three houses (Houses 8, 9, and the excavation block) are all located in close proximity to one another in the northwestern portion of the site. While the distribution of kcal/au appears to be fairly even among all the houses, the returns for Houses 2, 7, and 10 are notably smaller.

Table 5.1: Distribution of FUI Anatomical Units based on minimum number of elements (MNE)

Portion	House MNE's										EB	Totals
	1	2	3	4	5	6	7	8	9	10		
Skull	7	34	4	7	11	35	1	7	20	7	18	151
Cervical	0	3	1	1	0	8	0	3	7	2	3	28
Thoracic	0	2	0	0	0	4	0	3	2	1	1	13
Lumbar	6	0	0	0	0	2	2	0	3	0	0	13
Innom.	1	2	1	1	3	3	1	2	3	2	1	20
Scapula	7	17	14	5	6	13	0	14	8	3	13	100
Humerus	11	33	10	14	37	23	4	6	19	3	9	169
Radioulna	9	15	11	12	5	20	6	4	14	4	14	114
Metacarpal	8	12	2	6	4	18	8	4	4	3	5	74
Femur	17	9	6	11	19	35	5	10	23	3	25	163
Tibia	13	44	14	18	34	37	5	10	16	4	22	217
Metatarsal	8	18	1	6	14	19	5	7	4	2	8	92
Total	87	189	64	81	133	217	37	70	123	34	119	1154

EB: Excavation Block

Table 5.2: The caloric (kcal) returns for each household using estimated values from O'Brien and Liebert (Chp. 4)

Portion	Caloric (kcal) Returns per provenance										EB	Totals
	1	2	3	4	5	6	7	8	9	10		
Skull	14,350	69,700	8,200	14,350	22,550	71,750	2,050	14,350	41,000	14,350	36,900	309,550
Cervical	-	24,213	8,071	8,071	-	64,568	-	24,213	56,497	16,142	24,213	225,988
Thoracic	-	34,802	-	-	-	69,604	-	52,203	34,802	17,401	17,401	226,213
Lumbar	15,504	-	-	-	-	31,008	5,168	-	7,752	-	-	59,432
Innom.	6,459	12,918	6,459	6,459	19,377	19,377	6,459	12,918	19,377	12,918	6,459	129,180
Scapula	29,344	71,264	58,688	20,960	25,152	54,496	-	58,688	33,536	12,576	54,496	419,200
Humerus	38,093	114,279	34,630	48,482	128,131	79,649	13,852	20,778	65,797	10,389	31,167	585,247
Radioulna	16,713	27,855	20,427	22,284	9,285	37,140	11,142	7,428	25,998	7,428	25,998	211,698
Metacarpal	304	456	76	228	152	684	304	152	152	114	190	2,812
Femur	268,124	141,948	94,632	173,492	299,668	552,020	78,860	157,720	362,756	47,316	394,300	2,570,836
Tibia	36,452	123,376	39,256	50,472	95,336	103,748	14,020	28,040	44,864	11,216	61,688	608,468
Metatarsal	344	774	43	258	602	817	215	301	172	86	344	3,956
Total	425,687	621,585	270,482	345,056	600,253	1,084,861	132,070	376,791	692,703	149,936	653,156	5,352,580
Average	4,893	3,289	4,226	4,260	4,513	4,880	3,569	5,383	5,632	4,410	5,489	4,595

EB: Excavation Block

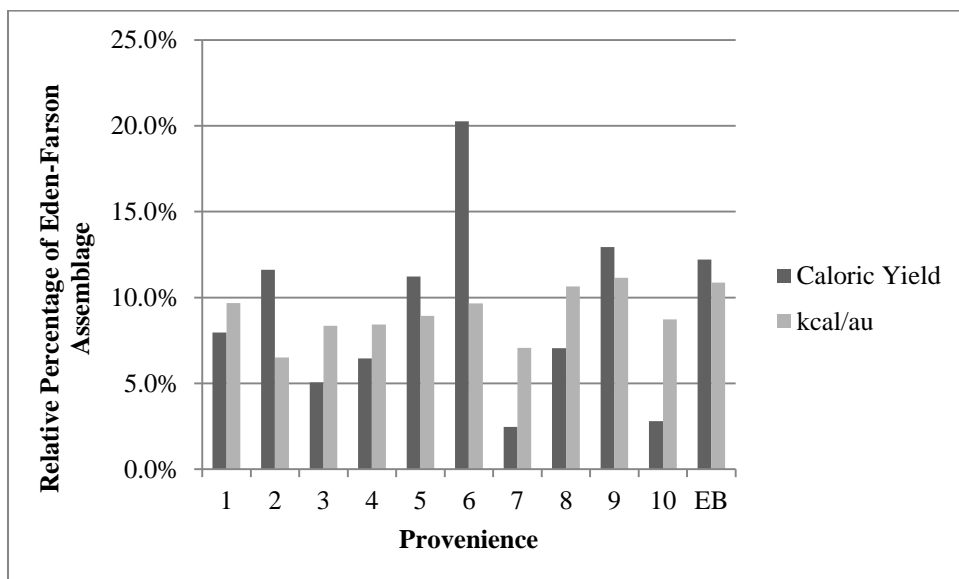


Figure 5.2: The distribution of Caloric yields and kcal/au for all proveniences (EB: Excavation Block).

Because processing times can influence the ranking of anatomical units, I used O'Brien and Liebert's (Chapter 4) energetic return rates (kcal/hr) for pronghorn meat and marrow (where applicable) for each anatomical unit. There are minor changes in the rankings caused by the shorter processing time associated with the femur relative to the thoracic vertebrae, but the top ranked provenience is the excavation block, followed by House 9 (Table 5.3). In addition, the ranking of kcal/hr per anatomical unit moves House 1 ahead of House 8 for the third highest ranking. These differences in the return rates per house are significant ( $H = 20.83$ ,  $df = 10$ ,  $p = 0.025$ ), but the overall skew of hunt proceeds still favors the northwestern portion of the site.



Table 5.3: The caloric (kcal/hr) return rates for each household using estimated values from O'Brien and Liebert (Chp. 4)

Portion	Energetic Return Rate (kcal/hr) per provenance										EB	Total
	1	2	3	4	5	6	7	8	9	10		
Skull	37,107	180,234	21,204	37,107	58,311	185,535	5,301	37,107	106,020	37,107	95,418	800,451
Cervical	-	202,485	67,495	67,495	-	539,960	-	202,485	472,465	134,990	202,485	1,889,860
Thoracic	-	199,822	-	-	-	399,644	-	299,733	199,822	99,911	99,911	1,298,843
Lumbar	244,284	-	-	-	-	81,428	81,428	-	122,142	-	-	529,282
Innominate	52,910	105,820	52,910	52,910	158,730	158,730	52,910	105,820	158,730	105,820	52,910	1,058,200
Scapula	248,556	603,636	497,112	177,540	213,048	461,604	-	497,112	284,064	106,524	461,604	3,550,800
Humerus	425,832	1,277,496	387,120	541,968	1,432,344	890,376	154,848	232,272	735,528	116,136	348,408	6,542,328
Radialulna	445,014	741,690	543,906	593,352	247,230	988,920	296,676	197,784	692,244	197,784	692,244	5,636,844
Metacarpal	6,312	9,468	1,578	4,734	3,156	14,202	6,312	3,156	3,156	2,367	3,945	58,386
Femur	2,826,318	1,496,286	997,524	1,828,794	3,158,826	5,818,890	831,270	1,662,540	3,823,842	498,762	4,156,350	27,099,402
Tibia	575,315	1,947,220	619,570	796,590	1,504,670	1,637,435	221,275	442,550	708,080	177,020	973,610	9,603,335
Metatarsal	6,904	15,534	863	5,178	12,082	16,397	4,315	6,041	3,452	1,726	6,904	79,396
Total	4,868,552	6,779,691	3,189,282	4,105,668	6,788,397	11,193,121	1,654,335	3,686,600	7,309,545	1,478,147	7,093,789	58,147,127
Average	55,960	35,871	49,833	50,687	51,041	51,581	44,712	52,666	59,427	43,475	59,612	50,442

EB: Excavation Block

### *Finding the Leader at Eden-Farson*

The division of meat at Eden-Farson shows statistical evidence of unequal food distribution, and furthermore, higher quality cuts of meat are concentrated in the northwest corner of the site. In terms of social organization, it is likely these families held important roles in the success of the game drive. There is a marginal difference in the proceeds attributed to the excavation block and House 9, which requires looking at other data that may distinguish the residential location of leadership. I turn to the size of the skeletal material and O'Brien's (Chapter 3) 38 inter-household anatomical linkages. Conceptually, leaders may receive the largest pronghorn, as seen among the Cheyenne (Hoebel 1960), which should translate into larger skeletal remains. In addition, models of cooperative leadership suggest that member houses would be required to pay the leader for their services.

### *Carcass Size*

One means of paying a leader is to offer him the first choice of carcasses from the successful hunt. Under such conditions, the leader would likely select the largest prey for himself, which can be tested by using a single bone measurement as a proxy for the size of the carcass. The largest sample of measured elements with proveniences is the tibia, and so I used the breadth of the distal epiphysis. The test sample consisted of 192 tibiae (excluding a single outlier from House 2) and reveal significant differences in the widths [ $F(10,181) = 2.06, p = 0.029$ ], but these results are misleading due to the small samples

from Houses 7 (N=4) and 8 (N=3). When these are removed, the comparison of tibiae size shows no significant differences [ $F(8,176) = 1.51, p = 0.157$ ]. This would suggest that the distribution of carcasses between houses was not determined by the size of the animal, and in the event of significant sexual dimorphism that no house received more males than its neighbors. This observation fits with Egan's (1917) account of Gosiute division of proceeds from communal hunts, where animals were butchered and shared among all hunt participants.

### *Anatomical Refits as Tribute*

Moving on to the refit data, ethnographic and historic accounts suggest that meat sharing is a common phenomenon among foraging societies. This practice establishes and maintains social ties, while also minimizing the risk of nutritional shortfalls. While food sharing is ubiquitous among hunter-gatherers, foragers tend to cooperate more often with closer kin. The examination of nomadic group camp structure suggests the spacing of houses is reflective of this relationship between kinship and cooperation (Gargett and Hayden 1990; Gould 1968; O'Brien and Surovell *in review*; Whitelaw 1983, 1991; Yellen 1977). From an archaeological perspective, this leads to the prediction that there should be more anatomical refits between neighboring houses than more distant ones.

On the other hand, if leadership existed at Eden-Farson, then the leader's house should exhibit patterns exceeding the expectations of kin-based meat sharing. Two interdependent methods of identifying leadership through meat sharing are the number

and distance of refits. The theoretical and ethnographic evidence suggest that the leader receives a payment from the proceeds for their role in the hunt. If the payment is meat, then the refits between houses should reflect these payments. First, payments should exist among all members of the camp, and therefore the leader's house should be associated with the greatest number of refits. Secondly, food sharing with leaders should occur regardless of the distance between houses if it represents payment for their services. The net difference (actual distance – average neighbor distance) in refit distance should identify particular households sharing with other houses regardless of proximity. The occurrence of this relationship would suggest that interaction is the result of non-kin factors.

