TAPHONOMY AND ZOOARCHAEOLOGY OF FAUNAL ASSEMBLAGES FROM ARCHAEOLOGICAL SITES ALONG THE UPPER SUSITNA RIVER, ALASKA

A Thesis

by

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ABSTRACT

Reported here is a zooarchaeological and taphonomic analysis of faunal material from the archaeological sites HEA-455 and HEA-499, located in the upper Susitna River basin in the central Alaska Range. The bones are highly fragmented, yet indications of human activities and behaviors related to subsistence and site maintenance can still be inferred. The goal of the study was to determine what kind of information can be gleaned from highly fragmentary burned faunal assemblages typical of prehistoric sites in Alaska. The faunal assemblages used in this study were zooarchaeologically and taphonomically analyzed by identifying any preserved skeletal elements using reference collections, sorted based on fragment sizes and degree of burning evident on the bone fragments, and by assessing the relationship between bone fragment size and degree of burning intensity within and between sites. The bone fragments from these two archaeological sites appear to be burned directly from human activities. Results provide insight into prehistoric subsistence and site activities related to intensive burning of hunted faunal remains in the mountainous Alaska Range during the middle Holocene, as well as a better understanding of taphonomic processes in play in northern, subarctic environments.

DEDICATION

To my Mother and Father,

For their unwavering love and support.

ACKNOWLEDGEMENTS

First, I would like to thank my parents and family for their support (in many ways) throughout my college career. Without their dedication to my education and pursuit of higher degrees I would not be here; therefore, I would like to acknowledge all that they have sacrificed and done so that I may fulfill my scholarly goals.

Next, I would like to thank my chair and advisor, Dr. Ted Goebel, for his aid and guidance during my time at Texas A&M University, along with my committee members Dr. Kelly Graf and Dr. Jane Packard for their support in completing this research. I would like to recognize the Mammalogy Department at the University of Alaska Museum of the North for providing access to their modern faunal reference collection.

I also extend thanks for assistance and guidance from John Blong, who not only provided the faunal assemblages used in this research, but who made the completion of this project possible. Thanks and appreciation must also be extended to my Alaska summer field buddies, Angela Gore, Josh Lynch, Whitney McLaren and Allie Pelto, for the many adventures we had (Helga, Bolio Lake, KJs, and so on).

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INTRODUCTION

Determination of prehistoric subsistence behaviors and strategies is limited by the material remains that survived site formation and deformation processes, which typically took place over a few thousand years. One way archaeologists have understood prehistoric human activities is through the analysis of faunal material from archaeological contexts (Betts 2004; Darwent 1995, 2001; Darwent and Foin 2010; Gotfredsen 2010; Hodgetts et al. 2003; Howse 2008; Lofthouse 2003; Moss and Bowers 2007; Potter 2007; Shirar 2009; Skeete 2008; Tremayne 2011). An ideal situation is when faunal material can be taxonomically identified and shown to be the result of human behavior, providing clear indications of prehistoric human subsistence and use. In many situations, however, faunal materials are not sufficiently preserved to determine taxonomic identifications, or even to perform in-depth taphonomic or zooarchaeological analyses (Lyman 1984; Marean 1991; Meadow 1980). Often, the faunal record at sites is so fragmentary that little data can be gleaned from faunal remains, limiting attempts to determine subsistence activities or behaviors. Typical analyses, including utility indices, transport, and processing patterns cannot be utilized in these situations, so that stone tools and debitage are often the only materials useful for reconstructing human behavior. Nonetheless, even highly fragmented and poorly preserved materials can provide signs of prehistoric subsistence activities.

In this study, I conducted taphonomic and zooarchaeological analyses of highly fragmented faunal materials from two prehistoric sites, HEA-455 and HEA-499, located

in the upper Susitna River valley, Alaska. The goals were to 1) understand subsistence behaviors at the two sites in the context of early to late Holocene subsistence patterns in central Alaska, 2) determine what information can be gleaned from highly fragmented faunal assemblages and how these types of assemblages can inform on subsistence patterns in the upper Susitna River valley, and 3) contribute to current knowledge about taphonomic processes leading to formation of highly fragmented burned-bone assemblages. The degree of burning evident in both faunal assemblages indicates intensive processing of hunted game as well as direct and intentional burning of bones in hearths occurred at the two sites. Despite poor preservation of these sites' faunal assemblages, some insight into prehistoric subsistence and formation processes can still be obtained from HEA-455 and HEA-499.

BACKGROUND

Site Information and Study Area

The prehistoric sites HEA-455 and HEA-499 are located in the upper Susitna River basin of the central Alaska Range (Figure 1). Both sites are located on the western side of the Susitna valley on elevated terraces overlooking the river. HEA-455 is approximately 12-15 km north of HEA-499, but on opposite sides of the Denali Highway. John Blong (Texas A&M University) conducted test excavations of both sites in summer 2012, collecting both stone artifacts and faunal artifacts.

At HEA-455 (Figures 2 and 3), three components were identified, with component III overlying the Devil tephra, component II situated below the Watana tephra, and component I above the Oshetna tephra. The faunal remains were found mainly in a hearth feature of component II, which yielded a wood charcoal AMS date of 3740 ± 30 ^{14}C BP (OS-101611). At HEA-499 (Figures 2 and 4), two components were identified, with component II above the Devil tephra and component I below the Watana tephra. Two hearth features were excavated from component I. Feature 1 contained dense concentrations of lithics, faunal remains, and charcoal, a sample of which yielded a wood charcoal AMS radiocarbon age of 4060 ± 30 ^{14}C BP (OS-101614), while Feature 2 also contained dense concentrations of lithics, bone fragments, and charcoal, the latter yielding an AMS radiocarbon age of 4280 ± 25 ^{14}C BP (OS-101615).

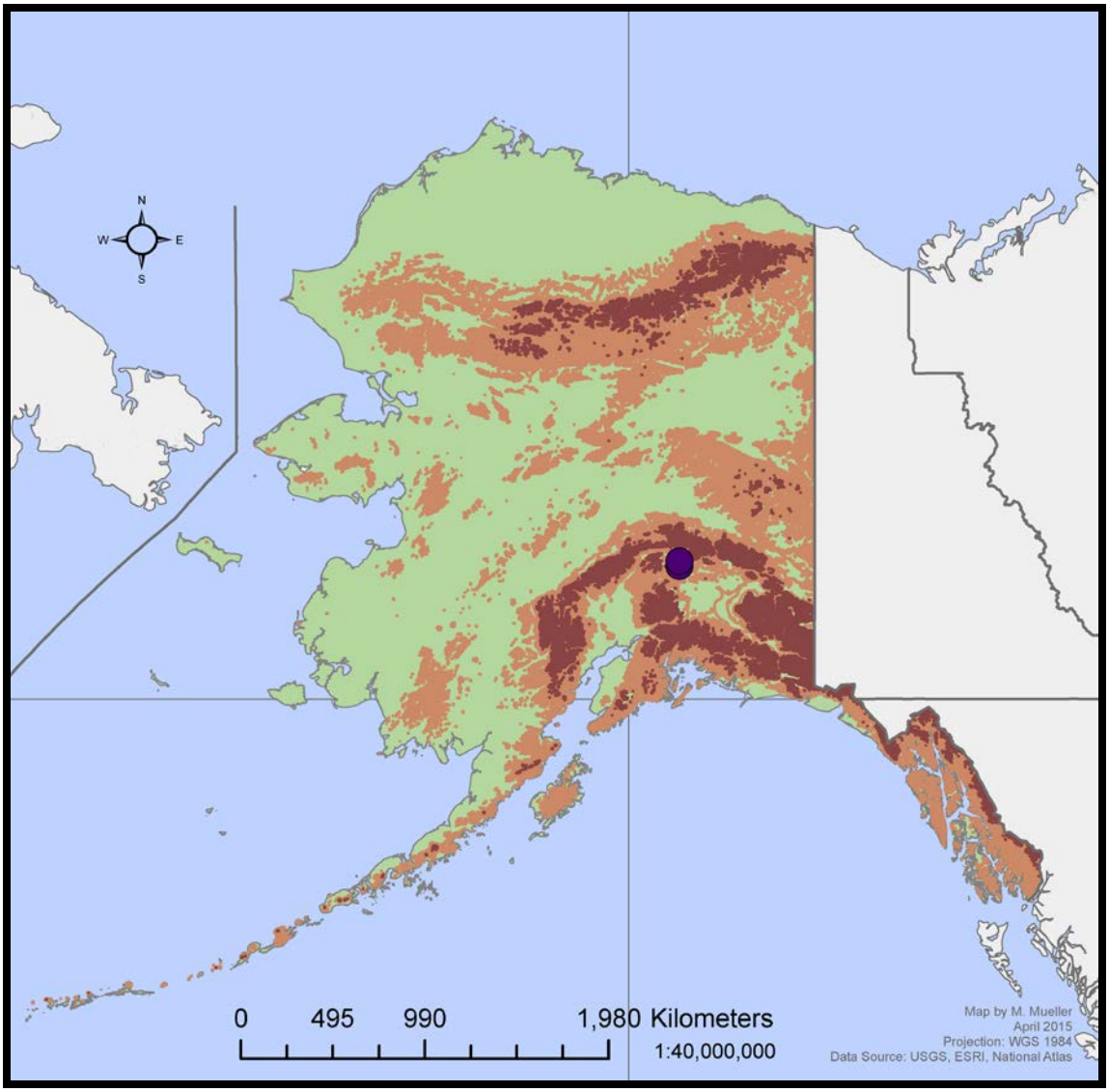

Figure 1. Location of sites in Alaska.