To obtain the distances between houses, I relied on the open source software of Quantum GIS (QGIS), which has similar functionality to the standard use of ArcGIS. Since I and others have failed to relocate all the separate archaeological units and Frison's excavation datum, I used the original site overview map produced by Frison (1971), and georeferenced the features present on both maps. The current topographic maps were provided by the University of Wyoming Geographic Information Science Center. While there is likely error in the real provenance of the archaeological units, this approach maintains the spatial relationship between households, provides an accurate scale of distance, and allows for the utilization of the QGIS spatial analysis tools. To examine refits that exceed linkages likely associated with kin food sharing, I calculated the average distance to the three closest houses for each provenience. This value could then be subtracted from the average distance of all refit links to gauge whether food sharing

fits or exceeds the expected cooperation between kin. If food sharing follows the standard pattern of sharing with close kin, then the net difference between average refit distance and closest neighbors should approach zero.

For each house, two tallies were compiled to reflect the number of units with which a particular house interacted and how many of those linkages fell outside the closest neighbor range. Table 5.4 shows the general pattern of widespread meat sharing between all the households with the exception of House 10. For the raw count of interactions, House 2 has links to eight of the nine units followed by Houses 6 and 9 which both have seven linkages (Fig. 5.3). House 2 does not have a connection to House 7, House 6 is not linked to Houses 5 and 9, and House 9 is not linked to Houses 6 and 7. When links with the nearest neighbor are excluded, the top household is House 6 with seven linkages. In this case, House 2 and 9 fall to six linkages. While highly ranked in terms of kilocalories, House 8 has links to four other units and the excavation block has five refits.

Table 5.4: A) The counts of bilateral refits matrix between proveniences, and B) the distance (m) between proveniences (EB: Excavation Block)

House	1	2	3	4	5	6	7	8	9	10	EB
1	0	2	0	0	0	2	0	0	2	0	0
2		7	1	1	2	3	0	1	2	0	2
3			0	0	1	1	0	0	2	0	0
4				0	0	2	0	0	1	0	2
5					5	0	0	1	2	0	1
6						8	1	2	0	0	1
7							0	0	0	0	0
8								0	1	0	0
9									2	0	1
10										1	0
EB	A)										1

House	1	2	3	4	5	6	7	8	9	10	EB
1		19	80	60	53	49	37	75	94	146	98
2			97	57	61	60	32	77	97	157	105
3				130	104	89	114	135	147	85	138
4					33	48	26	22	93	204	57
5						17	39	31	44	185	45
6							47	47	59	170	54
7								46	66	183	77
8									21	214	36
9										229	22
10											223
EB	B)										

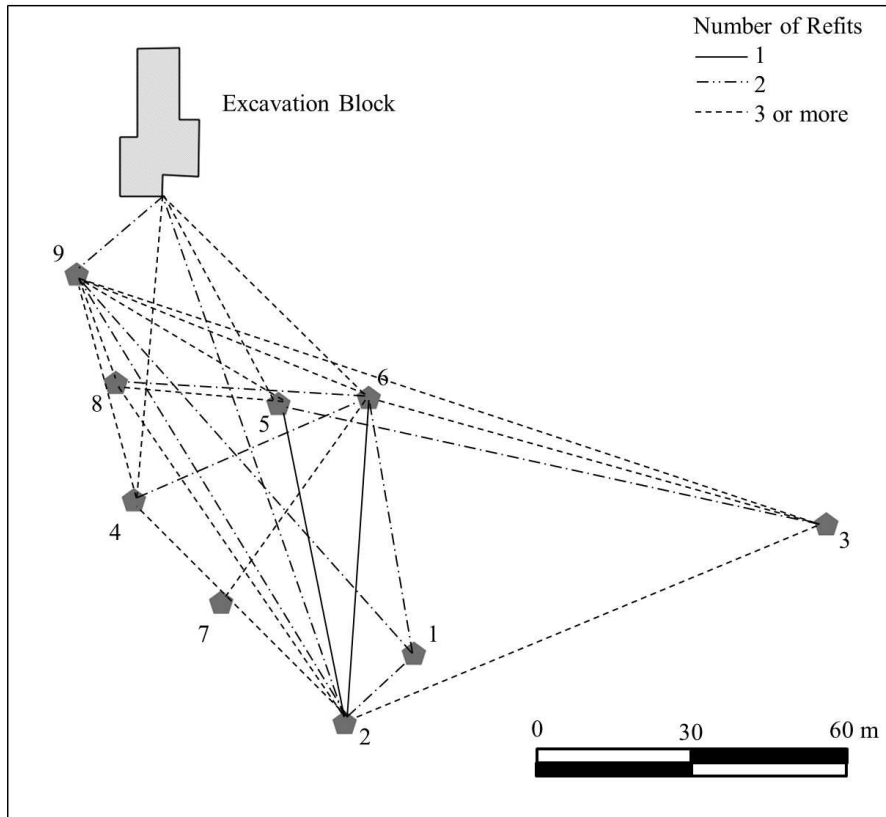


Figure 5.3: Map of refits between houses and the excavation block excluding House 10 (Reproduced from O'Brien Chapter 3).

The distance of refits also reveals that residents of some houses consistently shared with residents of other houses regardless of distance. While it was expected that kin-based food sharing would occur only with the closest neighbors, this did not occur. Instead, the average of net distance (refit distance - the average distance of its 3 closest neighbors) for all the houses was greater than zero, reflecting sharing with all hunt participants across the site. When the average net distances are compared, House 9 ranks highest. House 9 averages 54 m between refits, which is over 8 m greater than the next provenience. The average net distance of refits for proveniences with high caloric rankings is 23 m for House 1, 21 m for House 8, and 31 m for the excavation block. This difference between

all proveniences is significant ( $F(9, 64) = 3.18, p = 0.003^2$ ) and a Tukey HSD test indicates that House 9 refit distances are significantly greater than those for Houses 2, 4, 5, and 6. This also indicates there is no statistical difference in the average net distance of refits between Houses 1, 3, 7, 8, 9 and the excavation block.

## **Discussion and Conclusions**

The faunal and spatial analysis of Eden-Farson provides a glimpse into the social organization associated with a successful game drive. The primary goal was to test whether the distribution of skeletal materials could indicate the existence of social inequality. When the energetic returns are compared spatially, the highest ranked houses are mostly located in the northwestern portion of the site. Lower returns from the communal hunt occurred in the central to eastern portions of the site. When the energetic return rate (kcal/hr) is used instead of kilocalories, House 1 moves ahead of House 8, which breaks up the concentration of highly ranked houses in the northwestern portion of the site. In either case, the distribution of meat from the hunt is not even, which suggests the presence of social inequality.

The existence of social inequality deviates with informants' accounts from early ethnographic efforts that described the Shoshone as strongly egalitarian. In all accounts of the Northern Shoshone, there are no references to the social organization of communal

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<sup>2</sup> For the ANOVA, the measurements (m) were transformed using  $[(ABS(m - \mu))^{0.6}]$  to approximate a normal distribution.

hunts, but there are indications that leaders were likely present or active in certain situations, given Hultzkrantz's (1961) discussion of winter and communal fishing camps. The results of this study indicate that the Eastern Shoshone made a temporary arrangement to pay leaders for their services. Although the ethnographic data is hardly conclusive, it appears that the Shoshone leadership more closely reflects the soft leadership model. Group leaders and hunt leaders were often the senior most active males, which would imply that they possessed the more knowledge and experience than their peers. Historically, Kelenka (2009) argues the adoption of the horse dramatically influenced the social organization of the North American Native Americans and the Eastern Shoshone were not an exception to this generalization (Russell 1970). While the horse likely allowed for more permanent aggregations of people, the temporary gathering of large groups, like those during communal hunts, likely facilitated the development of alternative social and political organizations.

Interestingly, even in the temporary instances of social inequality, the Shoshone continue to redistribute meat through food sharing. Despite leader payments, participating families still practiced some combination of reciprocity and tolerated theft. Among nomadic groups, families choose to live in close proximity to close relatives (Gargett and Hayden 1991; Gould and Yellen 1987; O'Brien and Surovell *in review*; Whitelaw 1983, 1991; Yellen 1977) and individuals tend to share more with close family than with non-family (Allen-Agrave et al. 2008; Gurven 2004; Ziker and Schnegg 2005). The distribution of food sharing between houses at Eden-Farson appears much more widespread with linkages occurring across the site. This may reflect differences in prescribed social



behavior associated with communal tasks. Unlike the dilemma faced by group hunters who must weigh partnering based on skill or kinship (Bailey 1991), communal hunting relies more on the ability to work together. If greater efficiency comes from greater cooperation, then widespread meat sharing may reward those involved. This pattern may also reflect a suggestion posed by Frison (1971) that the animals were processed at a nearby butchering area. If so, then this processing area may represent a central location where animals were dismembered and shared with various families. The large numbers of refits associated with Houses 2 and 6 are also intriguing, given the low rank of these houses in caloric returns. This pattern seems to reflect expectations associated with tolerated theft – the redistribution of foods with low value to those with greater need. While the directionality of the refits or food sharing is unclear, Houses 2 and 6 appear to have less to food to offer others.

Although the food sharing patterns occur across the site, the skewed divisions of caloric proceeds suggest that Houses 8, 9, and the excavation block may have served a vital role in the hunt. This raises the possibility the leader (or leaders) of the hunt resided in one (or more) of these locations. The exact location is likely obscured due to food sharing with the leader's closest relatives, who also were likely the closest neighbors. When anatomical refitting is incorporated into this analysis, it does appear that a leader resided in House 9. While the payment for services was not associated with larger pronghorn, the house received many high ranked and very few low ranked anatomical units. The subtle, but real disparities in the division of hunt proceeds may explain why ethnographic informants failed to report payments made to Shoshone hunt leaders. Therefore, this

analysis provides a useful supplement to our existing knowledge on the socioeconomics associated with Shoshone communal hunt organization.

Successful game drives hinged on the organization, construction, and execution that often warranted the temporary adoption of leadership among traditionally egalitarian people. This willingness to suspend autonomy in favor of consolidated leadership suggests that all hunt members profited from their participation, regardless of their role. Assuming that participants retained their right to defect from the communal task, this leader faced the challenge of balancing his individual interests with those of the group. Therefore, this situation likely diminished the proportion of the hunt proceeds skewed toward the leader. Nevertheless, the archaeological evidence at Eden-Farson suggests that payments to leaders were nominal, and through the spatial patterning of the faunal remains, they are visible from the past.