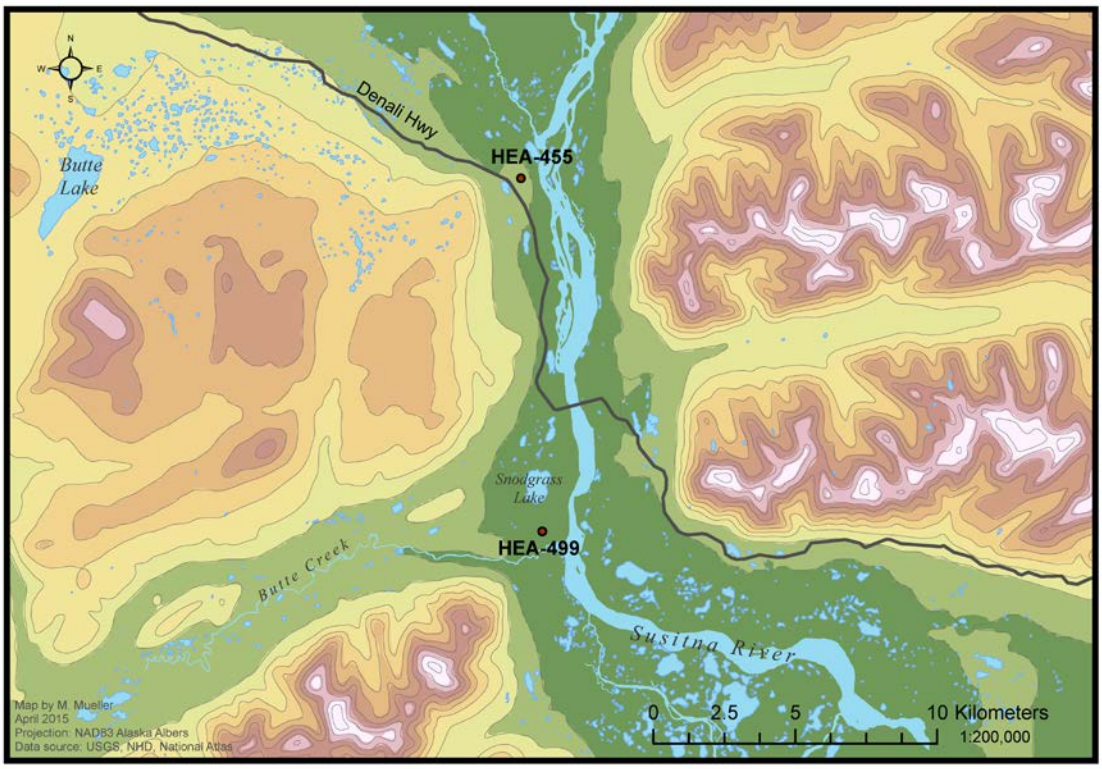

Figure 2. Map of study area. Contour intervals are 100 meters, from 700 to 1,700 meters above sea level.

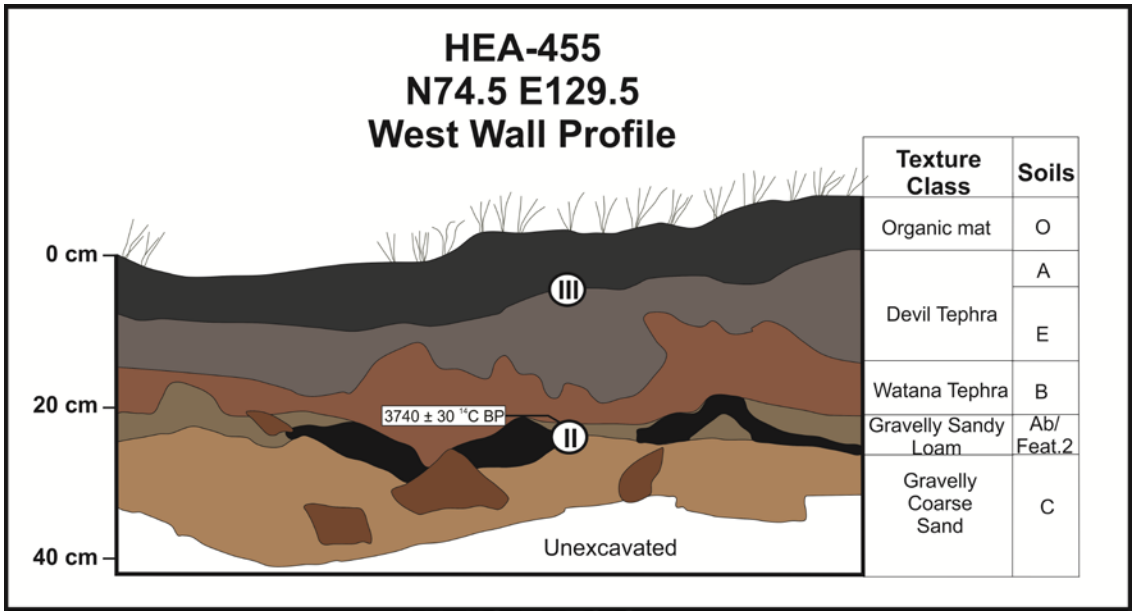

Figure 3. HEA-455 stratigraphic profile. Position of cultural components are designated by roman numerals. (Courtesy of John Blong.)

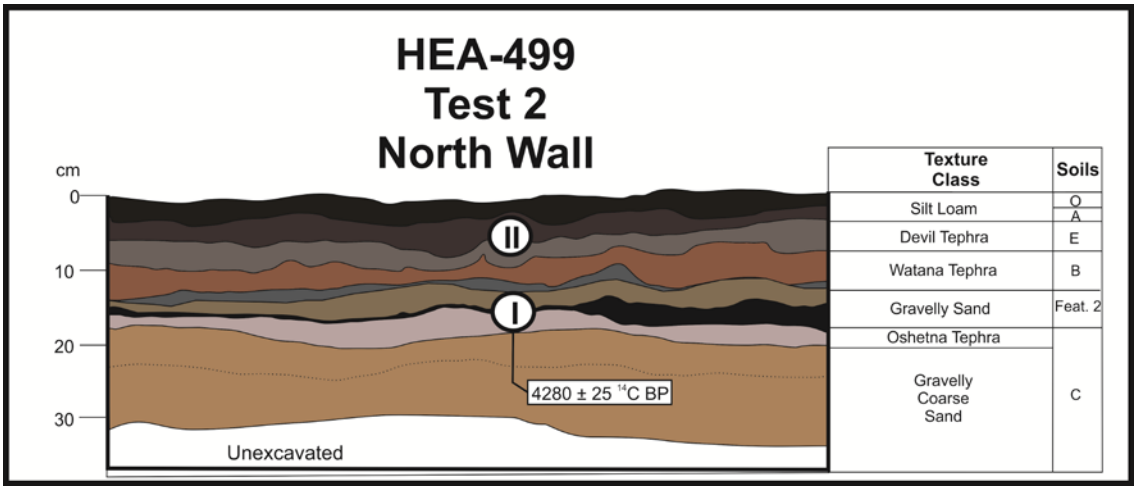

Figure 4. HEA-499 stratigraphic profile. Position of cultural components are designated by roman numerals. (Courtesy of John Blong.)

Together, the assemblages from the two sites represent middle to late Holocene use of the upper Susitna River valley in which heavily fragmented and highly calcined bones characterize the composition of the assemblages. During summer 2012, four 1 m^2 test units were excavated at each site, and both lithic and faunal materials were collected. Additional details regarding HEA-455 and HEA-499 will be presented in John Blong's PhD dissertation (Texas A&M University).

The study area, the upper Susitna River basin, is located south of the Alaska Range where summer melt from the Susitna Glacier acts as the headwater for the south-flowing river. Earliest deglaciation of the upland landscape and river basin is uncertain; however, peat deposits that likely formed after glacial retreat in the Susitna River valley, dated to 9,035 ± 335 ^{14}C BP and 9,195 ± 150 ^{14}C BP, provide a timeframe for when the area could have become accessible to prehistoric human and animal populations (Reger and Bundtzen 1990). After the onset of the Holocene, when general climate trends shifted to warmer and wetter conditions, boreal forest and shrub tundra biomes replaced herbaceous tundra in interior Alaska (Bigelow and Edwards 2001). Today, the Alaska Range ecoregion can be characterized by shallow and rocky soils with relatively little vegetation other than shrubs, such as willow, birch, and alder in valley bottoms, and sparse spruce stands dotting the landscape (Nowacki et al. 2001).

Modern faunal communities in the Susitna River valley are likely to represent available faunal resources exploitable to middle and late Holocene foragers subsisting in the area, as significant shifts in climate and vegetation communities are not documented from then to now. Large mammal species available in the uplands include moose (*Alces*

alces), Dall sheep (*Ovis dalli*), caribou (*Rangifer tarandus*), brown bear (*Ursus arctos*), and black bear (*Ursus americanus*), along with a variety of smaller mammals, including porcupine (*Erethizon dorsatum*), beaver (*Castor canadensis*), snowshoe hare (*Lepus americanus*), arctic ground squirrel (*Spermophilus parryii*), mink (*Neovison vison*), and muskrat (*Ondatra zibethicus*), as well as birds and fish (Nowacki et al. 2001; Reckord 1983; Skeete 2008).

Particularly significant for human subsistence studies in the upper Susitna River valley is the presence of migratory herds of caribou. The migratory range of the Nelchina caribou herd is bordered by the Alaska Range to the north, the Wrangell Mountains to the east, the Talkeetna Range to the west, and the Chugach Range to the south (Hemming 1975; Pitcher 1984). During the spring, caribou migration occurs to the calving grounds in the Talkeetna Range, and during the fall caribou move to the Chugach Range for over-wintering (Hemming 1971; Pitcher 1984). Although caribou from the small Upper Susitna-Nenana sub-herd are present in the area year-round, the main Nelchina herd, with a population ranging from about 10,000 to 40,000 individuals over the last few decades, can be found in the upper Susitna River valley during the late summer and early fall as they migrate east (Harper 2009; Hemming 1975; Pitcher 1984). The Upper Susitna-Nenana sub-herd has a population that ranges from 1,000 to 2,000 and can be found wintering along the Susitna River and the Butte Lake area, while calving by those in the sub-herd is known to occur over a wide geographic range (Pitcher 1984).