This recurrent tension between the leader and followers likely plays a role in the evolution of hierarchical societies. In the absence of spatially fixed and near-limitless resource niches, the exploitation of heterogeneously distributed food resources caused by prey behavior and seasonality provide the initial opportunities for population aggregation. It is during these occasional gatherings when the groups likely experimented with alternative political structures to improve the efficiency of these activities. As such, the initial seeds of later, more complex forms of social organization are likely tied to these temporary communal arrangements. While the idea that social complexity initially arises from temporary increases in group size is not new, the use of the archaeological record of

communal hunts does provide a viable way of examining pre-institutionalized social inequality. Through the incorporation of additional sites associated with communal activities, it may be possible to determine whether Eden-Farson represents an anomaly or a pattern of social organization promoting leadership.

## **Chapter 6: Conclusions**

This dissertation research is a relevant contribution to archaeological method and theory and to our understanding of Shoshone social organization at the Eden-Farson site. The introduction of new methodological tools for anatomical refitting and food utility indices (FUI) provides significant contributions beyond the application presented here. The development of a new bilateral refit model frees zooarchaeologists from limiting their refitting to small assemblages through the use of two or more measurements to identify paired elements from a single individual. The model also accounts for bilateral asymmetry in an individual's left and right bones of the same element, which had been unaccounted for in previous approaches. While the model represents an improvement over existing methods, it still does not free the analyst from physically verifying predicted pairings isolated by the model. Instead, the model provides a means of narrowing down the sample of potentially refitting bones to be physically verified, which is necessary in large sample sizes.

The second methodological contribution is the addition of a pronghorn food utility index (FUI) that quantifies the caloric returns for each anatomical unit. While there are general physical similarities between pronghorn and other ungulates, the experimental results suggest that the pronghorn axial skeleton carries more nutritional benefit than those of white-tailed deer or caribou. These differences are significant when considering transport decisions or the processing of many carcasses. When these experimental results are compared to a small sample of pronghorn-dominated archaeological sites, it is clear that

the prehistoric butchers valued the marrow contributions from the long bones in each of the cases. Therefore, I would predict that when foragers face transport constraints, they will chose to field process axial anatomical units for the meat and then carry the appendicular remains back to camp for marrow extraction. While marrow constitutes a small portion of the overall caloric return, Bar-Oz and Munro (2007) argue the higher fat content becomes the dominant currency in the low-fat diets of foraging societies. This argument is supported in the three archaeological cases presented in Chapter 4.

The combination of refits and a pronghorn FUI provides the tools necessary to address the primary research question of identifying the existence of leadership at the Eden-Farson site. The results of this analysis provide contributions to our understanding of Shoshone social organization and have broad implications for the importance of communal activities as a means of fostering the development of non-egalitarian political structure.

#### *Relevance of this research to Shoshone social organization*

The ethnographic record of Shoshone culture provides a wealth of information about social organization, seasonal variation in group size, and subsistence practices, but these early studies overlooked many cultural aspects of interest to archaeologists and behavioral ecology. This study of Shoshone communal hunting begins to fill in the gap of the social organization of the Eastern Shoshone overlooked in the ethnographic record. Missing from these ethnographic accounts was whether the Eastern Shoshone adopted a

non-egalitarian social structure during communal hunts, and whether leaders received payments for their service.

Through the use of anatomical refitting and a pronghorn food utility index, I have provided quantitative evidence that supports the existence of preferential food distribution. This in turn strongly suggests that leaders were recognized by the occupants of the Eden-Farson site. This is significant given our preconceived notions that the Shoshone were strongly egalitarian. In the case of refits, I have established that the site represents a single occupation which, when tooth eruption sequences are considered (Lubinski 1997), entails a single mass kill event. These inter-household linkages indicate that the Shoshone maintained the practice of reciprocity, but there is also evidence of skewed redistribution to a single domestic structure. Beyond inter-house refits, the comparison of the energetic returns by house also provides support for House 9 being the likely residence of centralized leadership at Eden-Farson.

The presence of leadership is not new to the study of Shoshone. Given ethnographic evidence by Hultzkrantz (1961), leaders were nominated during communal fishing efforts along the Snake River. During these communal fishing events, leaders served as the central figures in the organization and execution of these activities. In reference to communal hunts of pronghorn, Egan (1917) observed that a shaman served a similar role as the leader among the Gosiute Shoshone in the Great Basin. Yet, these accounts failed to record whether leaders received payment for their efforts, which would be expected given the theoretical justification for the existence of leadership.

This analysis of the faunal assemblage at Eden-Farson provides the first attempt to determine whether leaders were rewarded for their efforts. Based on the faunal data, it appears that leaders received payment in the form of meat from other households, which resulted in receipt of better cuts of meat relative to the other participants. While a leader received nutritional payments, it is also likely that individual was also paid with other intangible currencies not seen in the archaeological record. For example, the leader also likely received a boost in social currency among his primary economic unit and those also participating in the hunt. Likewise, it is possible he also received additional payments in foods not associated with a skeletal anatomical unit or in animal byproducts such as hides. Therefore, the evidence of payment exhibited by the skeletal data should be considered the minimum reward provided to the leader of the hunt.

The acceptance of leadership among the Shoshone is an interesting phenomenon given the fluidity of group membership (Hultzkrantz 1961; Malouf 1974; Murphy and Murphy 1960; Steward 1938, 1943). Traditionally, the Shoshone redistributed goods and resources among all group members, and any occurrence of hoarding would result in the application of social leveling mechanisms (Boehm 2001). Among the Gosiute, the most common response to unequal redistribution of resources was group fission. If this was a common practice among all Shoshone groups, then the presence of skewed resources at Eden-Farson provides support for Driver's (1990) argument that participation in communal hunts results in higher return rates than those obtained through individual

subsistence activities. In light of this interpretation, the Eden-Farson site study provides evidence for the economic viability of game drives for all members of the hunt.

#### *Broader importance of communal hunting*

Archaeological research into social inequality is relevant in a broad sense to the study of cultural evolution. Anthropologically, social complexity is consistently intertwined with the adoption of sedentism and food production. The accompanying increase in population and the potential ensuing conflict between groups promotes social awareness and non-kin cooperation, leading to hierarchical societies (Carneiro 1970; Bowles 2009; Boyd and Richerson 1985). The discussion of social inequality often overlooks foragers due to the generalized arguments relying on all or some of the following assumptions: 1) forager population densities are low; 2) foragers lack food surpluses; and 3) fluidity of group membership prevents aggrandizement of resources. Simply, egalitarianism is a sufficient political structure to satisfy societies living under these related conditions. When societies are forced to subsist on limited natural resources, they must maintain fluidity in group size to prevent population aggregation and avoid depletion of relatively scarce food resources.

The evidence presented in this thesis indicates that communal hunting violates the assumptions listed above. First, the presence of dense populations of prey indicates that forager resources are not homogeneous in nature, and seasonally, these resources are predictable and common. If resources are clumped, then it becomes possible and advantageous for human hunters to clump as well. Secondly, the hunting of these



aggregated populations can and should produce food surpluses that cannot be obtained individually. Finally, the prospects of killing multiple animals in a single hunting operation negates the benefit of group fission. Therefore, communal hunting is a unique situation in which forager subsistence provides returns typically associated with food-producing societies. As such, the organization of these events is also likely to foster restructuring of social leadership organization, albeit temporarily, in the absence of food production.

At a general level of inquiry, this suggests that these temporary periods of aggregated food resources provide the first opportunities for foraging communities to adopt more complex social organizations. This is contrary to the basic notion of egalitarian society only giving way when reliable food resources become permanent through nearly inexhaustible food supplies like those available in coastal environments or food-producing economies. To suggest that experimentation with new political systems did not occur until these conditions were met is to limit the cognitive ingenuity of foraging societies. Therefore, I would speculate communal tasks visible in the archaeological record represent the earliest periods of non-egalitarian behavior which then become more common with the establishment of newer forms of subsistence associated with sustained food surpluses.

### *Summary*

This research on the social organization of communal game drives represents a first step in the identification of precursors to institutionalized non-egalitarian political

organization seen later in more complex societies (Price and Feinman 1995). While this research is important, it is only the first step in furthering our understanding of communal activities. In the case of the Eden-Farson site, we have gained a greater understanding of the social structure of the participants involved in the hunt, but more questions remain. This analysis only focuses on the faunal remains from the site, and there has been little analytical attention devoted to the other cultural materials recovered from the site. For example, does the lithic assemblage provide additional information about the origins of the participating families through lithic sourcing? Does the flint-knapping skill represented by the lithic artifacts in each house play a role in the social rank of the group? Can the limited supply of ceramic vessels provide insights into the social organization of the occupants? All these questions will push the interpretation of Eden-Farson into a more holistic approach to the past lifeways of the Shoshone during the Protohistoric period of southwestern Wyoming.

In reference to communal hunting, do the results of the Eden-Farson site represent a unique pattern or is this social organization representative of all communal hunting? Only through the expanded application of these methods to other communal kill sites can we address this question. While very few sites possess a similar pattern of spatially segregated artifact assemblages associated with individual households, there must be similar situations elsewhere in the archaeological record with pronghorn or other species. By expanding this analysis to other case studies, we can move the discussion of the importance of communal hunting's contribution to the development of non-egalitarian social structure from speculation to a formal hypothesis.

## Appendix A

Here we formally demonstrate the relation in equation (1). We need to show that for a random vector  $\mathbf{d}$  with multivariate normal distribution  $N(\mathbf{0}, \Sigma)$ ,

$$\Pr(\mathbf{d} = \mathbf{d}_{ik} | \mathbf{d} = \mathbf{d}_{ij}, \text{ for some } j = 1, \dots, n) = \frac{\phi(\mathbf{d}_{ik}; \mathbf{0}, \Sigma)}{\sum_{j=1}^n \phi(\mathbf{d}_{ij}; \mathbf{0}, \Sigma)}.$$

Now, in general for some random vector  $\mathbf{X} = [X_1, \dots, X_p]'$  with a continuous multivariate cumulative distribution function (CDF)  $\Phi(\mathbf{x})$ , like the multivariate normal distribution, the mixed derivative of  $\Phi(\mathbf{x})$  gives the density function  $\phi(\mathbf{x})$ , i.e.,

$$\phi(\mathbf{x}) = \frac{\partial^p}{\partial x_1 \dots \partial x_p} \Phi(\mathbf{x}).$$

In the univariate case this leads to

$$\phi(x) = \frac{\partial}{\partial x} \Phi(x) = \lim_{\varepsilon \rightarrow 0} \frac{\Phi(x) - \Phi(x + \varepsilon)}{\varepsilon} = \lim_{\varepsilon \rightarrow 0} \frac{\Pr(x \leq X \leq x + \varepsilon)}{\varepsilon}.$$

In the multivariate case, this becomes

$$\phi(\mathbf{x}) = \frac{\partial^p}{\partial x_1 \dots \partial x_p} \Phi(\mathbf{x}) = \lim_{\varepsilon \rightarrow 0} \frac{\Pr\left(\bigcup_{k=1}^p \{x_k \leq X_k < x_k + \varepsilon\}\right)}{\varepsilon^p}.$$

Finally,

$$\begin{aligned}
\Pr(\mathbf{d} = \mathbf{d}_{ik} \mid \mathbf{d} = \mathbf{d}_{ij}, \text{ for some } j = 1, \dots, n) &= \Pr\left(\mathbf{d} = \mathbf{d}_{ik} \mid \bigcup_{j=1}^n \{\mathbf{d} = \mathbf{d}_{ij}\}\right) \\
&= \lim_{\varepsilon \rightarrow 0} \Pr\left(\bigcup_{l=1}^p \{d_{l,ik} + \varepsilon \leq d_l \leq d_{l,ik}\} \mid \bigcup_{j=1}^n \left\{ \bigcup_{l=1}^p \{d_{l,ij} + \varepsilon \leq d_l \leq d_{l,ij}\} \right\}\right) \\
&= \lim_{\varepsilon \rightarrow 0} \frac{\Pr\left(\bigcup_{l=1}^p \{d_{l,ik} + \varepsilon \leq d_l \leq d_{l,ik}\}\right) / \varepsilon^p}{\sum_{j=1}^n \Pr\left(\bigcup_{l=1}^p \{d_{l,ij} + \varepsilon \leq d_l \leq d_{l,ij}\}\right) / \varepsilon^p} \\
&= \frac{\phi(\mathbf{d}_{ik}; \boldsymbol{\theta}, \Sigma)}{\sum_{j=1}^n \phi(\mathbf{d}_{ij}; \boldsymbol{\theta}, \Sigma)},
\end{aligned}$$

which is the relation used in equation (1).