Local Traditional Subsistence

Caribou has been a seasonally available resource for local communities present in the area surrounding the upper Susitna River basin during modern, historic, and prehistoric times. Specifically relevant to understanding prehistoric subsistence practices from the upper Susitna River basin are the Western Ahtna, a linguistically distinct Alaskan Native Athabaskan community that has traditionally utilized and inhabited the Susitna River area (de Laguna and McClellan 1981; Reckord 1983; Skeete 2008). Ethnographic and anthropological knowledge of the Western Ahtna and their historical and prehistoric background is relatively limited, as oral histories form the basis of past accounts (de Laguna and McClellan 1981; Reckord 1983). Early depictions of Ahtna culture in particular are based on contact with Russian traders during the nineteenth century, which eventually led to a shift in subsistence and economic practices not reflective of pre-contact subsistence behaviors (de Laguna and McClellan 1981; Reckord 1983).

Archaeological awareness of prehistoric Ahtna culture has largely focused on the more well-known Copper River basin region, where salmon and other fish were the main food resource (Irving 1957; Ketz 1982; Reckord 1983; Skeete 2008). Surveys of the Susitna River region have yielded sites ranging in age from early to late Holocene, shedding light on the potential for increasing understanding of not only prehistoric studies of the area, but also potential uses of the landscape by Western Ahtna speaking groups during the middle to late Holocene (Dixon et al. 1985; Skeete 2008). Understanding how Western Ahtna groups utilized this region is important not only for

interpreting how prehistoric groups possibly subsisted, but also for providing insight into how subsistence activities in the upper Susitna River basin changed through time. Determining when and how ethnographic patterns of subsistence emerged can only be done through archaeological analysis.

While not much is known anthropologically about Western Ahtna historic and prehistoric practices, de Laguna and McClellan (1981) depict a basic understanding of historic settlement and subsistence behaviors that can be used to model prehistoric subsistence practices utilized in the upper Susitna River basin. Western Ahtna populations were considered to be semi-nomadic, in that they had "villages" during the winter and seasonally mobile hunting camps during the spring, summer, and fall (de Laguna and McClellan 1981). As mentioned above, Copper River basin Ahtna groups are known for their heavy utilization of salmon and other fish as a food resource; however, Western Ahtna groups did not have the same level of access to salmon and therefore focused more on migratory herds of caribou and other small mammals, as well as lake fish (de Laguna and McClellan 1981; Reckord 1983).

Ahtna Athabaskans traditionally hunted large game such as caribou, moose, Dall sheep, brown bear, and black bear, and smaller game such as beaver, porcupine, rabbit, ground squirrels, birds, and fish (de Laguna and McClellan 1981). Caribou hunting occurred during both the spring and fall migrations, although Western Ahtna groups are believed to have hunted caribou more intensively during the late summer and early fall periods (de Laguna and McClellan 1981; Skeete 2008). Ahtna groups rendered grease and fat from caribou and moose bones, and subsequently disposed of bone as well as

carcass materials of other terrestrial animals into hearth fires. Fish bones were also cooked to render grease but were disposed of in the water (de Laguna and McClellan 1981).

Early to Late Holocene Prehistory in Central Alaska

Investigation of technological and cultural change from the early to late Holocene of central Alaska has been the focus of several studies attempting to understand similarities and/or differences in settlement strategies, subsistence patterns, and lithic technological organization through time (Clark 1992; Dixon 1985; Potter 2008a, 2008b, 2008c). General subsistence patterns interpreted from archaeological assemblages dating to this time period indicate continuity in the form of wide diet breadth and the utilization of broad spectrum resources in central Alaska (Potter 2008c). This pattern of faunal exploitation suggests that differences will, therefore, be seen in resource scheduling and land-use strategies (Potter 2008b, 2008c). Interpretations of cultural or population changes from the early to middle to late Holocene in interior Alaska have been largely based on changes in lithic technology (Potter 2008b; Wendt 2013; Wygal 2010; Wygal and Goebel 2012). Faunal assemblages are relatively limited in the Alaskan archaeological record, as organic materials are not known to preserve well in Alaska due to acidic soils (Potter 2008b). Efforts to include faunal data in the discussion of cultural or population change in central Alaska are based on the documentation of presence or absence of taxonomically identifiable species (Potter 2008b, 2008c).