## Appendix B

This section provides a brief discussion of how to format your data to use the proposed model and the associated R code.

The first concern is the format of the measurements in the text file. The comparative and test samples must follow the same format of listing all of one side and then the other:

File name: radiusexample.txt

Ind	Side	rd3	rd4	rd7	rd8	rd9
1	L	49.33	27.91	45.73	27	20.1
4	L	44.74	27.9	41.41	24.81	17.58
1	R	49.74	28.2	45.83	26.74	19.64
4	R	45.37	28.49	42.01	25.05	17.64

File name: radiustest.txt

Ind	Side	rd3	rd4	rd7	rd8	rd9
1	L	48.50	27.02	44.73	26.20	18.90
4	L	43.74	26.9	39.41	23.81	16.58
1	R	48.45	27.25	44.89	26.02	18.65
4	R	42.37	27.49	40.01	24.05	16.64

Note that the model requires the number of variables in the comparative and the test sample to be identical. The comparative sample must be sorted to maintain the same sequence of individuals per side.

The R code is as follows:

```
# This code is a common method of importing data files into R.
```

```
data <- read.table(file="C:\\radiusexample.txt", header=T)
```

```
data2 <- read.table(file="C:\\radiustest.txt", header=T)
```

```

# This code establishes the matrices for both the comparative and test samples

comp.sample<-as.matrix(data[,3:7])

test.sample<-as.matrix(data2[,3:7])

comp.left<-comp.sample[1:2,]

comp.right<-comp.sample[3:4,]

diff.comp<-comp.right-comp.left

comp.cov<-cov(comp.right-comp.left)

Univ.comp<-cor(diff.comp)

test.lefthum<-test.sample[1:2,]

test.righthum<-test.sample[3:4,]


# This portion refers to the multivariate density function (Equation 2)

mvdnorm <- function(x, mu, sigma) { # a more complex, but more efficient implementation of the density

  if (is.vector(x)) x <- t(x)      # if x is a vector, coerce it into a matrix

  x.minus.mu <- t(sweep(x,2,mu,'-')) # subtract mu from x

  sigma.chol <- chol(sigma)        # compute the Choleski decomposition of sigma

  sqrt.det <- prod(diag(sigma.chol)) # compute sqrt(det(sigma))

  exp.arg <- -0.5 * colSums(x.minus.mu * backsolve(sigma.chol,forwardsolve(sigma.chol,
                                          x.minus.mu,upper.tri=TRUE,transpose=TRUE)))

  # evaluate what's inside the exp(...)

  drop(1 / ((2*pi)^(ncol(x)/2) * sqrt.det) * exp(exp.arg))

  # return the density}


# This section deals with constructing a probability following Equation (1)

nr <- nrow(test.righthum)

nl <- nrow(test.lefthum)

numerator.r2l <- matrix(0, nrow=nr, ncol=nl)

pr.ij <- matrix(0, nrow=nr, ncol=nl)

```

```

pl.ij <- matrix(0, nrow=nl, ncol=nr)

for(i in 1:nr){

  for(j in 1:nl){

    numerator.r2l[i,j] <- mvdnorm(test.righthum[i,] - test.lefthum[j,], diff.comp, comp.cov) } }

denom.r2l <- rowSums(numerator.r2l)

for(i in 1:nr){

  for(j in 1:nl){

    pr.ij[i,j] <- numerator.r2l[i,j]/denom.r2l[i] } }

numerator.l2r <- t(numerator.r2l)
denom.l2r <- rowSums(numerator.l2r)

for(i in 1:nl){

  for(j in 1:nr){

    pl.ij[i,j] <- numerator.l2r[i,j]/denom.l2r[i] } }

pl.j <- t(pl.ij)

# Min.P and Max.P refer to the output commands for the probability matrices

min.p <- matrix(0, nrow=nr, ncol=nl)

for(i in 1:nr){

  for(j in 1:nl){

    min.p[i,j] <- min(pl.j[i,j], pr.ij[i,j]) } }

l.j <- t(pl.ij)

max.p <-matrix(0,nrow=nr,ncol=nl)

for(i in 1:nr){

  for(j in 1:nl){

    max.p[i,j] <- max(pl.j[i,j],pr.ij[i,j]) } }

```

## Appendix C: Measurements and the Comparative Sample of Used Specimen

Skeletal Part		Astragalus
Dimensions	AS1	<i>Greatest Lateral Length</i>
	AS2	<i>Greatest Breadth</i>
	AS3	<i>Breadth of Distal Articular Surface</i>
Skeletal Part	Measurement	Distal Epiphysis of Humerus
Dimensions	HM6	<i>Greatest Breadth of Distal End</i>
	HM7	<i>Breadth of Distal Articular End</i>
	HM8	<i>Least Breadth of Olecranon Fossa</i>
	HM11	<i>Greatest Depth of Medial Distal End</i>
	HM14	<i>Least Depth of Distal Medial end</i>
	HM15	<i>Depth of Olecranon Fossa</i>
Skeletal Part		Distal Epiphysis of Radius
Dimensions	RD2	<i>Greatest Breadth</i>
	RD3	<i>Greatest Breadth of Articular Surface</i>
	RD8	<i>Greatest Depth</i>
	RD9	<i>Greatest Breadth of Articular Surface with Radial Carpal</i>
Skeletal Part		Proximal Epiphysis of Radius
Dimensions	RD6	<i>Greatest Breadth</i>
	RD7	<i>Greatest Breadth of Articular Surface</i>
	RD10	<i>Greatest Depth of Medial End</i>
	RD11	<i>Greatest Depth of Lateral End</i>
Skeletal Part		Distal Epiphysis of Tibia
Dimensions	TA7	<i>Greatest Breadth</i>
	TA10	<i>Greatest Depth</i>
	TA14	<i>Breadth of Distal Articular Surface</i>
	TA1A	<i>Maximum Depth of the Lateral Groove*</i>
	TA2A	<i>Articular Depth of Medial Groove*</i>
	TA3A	<i>Articular Depth of Lateral Groove*</i>



### Astragali Comparative Sample

CSN	SIDE	AS1	AS2	AS3
8425	LEFT	32.75	22.04	20.87
40082L	LEFT	31.71	19.87	18.46
42162L	LEFT	36.11	23.21	20.72
42174L	LEFT	33.3	21.55	18.34
42176L	LEFT	34.69	22.96	21.43
53505L	LEFT	32.76	20.56	18.37
8255B	LEFT	36.37	22.79	22.16
8361B	LEFT	35.51	22.24	21.28
8403B	LEFT	36.14	22.27	22.72
8409B	LEFT	35.31	21.75	20.95
87751L	LEFT	33.81	21.26	19.96
87752L	LEFT	32.78	21.46	19.18
87753L	LEFT	36.05	21.43	20.22
9273B	LEFT	34.48	21.49	20.77
9281B	LEFT	38.51	22.5	21.77
9314B	LEFT	35.85	21.69	21.14
9981B	LEFT	37.88	23.09	21.94
9982B	LEFT	34.68	21.31	21.16
8425	RIGHT	32.58	22.24	20.61
40082R	RIGHT	31.97	19.39	17.8
42162R	RIGHT	36.17	23.18	20.92
42174R	RIGHT	33.25	21.31	18.34
42176R	RIGHT	34.63	23.15	21.44
53505R	RIGHT	32.91	20.86	18.75
8255B	RIGHT	36.14	22.62	21.46
8361B	RIGHT	35.49	22.39	20.79
8403B	RIGHT	36.01	22.68	22.68
8409B	RIGHT	35.5	21.42	20.82
87751R	RIGHT	33.95	21.24	19.95
87752R	RIGHT	32.59	21.82	19.32
87753R	RIGHT	35.74	21.97	20.02
9273B	RIGHT	34.82	22.07	20.51
9281B	RIGHT	38.1	22.46	21.83
9314B	RIGHT	35.94	21.46	20.89
9981B	RIGHT	37.47	23.43	22.37
9982B	RIGHT	34.65	21.09	21.2