The origins of northern Athabaskan populations and their characteristic subarctic adaptation remain unclear, although differences between the archaeological signatures of the middle and late Holocene in Interior Alaska have been used to answer this question (Derry 1975; Ives 1990; Potter 2008a, 2008b, 2008c; Wendt 2013). One possible explanation is that ancestral Ahtna populations migrated into the region and replaced the existing Northern Archaic prehistoric populations, establishing the northern Athabaskan way of life, while another is that northern Athabaskan groups developed *in situ* from the Northern Archaic, but changed their subsistence and land-use strategies from residential to logistical mobility along with an increased focus on overabundant seasonally available resources (Derry 1975; Potter 2008b, 2008c). Trying to assess which pattern depicts the origins of Athabaskan populations has typically occurred through technological analysis; however, incorporating analyses of faunal materials can help to highlight variation seen in the record, as well as address possible taphonomic biases or issues that could be influencing perceived differences in the archaeological record throughout the Holocene.

Faunal Analysis in Alaska and the Arctic

Various factors influence the formation of faunal assemblages in archaeological settings. In Interior Alaska, modification of faunal remains arises from both natural and human activities, including freeze/thaw actions, natural fires, leaching from acidic soils, trampling, soil compaction, gnawing from rodents or carnivores, cutmarks from butchery, burning as fuel in fire, discard of waste in fire, boiling, and pounding for marrow or grease (Binford 1978; Costamagno et al. 2005; Leechman 1951; Lyman 1994; Mentzer 2009; Thery-Parisot 2002; Vehik 1977). Archaeological sites in Interior

Alaska tend to lack extensive faunal assemblages, and few prehistoric sites exist in the region that contain preserved faunal remains that can be used to understand past human subsistence behaviors and patterns of site occupations (but see Holmes 1996; Holmes et al. 1996; Potter 2007; Shirar 2009; Tremayne 2011; Yesner 1996). Detailed analyses of fragmentary faunal remains are infrequent in the archaeological literature and tend to focus on simply stating the presence of fragmented bone, largely due to the limited amount of information that can be gleaned from such poorly preserved assemblages.

In the last two decades, efforts have been made to increase taphonomic and zooarchaeological analyses of faunal remains recovered from sites in arctic contexts (Darwent 1995, 2001; Darwent and Foin 2010; Gotfredson 2010; Hodgetts et al. 2003; Howse 2008; Johansen 2012; Lefevre et al. 1997, 2011; Lofthouse 2003; Moss and Bowers 2007; Shirar 2009; Tremayne 2011). In general, preservation of organic and faunal remains from high arctic settings, in which permafrost is year-round and not discontinuous, indicates a taphonomic bias reflected in the prehistoric faunal records of Alaska and neighboring countries located in the Arctic. The faunal record of Alaska and the Arctic is shaped not only by regional biases but also temporal ones. The early and middle Holocene archaeological records are relatively lacking in preserved faunal remains from which meaningful subsistence information can be garnered; however, the Alaskan faunal record is inclined towards preservation in late Holocene and later, more recent historic populations, especially in coastal settings (Lefevre et al. 1997, 2011; Moss and Bowers 2007; Shirar 2009; Tremayne 2011).

Zooarchaeological analyses for Pre-Dorset, Dorset, and Thule occupations are mainly reported from sites located in the Canadian Arctic and Greenland (Darwent 1995; 2001; Gotfredson 2010; Hodgetts et al. 2003; Johansen 2012; Lofthouse 2003), while two relatively recent reports provide insight into these periods within Alaska (Shirar 2009; Tremayne 2011). The majority of Paleoeskimo sites with extensive faunal assemblages are located along or near the Arctic coast. For this reason, it is not surprising that marine mammals and other marine resources dominate the faunal assemblages from many of these sites; however, both intra- and inter-site variability has formed the basis for determining site seasonality and shifts in subsistence strategies over time and across space.

Procurement of seasonally available resources such as migratory birds and anadromous fish, both less likely to survive destructive cultural and natural taphonomic activities, is documented at Paleoeskimo residential occupation sites alongside large marine mammal resources (Darwent and Foin 2010; Hodgetts et al 2003). In contrast, a zooarchaeological analysis of a Denbigh Flint Complex site in interior Alaska (Tremayne 2011) and a Late Dorset site on Victoria Island (Howse 2008) reflect Paleoeskimo reliance largely on caribou and other terrestrial resources. Important for understanding possible cultural taphonomic influences on faunal assemblages is the practice of grease extraction from the long bones of large mammals. It is documented based on a taphonomic study of Paleoeskimo and medieval Norse sites in Greenland, both of which have evidence of selective extraction of grease from long bones of caribou and other large terrestrial mammals, but not from the bones of seals (Outram 1999).

Zooarchaeological and taphonomic analyses of faunal assemblages have provided knowledge regarding seasonality of occupations and shifts in subsistence strategies and resource acquisition, both temporally and regionally. Investigations of this nature, however, are not as extensive for Interior Alaska during the early and middle Holocene (but see Bowers 1980; Plaskett 1976; Potter 2005; Powers et al. 1983; Skeete 2008).