### Humeri Comparative Sample

CSN	Side	HM6	HM7	HM8	HM11	HM14	HM15
-----	------	-----	-----	-----	------	------	------

21271L	LEFT	34.73	33.03	15.02	30.48	23.38	7.65
40082L	LEFT	29.37	30.22	13.36	26.8	19.86	6.53
42162L	LEFT	37.27	36.84	14.15	32.13	26.65	8.54
42162L	LEFT	36.69	37.08	14.08	32.05	26.6	8.56
42174L	LEFT	36.32	35.4	11.77	30.31	23.71	8.13
53505L	LEFT	33.47	34.24	14.05	28.98	23.76	7.36
8171B	LEFT	35.2	31.89	14.85	29.67	24.36	7.9
8192B	LEFT	38.8	36.75	12.57	30.42	25.55	8.13
8255B	LEFT	35.77	36.37	14.46	30	23.83	8.04
8263B	LEFT	35.31	34.39	11.63	30.67	24.97	9.3
8361B	LEFT	37.24	36.09	13.3	31.06	24.8	9.22
8363B	LEFT	40.48	41.28	15.91	33.02	25.85	9.41
8403B	LEFT	36.71	36.81	13.25	31.63	25.52	8.83
8409B	LEFT	36.06	36.43	13.56	30.57	24.04	9.23
86329L	LEFT	35.86	36.87	15.93	31.67	24.2	8.12
87751L	LEFT	35.13	34.7	12.93	29.35	22.86	8.02
87752L	LEFT	34.74	35.56	15.4	29.9	22.39	7.88
87753L	LEFT	34.98	34.11	15.2	30.3	23.49	7.62
9271B	LEFT	37.58	38.16	14.41	31.77	24.84	7.9
9314B	LEFT	37.61	37.21	15.62	31.27	23.49	8.02
9981B	LEFT	37.74	37.28	14.17	31.3	26	8.95
9982B	LEFT	34.82	34.81	15.29	30.77	23.31	8.24
21271R	RIGHT	34.36	33.9	15.35	29.94	23.67	7.62
40082R	RIGHT	29.66	30.75	13.96	26.85	20.28	6.56
42174R	RIGHT	36.65	34.91	12.02	29.77	23.87	8.38
42176R	RIGHT	35.41	35.88	14.82	30.93	25.32	9.05
42176R	RIGHT	36.56	36.96	14.1	31.58	25.35	9.03
53505R	RIGHT	33.39	33.89	13.88	28.82	24.1	7.48
8171B	RIGHT	35.1	32.69	15.33	29.81	24.1	8.04
8192B	RIGHT	38.63	37.55	12.04	30.52	25.25	7.39
8255B	RIGHT	35.57	35.5	13.96	30.27	24.24	8.01
8263B	RIGHT	36.39	36.11	11.64	30.48	25.36	9.3
8361B	RIGHT	36.78	36.78	12.46	31.12	24.63	9.2
8363B	RIGHT	40.37	40.9	15.46	33.16	26.22	9.9
8403B	RIGHT	36.3	36.63	13.01	31.91	25.79	9.16
8409B	RIGHT	36.52	36.27	13.25	30.32	24.17	8.9
86329R	RIGHT	35.88	36.65	15.15	31.8	24.17	8.32
87751R	RIGHT	35.02	34.46	13.21	29.39	22.76	7.95
87752R	RIGHT	35.16	35.36	15.42	29.51	22.82	7.75
87753R	RIGHT	35.35	35.02	15.21	30.12	23.62	7.83
9271B	RIGHT	37.96	38.28	14.58	31.41	24.62	7.69
9314B	RIGHT	37.53	37.24	15.06	31.1	23.35	7.85
9981B	RIGHT	37.57	37.02	13.98	31.22	25.61	9.19

9982B	RIGHT	34.85	34.59	15.17	30.65	23.14	8.05
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#### Distal Epiphyses of Radi

CSN	SIDE	RD6	RD7	RD10	RD11
21271L	LEFT	30.45	28.78	22.64	9.2
40082L	LEFT	28.66	27.73	20.9	8.87
42162L	LEFT	33.41	26.66	24.92	9.56
42174L	LEFT	29.51	29	21.87	10.76
42176L	LEFT	31.51	26.09	24.58	9.69
53505L	LEFT	29.04	24.28	23.21	9.04
8171B	LEFT	31.6	29.74	23.35	10.1
8255B	LEFT	31.68	27.5	23.16	13.44
8262B	LEFT	34.4	32.3	24.95	11.68
8363B	LEFT	35.53	28.67	26.97	14.16
8403B	LEFT	32.17	26.07	24.54	12.91
8409B	LEFT	33.13	27.15	24.96	13.29
86329L	LEFT	31.24	25.58	24.48	9.34
87751L	LEFT	30.9	25.2	22.04	9.39
9271B	LEFT	31.91	26.52	24.58	13.27
9314B	LEFT	32.49	30	24.09	9.72
9982B	LEFT	30.79	27.51	23.04	11.04
21271R	RIGHT	29.98	28.31	23.12	9.58
40082R	RIGHT	27.74	26.86	21	10.4
42162R	RIGHT	33.58	26.71	24.59	9.58
42174R	RIGHT	30.17	24.91	22.49	10.4
42176R	RIGHT	30.87	25.79	23.71	10.34
53505R	RIGHT	30.72	24.64	23.22	9.08
8171B	RIGHT	31.64	30.02	23.27	9.24
8255B	RIGHT	31.73	27.23	23.46	13.49
8262B	RIGHT	34.14	32.31	25.17	11.23
8363B	RIGHT	34.86	28.61	27.07	14.49
8403B	RIGHT	32.39	27.54	24.66	14.69
8409B	RIGHT	32.67	26.24	25.08	47.89
86329R	RIGHT	31.59	25.9	24.1	9.17
87751R	RIGHT	30.65	24.9	22.23	9.47
9271B	RIGHT	33.66	27.93	24.28	13.6
9314B	RIGHT	32.8	30.24	24.43	9.44
9982B	RIGHT	30.39	27.28	23.07	11.09

#### Proximal Epiphyses of Radi

CSN	SIDE	RD2	RD3	RD8	RD9
21271L	LEFT	32.29	30.93	17.37	12.22
42162L	LEFT	37.16	33.6	20.05	12.68

42174L	LEFT	34.28	30.97	18.34	14.06
42176L	LEFT	35.97	32.51	19.49	12.14
53505L	LEFT	33.77	30.72	17.38	13.58
8171B	LEFT	33.61	31.35	17.62	11.2
8192B	LEFT	35.22	33.79	17.9	14.07
8255B	LEFT	36.04	35.01	19.05	13.22
8262B	LEFT	36.46	34.63	20.56	14.18
8363B	LEFT	39.71	38.33	20.39	14.46
8403B	LEFT	35.7	35.3	18.75	14.52
8409B	LEFT	35.88	35.5	18.12	12.49
86329L	LEFT	35.9	32.77	18.6	12.87
87751L	LEFT	32.83	31.09	17.39	13.07
87752L	LEFT	32.76	31.09	18.4	11.02
87753L	LEFT	33.68	31.39	18.1	10.88
9271B	LEFT	38.5	36.74	19.52	14.6
9314B	LEFT	35.06	33.29	20.01	13.03
9982B	LEFT	34.7	33.52	18.95	13.39
21271R	RIGHT	32.6	31.16	17.85	11.7
42162R	RIGHT	37.59	34.58	20.1	12.62
42174R	RIGHT	33.71	31.28	18.19	13.06
42176R	RIGHT	35.44	31.67	19.17	12.36
53505R	RIGHT	33.62	31.31	17.75	13.16
8171B	RIGHT	33.38	31.38	17.44	10.98
8192B	RIGHT	34.88	33.6	17.85	13.41
8255B	RIGHT	35.9	34.33	18.79	13.47
8262B	RIGHT	36.41	34.31	20.55	14.02
8363B	RIGHT	39.86	38.28	20.49	14.58
8403B	RIGHT	35.8	35.48	18.71	14.5
8409B	RIGHT	36.41	34.99	18.2	13.08
86329R	RIGHT	36.19	31.96	19.31	13.44
87751R	RIGHT	32.68	31.14	17.57	12.98
87752R	RIGHT	32.62	31.23	17.92	11.23
87753R	RIGHT	33.77	31.02	18.23	10.99
9271B	RIGHT	38.49	36.71	19.48	14.58
9314B	RIGHT	35.06	32.8	19.86	14.02
9982B	RIGHT	34.92	33.6	18.94	13.68

#### Tibiae Comparative Sample

CSN	SIDE	TA1A	TA2A	TA3A	TA7	TA10	TA14
42162L	LEFT	19.74	15.67	21.9	33.48	25.51	18.81
42162R	RIGHT	19.83	16.24	21.86	32.97	24.8	19
42174L	LEFT	18.98	15.32	20.38	29.97	23.95	17.7

42174R	RIGHT	18.99	15.1	20.48	30.58	23.92	17.95
42176LM	LEFT	18.84	17.3	20.41	32.61	23.93	19.61
42176RM	RIGHT	19.09	16.73	20.81	33.2	23.72	19.75
53505L	LEFT	17.89	13.75	20	29.52	23.91	18.23
53505R	RIGHT	17.82	13.67	20.05	29.04	24.21	17.73
8171B	LEFT	19.32	14.34	20.05	30.39	24.88	21.72
8171B	RIGHT	19.49	14.48	20.58	29.42	24.58	21.73
8192B	LEFT	18.96	14.63	20.6	30.16	24.31	22.57
8192B	RIGHT	18.73	14.72	21.02	30.12	24.16	22.68
8199B	LEFT	19.2	13.7	20	30.33	23.65	21.54
8199B	RIGHT	19.27	14.37	20.28	30.63	23.5	21.46
8255B	LEFT	18.89	14.5	21.09	31.67	23.55	20.87
8255B	RIGHT	19.24	14.61	21.14	31.99	23.59	20.74
8361B	LEFT	19.17	14.88	20.86	31.62	24.03	21.94
8361B	RIGHT	19.11	14.97	20.75	32.01	23.41	22.11
8403B	LEFT	20.03	15.66	21.54	32.36	24.43	23.47
8403B	RIGHT	20.28	16.14	22.39	31.77	23.72	20.2
8408B	LEFT	17.82	14.29	19.57	31.65	23.64	21.2
8408BR	RIGHT	18.09	14.38	19.7	31.28	23.35	20.86
8409B	LEFT	19.38	14.89	20.83	31.85	23.18	18.96
8409B	RIGHT	19.24	14.93	21.25	32.06	23.29	18.74
86329L	LEFT	19.19	16.14	20.13	32.33	24.27	18.19
86329R	RIGHT	18.98	15.27	20.27	31.21	24.21	18.38
87551R	RIGHT	18.42	14.47	20.64	30.41	22.8	17.73
87751L	LEFT	18.54	15.36	20.57	31.06	23.01	18.07
87752L	LEFT	18.52	12.95	19.1	30.41	23.57	17.23
87752R	RIGHT	17.72	13.3	19.18	29.86	23.5	17.27
87753L	LEFT	17.84	15	19.99	30.18	23.27	17.88
87753R	RIGHT	18.09	15.05	20.6	29.55	22.91	17.58
9270B	LEFT	20.55	14.46	22.35	34.91	26.51	22.99
9270B	RIGHT	20.34	14.47	22.45	33.59	25.3	23
9273B	LEFT	18.98	14.06	20.7	31.91	23.28	21.54
9273B	RIGHT	19.25	14.27	21.32	31.79	23.85	22.08
9981B	LEFT	20.29	16.45	22.52	31.19	24.45	19.38
9981B	RIGHT	20.16	16.01	22.9	30.48	24.46	19.07

## Appendix D: Visually Verified Refits with Corresponding Left and Right Skeletal Parts

### Astragalus Refits

CSN	HOUSE	SIDE	AS1	AS2	AS3	CSN	HOUSE	SIDE	AS1	AS2	AS3
2718	2	LEFT	37.81	24.05	22.25	3557	0	RIGHT	37.8	23.88	22.27
2932	4	LEFT	37.42	21.52	21.21	2719.6	2	RIGHT	37.58	21.65	21.11
125	9	LEFT	35.77	23.33	21.91	3462	5	RIGHT	35.66	23.14	21.79
3463	5	LEFT	34.91	21.88	22.07	2826	3	RIGHT	35.52	21.64	21.44
3468	5	LEFT	38.95	25.04	22.9	3624	8	RIGHT	38.93	24.89	22.87
3027	6	LEFT	35.52	21.24	20.55	2926	4	RIGHT	35.4	21.14	20.69
3026	6	LEFT	38.8	23.82	21.58	3625	8	RIGHT	38.6	23.76	21.86
3032	6	LEFT	36.66	21.5	21.27	3163	11	RIGHT	36.41	21.88	20.93
3565	0	LEFT	34.98	22.65	21.74	2827	3	RIGHT	36	22.57	21.22