Burned Bones at Archaeological Sites

Ethnographically it is known that multiple natural and human activities can create burned bone assemblages; therefore, a focus on taphonomic analysis of burning is needed. Analysis of the degree and intensity of burning by categorizing color codes from Stiner et al. (1995) is done to determine possible site activities and human behavior. Patterns of burning seen in the faunal remains from the two sites included in this study were compared to patterns seen in bones from experimental hearths (Bennett 1999; Nicholson 1993; Shipman et al. 1984; Stiner et al. 1995; von Endt and Ortner 1984). Other taphonomic processes were considered as possible site formation processes that could have produced the faunal assemblages from HEA-499 and HEA-455.

Bones found at archaeological sites are not guaranteed to be the result of human activities, as natural sources have to be taken into account. Determining whether or not burned faunal remains were produced through human influences or through natural fire processes, as well as whether the bones themselves were intentionally or incidentally burned, has been the subject of several studies (Asmussen 2009; Bennett 1999; Hanson and Cain 2007; Taylor et al. 1995). Creating concrete associations between faunal

remains and human activities depends not only on contextual associations, but also a deeper understanding of the forces that created the nature of the assemblage. Patterns seen in faunal assemblages can be evaluated to determine taphonomic processes that may have influenced the formation of that assemblage (Lyman 1994). Heavily fragmented bones could have been produced through several different natural or anthropogenic forces; therefore, determining which processes created the fragmented bones depends on the taphonomic signatures present. Burning may be only one factor to consider in determining processes affecting bone assemblages. Cooking activities result in different signatures that could be present on faunal remains, such as fragmentation from marrow and grease extraction or weakening of the bone structure from boiling activities. Other activities include trampling, soil compaction, freeze/thaw actions, and other natural processes.

Bones that are burned at a site do not automatically reflect cooking activities or deliberate burning incidences, as natural fires have been known to contribute to burning found at sites (Bennett 1999). Stiner et al. (1995), Bennett (1999) and Clark and Ligouis (2010) demonstrated that sheer intensity of burned bone to the point of calcination, as well as a direct association with hearths and other features, can be strong indicators that burned bones found at a site resulted from human activities. Demonstrating a clear anthropogenic versus natural pattern of origins for burned bones found in cultural contexts depends on the ability to distinguish taphonomic signatures seen in bones (Hanson and Cain 2007); however, this is not an easy feat to accomplish using highly fragmented bone assemblages.

Archaeological studies concerning the identification of burning damage on bones and evidence of controlled fire have been paramount to studies focused on identifying the earliest use of fire by modern humans (or earlier hominins), generating much of the current research on the subject (Alperson-Afil et al. 2007; Brain and Sillen 1988; Goldberg et al 2012; Goren-Inbar et al. 2004; Karkansas 2007; Mentzer 2014; Shen et al. 2004; Zhong et al. 2014). Ethnographic and ethnoarchaeological accounts of traditional use and maintenance of fires among indigenous populations have contributed to understanding how hearths and associated debris reflect different human site activities and behaviors (Binford 1978; Murray 1980; Yellen 1977). Resulting research has focused not only on identifying burning damage on bones, but also on categorizing the degree and intensity of burning present (Brain 1993; Nicholson 1993; Shipman et al. 1984; Stiner et al. 1995). Level, intensity, and type of burning have been evaluated and identified through observations of physical changes of the color of the bone, changes in the mineral content and structure of bone, effects of surrounding soils on bone, effects of weathering, and changes in physical strength of bones (Behrensmeyer 1978; Bennett 1999; Castillo et al. 2013; Nicholson 1993; Ruff 1983; Shipman et al. 1984; Stiner et al. 1995; White and Hannus 1983). Analysis of burned bone assemblages by using the above outlined techniques to identify burned bone and intensity of burning together with considering ethnographic accounts of fire use can provide some insight into prehistoric human subsistence, land-use, and site activities.

Understanding the context of bones at sites can indicate possible site activities or even site organization among prehistoric populations (Asmussen 2009; Cain 2005; Clark

and Ligouis 2010; Nicholson 1993; Potter 2007; Shirar 2009; Tremayne 2011); however, determination of prehistoric human behavior through analysis of fragmentary and burned faunal remains has proven difficult. Faunal material at archaeological sites could result from different site and subsistence activities, as can the taphonomic signatures seen on bones. Bones that are burned to high numbers of calcined pieces and high degrees of fragmentation within a hearth context are usually assumed to result from human activities, while those that are burned to the point of carbonization in an ambiguous association with site activity areas may more accurately reflect natural sources for the fire (Bennett 1999; Stiner et al. 1995). Other patterns seen on bones can provide insight as well, including degree of fragmentation, intensity and degree of burning seen on bones, context in which the bones are found at the site, and number of bones. Overall, various taphonomic processes that could have led to formation of the faunal assemblages seen here include natural fire, leaching from acidic soils, solifluction and freeze/thaw actions, animal trampling, trampling at a well-occupied site by humans, remains of a meal, cooking, discarding of bones into the fire after a meal, bones used as fuel for fires, or pounding of bones to obtain grease or marrow (Binford 1978; Costamagno et al. 2005; Leechman 1951; Mentzer 2009; Thery-Parisot 2002; Vehik 1977).