### Humeri Refits

House	SIDE	HM6	HM7	HM8	HM11	HM14	HM15	Cat	House	SIDE	HM6	HM7	HM8	HM11	HM14	HM15
1	LEFT	35.06	34.2	14.71	29.39	23.9	8.52	2688	2	RIGHT	34.76	33.61	13.51	30.14	24.09	8.45
2	LEFT	41.23	39.58	14.27	33.27	27.08	9.91	3542	1	RIGHT	39.97	38.75	14.5	32.94	26.65	9.58
2	LEFT	36.69	35.9	14.15	30.42	24.4	7.74	2694	2	RIGHT	36.77	36.13	14.82	30.65	24.08	7.34
2	LEFT	39.05	37.9	13.95	30.58	24.95	8.64	2686	2	RIGHT	38.67	38.89	13.43	30.18	24.24	8.47
2	LEFT	39.18	37.86	14.84	31.41	26.21	8.63	2689	2	RIGHT	39.08	38.1	14.56	31.65	26.48	8.72
2	LEFT	37.11	35.45	15.14	31.87	25.07	8.98	708	6	RIGHT	37.64	36.42	15.71	31.81	24.33	8.77
2	LEFT	40.61	38.8	13	32.03	26.04	9.19	706	6	RIGHT	40.23	39.23	12.7	32.04	25.99	8.45
2	LEFT	37.52	35.63	15.47	32.39	26.7	9.15	2997	9	RIGHT	37.27	36.13	14.9	32.91	25.7	8.84
5	LEFT	36.79	35.75	14.87	29.5	24.71	7.68	19	5	RIGHT	36.29	36.21	14.64	29.9	24.23	7.6
5	LEFT	38.56	37.98	17.5	31.61	24.88	7.77	18	5	RIGHT	38.47	37.72	17.08	31.54	24.48	7.94
5	LEFT	37.1	36.64	14.57	31.26	24.75	8.12	9	5	RIGHT	37.33	36.79	14.54	31.46	24.84	8.25

6	LEFT	39.99	39	14.57	33.78	27.11	9.23	711	6	RIGHT	38.95	38.76	14.02	33.59	26.26	9.09
6	LEFT	39.3	36.57	13.56	31.25	24.91	8.77	716	6	RIGHT	37.59	35.84	13.16	31.64	24.14	8.71
6	LEFT	41.3	38.48	15.2	33.09	25.88	8.88	726	6	RIGHT	40.65	38.27	15.05	32.8	26.01	8.62
8	LEFT	34.95	33.58	14.64	31.29	23.96	8.76	2998	9	RIGHT	34.94	34.24	14.53	31.12	23.38	8.18
9	LEFT	38.89	37.49	13.6	31.95	25.48	8.66	114	9	RIGHT	38.55	37.55	14.05	32.16	25.48	8.34
9	LEFT	39.01	37.6	16.04	33.66	26.88	9.56	116	9	RIGHT	38.93	37.28	15.73	33.35	26.37	9.48

#### Distal and Proximal Epiphysis of Radi Refits

CSN	House	SIDE	RD2	RD3	RD8	RD9	CSN	House	SIDE	RD2	RD3	RD8	RD9
768	6	LEFT-DI	32.03	31.95	24.79	10.94	3265	7	RIGHT-DI	32.73	32.36	24.27	11.49
2577	2	LEFT-DI	37.05	33.28	26.8	10.61	3517	0	RIGHT-DI	36.07	33.74	26.16	10.98
2792	3	LEFT-DI	35.1	32.19	24.89	10.85	3513	0	RIGHT-DI	34.95	32.17	24.71	11.02
CSN	House	SIDE	RD6	RD7	RD10	RD11	CSN	House	SIDE	RD6	RD7	RD10	RD11
783	6	LEFT-PR	39.09	35.56	20.79	15.19	2802	3	RIGHT-PR	40.21	36.68	20.38	14.92
784	6	LEFT-PR	37.89	35.43	20.64	12.67	47	1	RIGHT-PR	38.43	36.48	20.44	11.54
3582	8	LEFT-PR	35.98	33.51	18.22	13.15	461	1	RIGHT-PR	35.42	34.3	17.69	11.03
3800	9	LEFT-PR	35.14	32.61	18.8	13.44	2591	2	RIGHT-PR	36.04	33.59	19.05	12.62
10	10	LEFT-PR	33.24	32.2	17.49	11.53	8	10	RIGHT-PR	33.53	32.03	17.69	11.85

# Tibiae Refits

CSN	House	SIDE	TA1A	TA2A	TA3A	TA7	TA10	TA14	CSN	House	SIDE	TA1A	TA2A	TA3A	TA7	TA10	TA14
2370	1	LEFT	20.37	15.87	20.16	32.45	24.95	19.5	2976	9	RIGHT	20.22	16.04	20.57	32.91	24.78	21.77
2635	2	LEFT	18.52	12.84	19.22	30.86	24.43	21.7	2621	2	RIGHT	18.72	13.24	20.34	30.31	24.18	21.32
2637	2	LEFT	18.5	12.87	20.49	29.83	22.78	21.08	2615	2	RIGHT	18.92	13.42	19.23	29.34	23.07	20.86
2649	2	LEFT	20.67	15.84	20.24	34.24	24.89	23.56	2614	2	RIGHT	20.13	14.92	22	33.4	24.91	23.74
2655	2	LEFT	18.82	14.76	20.87	31.11	23.85	21.95	2626	2	RIGHT	18.86	15.42	20.12	32.69	22.7	22.15
2640	2	LEFT	20.72	15.46	22.56	33.5	26.42	23.78	3385	5	RIGHT	20.81	16.13	23.04	34.6	26.45	23.07
2646	2	LEFT	19.13	14.97	20.47	32.13	16.02	22.51	3387	5	RIGHT	19.52	15.57	20.99	32.48	16.43	22.35
2647	2	LEFT	19.34	14.11	20.45	33.45	24.34	22.52	3132	11	RIGHT	19.94	14.36	20.73	33.27	23.67	22.23
2812	3	LEFT	19.07	14.02	21.76	31.89	24.86	23.56	2627	2	RIGHT	19.25	14.51	21.89	32.48	24.68	22.91
2815	3	LEFT	20	15.3	21.57	33.86	25.77	22.07	739	6	RIGHT	20.18	16.57	22.18	33.54	25.55	22
2916	4	LEFT	19.62	14.89	20.56	32.48	24.78	21.38	3134	11	RIGHT	19.41	14.88	20.56	32.31	24.76	21.87
3427	5	LEFT	18.63	15.02	22.63	33.39	25.32	23.64	3389	5	RIGHT	18.73	15.36	21.84	33.17	24.35	23.22
3435	5	LEFT	20.87	15.73	22.71	34.68	26.38	22.77	3385	5	RIGHT	20.81	16.13	23.04	34.6	26.45	23.07
3431	5	LEFT	20.37	15.31	22	32.9	25.16	23.03	2981	9	RIGHT	20.48	15.82	22.04	33.2	25.41	23.3
3437	5	LEFT	18.91	14.53	22.52	34.11	26.82	22.79	3127	11	RIGHT	19.1	14.43	22.38	34.71	26.74	23.51
732	6	LEFT	19.54	15.71	20.37	32.47	23.02	22.44	2628	2	RIGHT	19.25	14.86	20.71	31.91	23.42	21.64
759	6	LEFT	20.2	15.59	19.53	32.86	24.19	22.45	2908	4	RIGHT	19.46	16.07	19.29	32.31	24.14	23.16
755	6	LEFT	18.91	14.96	21.12	32.69	25.03	19.93	754	6	RIGHT	19.54	14.89	21.83	32.52	24.97	23.33
756	6	LEFT	20.66	16.32	21.96	33.84	25.58	23.68	757	6	RIGHT	20.64	16.31	22.37	34.32	25.29	22.91
760	6	LEFT	19.28	16.12	21.34	31.81	24.47	22.91	761	6	RIGHT	19.31	15.18	21.45	31.32	24.25	22.71
763	6	LEFT	18.72	16.15	21.2	33.28	24.81	24.23	762	6	RIGHT	19.02	14.84	21.39	33.19	25.36	24.32
765	6	LEFT	17.69	14.46	19.58	28.67	22.97	21.54	764	6	RIGHT	18.71	14.68	19.97	28.83	23.51	21.19
3616	8	LEFT	19.97	15.66	22.11	34.23	26.28	24.15	2630	2	RIGHT	20.32	15.81	22.24	33.99	26.31	23.61
2989	9	LEFT	18.92	14.89	20.75	32.54	23.56	23.5	2811	3	RIGHT	19.14	14.39	21.45	32.41	23.65	22.74



2985	9	LEFT	20.92	15.75	23.37	34.57	26.96	24.05	2903	4	RIGHT	21.03	16.94	23.8	34.19	26.67	23.85
2987	9	LEFT	19.72	14.81	20.77	32.68	25.35	22.67	3131	11	RIGHT	19.67	14.65	20.38	33.19	25.42	23.72
3140	11	LEFT	18.79	14.47	20.71	32.35	24.25	23.22	2622	2	RIGHT	18.83	14.67	21.06	31.52	24.16	21.81
3441	5	LEFT	20.98	14.98	21.88	34.28	25.58	24.14	2902	4	RIGHT	19.41	15.72	21.56	32.51	25.6	22.59
3142	11	LEFT	18.93	15.47	20.69	32.45	24.75	21.88	3135	11	RIGHT	19.08	14.84	20.7	32.33	24.83	22.51

## References Cited

- Allen-Arave, W., M. Gurven, and K. Hill  
2008. Reciprocal altruism, rather than kin selection, maintains nepotistic food transfers on an Ache reservation. *Evolution and Human Behavior* 29, 305-318.
- Alvard, M.S.  
2002 Carcass ownership and meat distribution by big game cooperative hunters. *Research in Economic Anthropology* 21:99-131.
- Alvard, M.S. and D.A. Nolin  
2002 Rosseau's Whale Hunt? *Current Anthropology* 43:533-559.
- Arkush, B. S.  
1986 Aboriginal Exploitation of Pronghorn in the Great Basin. *Journal of Ethnobiology* 6:239-255.
- Bachuchet, S.  
1990 Food Sharing Among the Pygmies of Central Africa. *African Study Monographs* 11:27-53.
- Bailey, R.C.  
1991 The Behavioral Ecology of Efe Pygmy Men in the Ituri Forest, Zaire. *Anthropological Papers No. 86*, Museum of Anthropology, University of Michigan, Ann Arbor.
- Bar-Oz, G. and N.D. Munro  
2007 Gazelle bone marrow yields and Epipaleolithic carcass exploitation strategies in the southern Levant. *Journal of Archaeological Science* 37:946-956.
- Binford, L.R.  
1978 *Nunamiut Ethnoarchaeology*. Academic Press, New York.
- Bleige Bird, R.L. and D.W. Bird  
1997 Delayed Reciprocity and Tolerated Theft: The Behavioral Ecology of Food-Sharing Strategies. *Current Anthropology* 38:49-78.
- Blumenschine, R. J. and C. W. Marean  
1993 A Carnivore's View of Archaeological Bone Assemblages. In *From Bones to Behavior: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains*, edited by J. Hudson, pp. 273-300. Center for Archaeological Investigations, Carbondale, IL.
- Bogan, A.

1983 Evidence for Faunal Resource Partitioning in an Eastern North American Chiefdom. In *Animals and Archaeology: Vol. 1, Hunters and Their Prey*, edited by C. Grigson and J. Clutton-Brock, pp. 305-324. vol. 163. B.A.R. International Series, Oxford.

Boyd, R. and P.J Richerson

1985 *Culture and Evolutionary Process*. University of Chicago Press, Chicago.

Burger, O., M. J. Hamilton and R. Walker

2005 The prey as a patch model: optimal handling of resources with diminishing returns. *Journal of Archaeological Science* 32:1147-1158.

Byers, D.A. and B.L. Hill

2009 Pronghorn Dental Age Profiles and Holocene Hunting Strategies at Hogup Cave, Utah. *American Antiquity* 2009:299-321.

Dall, S.R.X.

2002 Can information sharing explain recruitment to food from communal roosts? *Behavioral Ecology* 13:42-51.

Davis, L. B. and J. W. Fisher

1990 A Late Prehistoric Prehistoric Model for Communal Utilization of Pronghorn Antelope in the Northwestern Plains Region, North America. In *Hunters of the Recent Past*, edited by L. B. Davis and B. O. K. Reeves, pp. 241-276. Unwin Hyman, London.

Davis, L. B., J. W. Fisher, M. C. Wilson, S. A. Chomko and R. E. Morlan

2000 Avonlea Phase Winter Fare at Lost Terrace, Upper Missouri River Valley of Montana: The Vertebrate Fauna. *Plains Anthropologist* 45(MEMOIR 32):53-69.

Driver, J. C.

1990 Meat in due season: the timing of communal hunts. In *Hunters of the Recent Past*, edited by L. B. Davis and B. O. K. Reeves, pp. 241-276. *One World Archaeology* 15. Unwin Hyman, London.

Dubois, F., L.A. Giraldeau and J.W.A. Grant

2003 Resource defense in a group-foraging context *Behavioral Ecology* 14:2-9.

Egan, H. R.

1917 *Pioneering the West, 1846 to 1878*. Howard R. Egan Estate, Richmond, Utah.

Emerson, T. E.

1990 *Archaeological Implications of Variability in the Economic Anatomy of Bison bison*, Unpublished Dissertation, Department of Anthropology, University of Michigan, Ann Arbor.

Enloe, J. G.

1991 Subsistence Organization in the Upper Paleolithic: Carcass Refitting and Food Sharing at Pincevent. Unpublished Dissertation, Department of Anthropology, University of New Mexico, Albuquerque.

2003 Food Sharing Past and Present: Archaeological Evidence for Economic and Social Interaction. *Before Farming* 1:1-23.

Enloe, J. G. and F. David (editors)

1992 Food Sharing in the Paleolithic: Carcass Refitting at Pincevent. 578. B.A.R. International Series Oxford.

Evans, S.T.

2004 Ancient Mexico & Central Mexico: Archaeology and Culture History. Thames & Hudson Inc., New York.

Fenner, J.

2008 The use of stable isotope ratio analysis to distinguish multiple prey kill events from mass kill events. *Journal of Archaeological Science* 35:704-716.

2009 Occasional hunts or mass kills? Investigating the origins of archaeological pronghorn bonebeds in southwest Wyoming. *American Antiquity* 74:323-350.

Field, R.A., F.C. Smith, W.G. Hepworth, and W.J. Means.

2003 The Pronghorn Antelope Carcass, Agricultural Experiment Station Report No. B-565R, University of Wyoming, Laramie.

Fisher, J. W. and G. C. Frison

2000 Site Structure and Zooarchaeology at the Boar's Tusk Site, Wyoming. *Plains Anthropologist* 45(MEMOIR 32):89-108.

Fraser, C.P., G.D. Ruxton and M. Broom

2006 Public information and patch estimation for group foragers: a re-evaluation of patch-quitting strategies in a patchy environment. *OIKOS* 112: 311-321.

Frison, G. C.

1971 Shoshonean antelope procurement in the upper Green River Basin, Wyoming. *Plains Anthropologist* 16:258-284.

1991 Prehistoric Hunters of the High Plains. Academic Press, San Diego.

2000 Observations on Pronghorn Behavior and Taphonomic Analysis of Bonebeds: Implications for Analysis of the Eden-Farson Pronghorn Kill. *Plains Anthropologist* 45(MEMOIR 32):29-37.

2004 *Survival by Hunting: Prehistoric Human Predators and Animal Prey*. Berkeley, University of California Press.

Gargett, R. and B. Hayden

1990 Site Structure, Kinship, and Sharing in Aboriginal Australia: Implications for Archaeology. In *The Interpretation of Archaeological Spatial Patterning*, edited by E. Kroll and T. D. Price, pp. 11-32. Plenum Press, New York.

Giraldeau, L.A. and T. Caraco

2000 *Social Foraging Theory*. Princeton University Press, Princeton.

Gould, R. A.

1968 Living archaeology: the Ngatatjara of Western Australia. *Southwestern Journal of Anthropology* 24:101-122.

Gould, R.A., J.E. Yellen

1987 Man the hunted: determinants of household spacing in desert and tropical foraging societies. *Journal of Anthropological Archaeology* 6, 77-103.

Gurven, M.

2004 To give or not to give: The behavioral ecology of human food transfers. *Behavioral and Brain Sciences* 27, 543-583.

Gurven, M., W. Allen-Arave and A.M. Hurtado

2001 Reservation Food Sharing among the Ache of Paraguay,. *Human Nature* 12:273-297.

Hamilton, I.M.

2000 Recruiters and Joiners: Using Optimal Skew Theory to Predict Group Size and the Division of Resources within Groups of Social Foragers. *The American Naturalist* 155:684-695.

Hamilton, W.D.

1963 The evolution of altruistic behavior. *American Naturalist* 97:354-356.

Hawkes, K. and R.L. Bleige Bird

2002 Showing Off, Handicap Signaling, and the Evolution of Men's Work. *Evolutionary Anthropology* 11:58-67.

Hawkes, K., J.F. O'Connell and N.B. Jones

2000 Hadza Meat Sharing. *Evolution and Human Behavior* 22:113-142.

Hayden, B.

2001 Richman, Poorman, Beggarman, Chief: The Dynamics of Social Inequality. In *Archaeology at the Millenium: A sourcebook*, edited by G. Feinman, and T. Price, Pp. 231-272. Kluwer Academic/Plenum Publishers: New York. Pp. 231–272.

Heaton, J.W.

2005 *The Shoshone-Bannocks: Culture and Commerce at Fort Hall 1870-1940*. University Press of Kansas, Lawrence.

Hill, K., H. Kaplan and K. Hawkes

1993 Why Male Foragers Hunt and Share Food. *Current Anthropology* 34:701-710.

Hill, W.W

1938 *The Agricultural and Hunting Methods of the Navajo Indians*. Yale University Press, New Haven.

Hockett, B. and T.W. Murphy

2009 Antiquity of Communal Pronghorn Hunting in the North-Central Great Basin. *American Antiquity* 74:708-734.

Hoebel, E.A.

1978 *The Cheyennes: Indians of the Great Plains*. Holt, Rinehart, and Winston, New York.

Hofman, J.L.

1981 The Refitting of Chipped-Stone Artifacts as an Analytical and Interpretive Tool. *Current Anthropology* 22:691-693.

Hofman, J.L. and J.G. Enloe (editors)

1992 *Piecing Together the Past: Applications of Refitting Studies in Archaeology*. 578. B.A.R. International Series, Oxford.

Hooper, P.L., H. Kaplan and J.L. Boone

2010 A theory of leadership in human cooperative groups. *Journal of Theoretical Biology* 265:633-645.

Hultzkrantz, A.

1961 The Shoshone of the Rocky Mountains. *Annals of Wyoming* 33:19-41.

Hultzkrantz, A.

1970 Attitudes to Animals. *Studies in Comparative Religion* 4:70-79.

Jackson, H.E. and S.L. Scott

1995 Mississippian Homestead and Village Subsistence Organization: Contrasts in Large Mammal Remains from Two Sites in the Tombigbee Valley. In *Mississippian*

Communities and Household, edited by J. D. Rogers and B. D. Smith, pp. 181-200. The University of Alabama Press, Tuscaloosa.

Johnson, R.A. and D.W. Wichern

2007 Applied Multivariate Statistical Analysis. 6th Edition ed. Pearson, New York.

Jones, K.T. and D. Metcalfe

1988 Bare Bones Archaeology: Bone Marrow Indices and Efficiency. *Journal of Archaeological Science* 15:415-423.

Kaplan, H. and K. Hill

1985 Food Sharing among Ache Foragers: tests of explanatory hypotheses. *Current Anthropology* 26:223-246.

Kaplan, H., K. Hill, J. Lancaster and A.M. Hurtado

2000 A Theory of Human Life History Evolution: Diet, Intelligence, and Longevity. *Evolutionary Anthropology* 9:156-185.

Kelenka, P.

2009 The Horse in Human History. Cambridge University Press, Cambridge.

Kelly, L.S.

1997 Patterns of Faunal Exploitation at Cahokia. In *Cahokia: Domination and Ideology in the Mississippian World*, edited by T. R. Pauketat and T. E. Emerson, pp. 69-88. University of Nebraska Press, Lincoln.

Kelly, R.L.

1995 The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways. Smithsonian Institution Press, Washington D.C.

Kitanishi, K.

1998 The Aka and Baka: Food Sharing Among Two Central Africa Hunter-Gatherer Groups. In *The Social Economy of Sharing: Resource Allocation and Modern Hunter-Gatherers*, edited by G. W. Wenzel, G. Hovelsrud-Broda and N. Kishigami, pp. 149-168. National Museum of Ethnology, Osaka.

2001 Food Sharing Among the Aka Hunter-Gatherers in Northeastern Congo. *African Study Monographs* 25:3-32.

Larson, R., J. Bozovich and J. Krmpotich

1969 Preliminary Report on Farson Site #48SW304. *Wyoming Archaeologist* 12:13-16.

Lubinski, P.M.

1997 Pronghorn Intensification in the Wyoming Basin: A Study of Mortality Patterns and Prehistoric Hunting Strategies. Unpublished Doctoral Dissertation, Department of Anthropology, University of Wisconsin, Milwaukee.

1999 The Communal Pronghorn Hunt: A Review of the Ethnographic and Archaeological Evidence. *Journal of California and Great Basin Archaeology* 21:151-181.

2013 What is adequate evidence for mass procurement of ungulates in zooarchaeology? *Quaternary International* 297: 167-175.

Lubinski, P.M. and V. Herren

2000 An Introduction to Pronghorn Biology, Ethnography and Archaeology. *Plains Anthropologist* 45(MEMOIR 32):3-11.

Lubinski, P.M. and C.J. O'Brien

2001 Observations of Seasonality and Mortality from a Recent Catastrophic Death Assemblage. *Journal of Archaeological Science* 28:833-842.

Lyman, R.L.

1992 Anatomical considerations of utility curves in zooarchaeology. *Journal of Archaeological Science* 19:7-22.

2006 Identifying bilateral pairs of deer (*Odocoileus* sp.) bones: How symmetrical is symmetrical enough? *Journal of Archaeological Science* 33:1256-1265.

2008a *Quantitative Paleozoology*. Cambridge University Press, Cambridge.

2008b (Zoo)Archaeological Refitting: A Consideration of Methods and Analytical Search Radius. *Journal of Anthropological Research* 64:229-248.

Lyman, R.L. and T.L. Van Pool

2009 Metric Data in Archaeology, *American Antiquity* 74, 458-504.

Madrigal, T.C. and J.Z. Holt

2002 White-Tailed Deer Meat and Marrow Return Rates and their Application to Eastern Woodlands Archaeology. *American Antiquity* 67:745-759.

Malouf, C.

1974 *Shoshone Indians*. Garland Publishing Inc., New York.

Marshall, F.

1994 Food Sharing and Body Part Representation in Okiek Faunal Assemblages. *Journal of Archaeological Science* 21:65-77.

McCullough, D.R. and D.E. Ullrey



1983 Proximate Mineral and Gross Energy Composition of White-Tailed Deer. The Journal of Wildlife Management 47:430-441.

Medeiros, L.C., J.R. Busboon, R.A. Field, J.C. Williams, G.J. Miller and B. Holmes  
2002 Nutritional Content of Game Meat. University of Wyoming.

Metcalf, D. and K. R. Barlow  
1994 A Model for Exploring the Optimal Trade-off between Field Processing and Transport. American Anthropologist 94:340-356.

Metcalf, D. and K.T. Jones  
1988 A Reconsideration of Animal Body-Part Utility Indices. American Antiquity 53:486-504.

Miller, M.E. and P.S. Sanders  
2000 The Tappers Point Site (48SU1006): Early Archaic Adaptations and Pronghorn Procurement in the Upper Green River Basin, Wyoming. Plains Anthropologist 45(MEMOIR 32):39-52.

Mulloy, W.T.  
1955 A Preliminary Historical Outline for the Northwestern Plains. In University of Wyoming Publications in Science 22 (1), Laramie, WY.

Murphy, R.F. and Y. Murphy  
1960 Shoshone-Bannock Subsistence and Society. In Anthropological Records, pp. 291-338. vol. 16, University of California.

Nimmo, B.W.  
1971 Population Dynamics of a Wyoming Pronghorn Cohort from the Eden-Farson Site, 48SW304. Plains Anthropologist 16:285-288.

Nolin, D.  
2010 Food-Sharing Networks in Lamalera, Indonesia: Reciprocity, Kinship, and Distance. Human Nature 21:243-268.

O'Brien, M.J.  
*In Press* Evaluating the Contemporaneity of Households at the Eden-Farson site. Submitted to the International Journal of Osteoarchaeology.

O'Brien, M. J. and C. B. Storlie  
2011 An Alternative Bilateral Refitting Model for Zooarchaeological Assemblages. Journal of Taphonomy 9:245-268.

O'Brien, M.J. and T.A. Surovell  
*In review* Camp Structure and Kinship among the Dukha Reindeer Herders of Mongolia. Submitted to Journal of Anthropological Archaeology.

- O'Connell, J.F.  
1987 Alywara Site Structure and Its Archaeological Implications. *American Antiquity* 52:74-108.
- O'Connell, J.F., K. Hawkes and N.B. Jones  
1991 Distribution of refuse-producing activities at Hadza base camps: Implications for analyses of archaeological site structure. In *The Interpretation of Archaeological Spatial Patterning*, edited by E. M. Kroll and T. D. Price, pp. 61-76. Plenum Press, New York.
- O'Gara, B.W.  
2004 Physical Characteristics. In *Pronghorn: Ecology and Management*, edited by B. W. O'Gara and J. D. Yoakum, pp. 109-144. University of Colorado Press, Boulder.
- Ostrom, E.  
1990 *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press, Cambridge.  
1997 A Behavioral Approach to the Rational Choice Theory of Collective Action. *The American Political Science Review* 92:1-22.
- Oswalt, W.H.  
1976 *An Anthropological Analysis of Food-Getting Technology*. John Wiley & Sons, New York.
- Outram, A. and P. Rowley-Conwy  
1998 Meat and Marrow Utility Indices for Horse (*Equus*). *Journal of Archaeological Science* 25:839-849.
- Price, T. and G. Feinman  
1995 Introduction. In *Foundations of Social Inequality: Fundamental Issues in Archaeology*, edited by G. Feinman and T. Price, Pp. 3-10. Springer Press, New York.
- Rands, S.A., R.A. Pettifor, J.M. Rowcliffe and G. Cowlishaw  
2006 Social foraging and dominance relationships: the effects of socially mediated interference. *Behavioral Ecological Sociobiology* 60:572-581.
- Renfrew, C. and P. Bahn  
2008 *Archaeology: Theories, Methods, and Practice*, 5th Edition. Thames & Hudson Inc., New York.
- Rowley-Conwy, P., P. Halstead and P. Collins  
2002 Derivation and Application of a Food Utility Index (FUI) for European Wild Boar (*Sus scrofa* L.). *Environmental Archaeology* 7:77-88.
- Russell, O.

- 1970 [1955] *Journal of a Fur Trapper*. University of Nebraska Press, Lincoln.
- Sahlins, M.  
1972 *Stone Age Economics*. Aldine Publishing Company, New York.
- Savelle, J. M. and T. M. Friesen  
1996 An Odontocete (Cetacea) Meat Utility Index. *Journal of Archaeological Science* 23:713-721.
- Service, E.R.  
1966 *The Hunters*. Prentice Hall, Englewood Cliffs, NJ.
- Shimkin, D.B.  
1947 Wind River Shoshone Ethnography. In *Anthropological Records*, pp. 245-284. vol. 5, University of California.
- Smith, A.M.  
1974 *Ethnography of the Northern Utes*. Papers in Anthropology No. 17. Museum of Santa Fe, Santa Fe.
- Smith, E.A.  
1991 *Inujjamiut Foraging Strategies*. Aldine de Gruyter, New York.
- Smith, E.A. and J.K. Choi  
2007 The emergence of inequality in small-scale societies: Simple scenarios and agent-based simulations. In *The Model-based Archaeology of Socionatural Systems*, edited by T. Kohler and S. v. d. Leeuw, pp. 105-119. SAR Press, Santa Fe.
- Smith, E.A., K. Hill, F.W. Marlowe, D. Nolin, P. Weissner, M. Gurven, S. Bowles, M.B. Mulder, T. Hertz and A. Bell  
2010 Wealth Transmission and Inequality among Hunter Gatherers. *Current Anthropology* 51:19-34.
- Smith, E.A. and B. Winterhalder  
1992 *Evolutionary Ecology and Human Behavior*. Walter de Gruyter & Co., New York.
- Sosis, R.  
1997 The Collective Action Problem of Male Cooperative Labor on Ifaluk Atoll, Unpublished Doctoral Dissertation, Department of Anthropology, University of New Mexico, Albuquerque.
- Speth, J.D. and K.A. Spielmann  
1983 Energy source, protein metabolism, and hunter-gatherer subsistence strategies. *Journal of Anthropological Archaeology* 2: 1-31.

- Stephens, D.W., J.S. Brown, R.C. Ydenberg  
2007 Foraging Behavior and Ecology. The University of Chicago Press, Chicago.
- Stephens, D.W. and J.R. Krebs  
1986 Foraging Theory. Princeton University Press, Princeton.
- Steward, J.  
1938 Basin-Plateau Aboriginal Sociopolitical Groups. In Bureau of American Ethnology Bulletin. vol. 120, Smithsonian Institution.
- Steward, J.  
1943 Cultural Element Distributions: XVIII Ute-Shoshoni. Anthropological Records 8:263-292.
- Stiner, M.C.  
1990 The Use of Mortality Patterns in Archaeological Studies of Hominid Predatory Adaptations. Journal of Anthropological Archaeology 9:305-351.
- Todd, L. C.  
1983 The Horner Site: Taphonomy of an early Holocene Bison Bonebed. Unpublished Doctoral Dissertation, Department of Anthropology, University of New Mexico, Albuquerque.
- 1987 Bison Bone Measurements. In The Horner Site: The Type Site of the Cody Cultural Complex, edited by G. C. Frison and L. C. Todd, pp. 371-403. Academic Press, New York.
- Trivers, R.L.  
1971 The evolution of reciprocal altruism. Quarterly Review of Biology 46:35-57.
- Vehrencamp, S.L.  
1983 A Model for the Evolution of Despotic Versus Egalitarian Societies. Animal Behaviour 31:667-682.
- Voland, E.  
1998 Evolutionary ecology of human reproduction. Annual Review of Anthropology 27:347-374.
- Waguespack, N.M.  
2002 Caribou Sharing and Storage: Refitting the Palangana Site. Journal of Anthropological Archaeology 21:396-417.
- Walker, D.N.

2000 Pleistocene and Holocene Records of *Antilocapra Americana*: A Review of the FAUNMAP Data. *Plains Anthropologist* 45:13-28.

Whitelaw, T.M.

1983 People and space in hunter-gatherer camps: a generalizing approach in ethnoarchaeology. *Archaeological Review From Cambridge* 2:48-66.

Whitelaw, T.M.

1991 Some Dimensions of variability in the social organization of community space among foragers. In: Gamble, C.S., Boismier, W.A. (Eds.), *Ethnoarchaeological approaches to mobile campsites*, pp. 371-93. *Ethnoarchaeological Series, 1, International Monographs in Prehistory*, Ann Arbor.

Winterhalder, B.

1997 Gifts Given, Gifts Taken: The Behavioral Ecology of Nonmarket Exchange. *Journal of Archaeological Research* 5:121-168.

Yellen, J.E.

1977 *Archaeological approaches to the present*. Academic Press, New York.

Yoakum, J.D.

2004 Distribution and Abundance. In *Pronghorn: Ecology and Management*, edited by B. W. O’Gara and J. D. Yoakum, pp. 75-108. University of Colorado Press, Boulder.

Ziker, J. and M. Schnegg

2005 Food Sharing at Meals: Kinship, Reciprocity, and Clustering in the Taimyr Autonomous Okrug, Northern Russia. *Human Nature* 16, 178-211.