The faunal assemblages from HEA-455 and HEA-499 represent highly fragmentary and burned material. These characteristics, along with their presence within hearth contexts, indicate that human cultural activities were the main agents involved in the formation of these sites. By conducting both zooarchaeological and taphonomic analyses, it is possible to distinguish the various types of behaviors that may have led to

the formation of these assemblages. Determining whether the taphonomic signatures present in the faunal materials represent natural or human agents can contribute to knowledge of central Alaskan subsistence behaviors and site formation processes.

MATERIALS AND METHODS

Faunal materials collected during 2012 from HEA-455 and HEA-499 were utilized in this study. These faunal assemblages were analyzed using the zooarchaeological reference collection at the Department of Anthropology, Texas A&M University, and modern faunal collections at the Mammalogy Department, University of Alaska Museum of the North. Faunal specimens from both sites were highly fragmented, with the bone fragments no larger than about 7 mm in overall size. The HEA-455 assemblage consists of approximately 700 bone fragments, and the HEA-499 assemblage consists of about 13,700 fragments. For the purpose of this study, analyses involving fragmentation, size categories, and level of burning were conducted on faunal remains associated with the hearth features of each site, and limited to those specimens from component II (n = 600) of HEA-455 and component I (n = 10,600) of HEA-499. This was done to ensure the contexts of the faunal material. These faunal specimens were sorted into three size categories (2-4 mm, 4-6.3 mm, and > 6.3 mm) using nested geological screens. Taphonomic analysis included looking for signs of surface modification, either from human, animal, and other natural agents. Modification present on the bones included strong evidence of burning; however, the degree of fragmentation and size of the fragments meant any other surface modifications, such as types of fractures or cutmarks, were not likely preserved.

After attempts to make taxonomic identifications using the reference and comparative faunal collections, the fragments were further taphonomically analyzed to

determine the degree of burning evident on each fragment. This was based on the color code for burning intensity constructed by Stiner et al. (1995) (Table 1). Each bone fragment was sorted into a code ranging from 0-6, representing a scale from not burned, to carbonized, to fully calcined (Table 1). Stiner et al. (1995) demonstrated that due to the increased friability of bones once they are burned, bone fragments should be smaller the more intensely the bones were burned.

Assessing the relationship between size of bone fragments and degree to which each bone fragment was burned was conducted using the Pearson's Chi-square test of independence (Hollander et al. 2014). This statistical analysis was utilized to determine if an association between size of bone fragments and the degree of burning could be detected. Further, a Pearson's Chi-square test was conducted to determine if no difference could be detected between the two sites in the frequency of fragments in each size category or in each burn level category. This analysis was applied to determine if an association between the patterns of distribution of the frequency of fragments in the size categories and in the burn level categories could be detected to possibly infer human behavioral patterns. If the frequency of either size categories or degree of burning was the same between the two sites, then it could reflect similar activities involved in the burning and formation of the faunal assemblages at both sites. Together with the Chi-square tests, a Freeman-Tukey Deviate Z-score was calculated as a means to determine which categories deviated from random, thus influencing the significant outcome of the Chi-square tests (Bishop et al. 2007).

Table 1. Burn level codes from Stiner et al. (1995).

Burn Color Code	Description
0	Not Burned (cream/tan)
1	Slightly burned; localized and < half carbonized
2	Lightly burned; > half carbonized
3	Fully carbonized (completely black)
4	Localized; < half calcined (more black than white)
5	> Half calcined (more white than black)
6	Fully calcined (completely white)

RESULTS

Results of taphonomic analysis of both assemblages were limited to evaluating the degree of fragmentation in regards to size distinctions and the level of burning evident. Gnaw marks from rodents or carnivores and other surface modifications were not present. Further determining the processes possibly affecting the assemblages is discussed below.

Taxonomic Identification

Of the 10,600 faunal specimens from HEA-499, five were identified to at least the element represented, and ten were identified to order (Table 3). The remaining specimens were too fragmentary to identify to any element or taxon. Of the identified fragments, five were sufficiently preserved to be identified as Class Mammalia with no further taxonomic designation; these included fragments of two rib facets, a sesamoid, and two vertebral elements. Nine of the remains, including two pisiforms and fragments of a medial phalanx, terminal phalanx, intermediate carpal, two astragali, a metapodial, and a distal condyle of a femur, represent Order Artiodactyla, likely caribou (*Rangifer tarandus*), as sizes and shapes are similar; however, due to the fragmentary nature and difficulty of identifying lower limb carpals and tarsals to species levels, this distinction cannot be made with certainty. One specimen, the proximal portion of a radius, was identified to Order Rodentia, likely North American beaver (*Castor canadensis*), based on size and shape, yet it is too fragmentary to identify with complete certainty.

Faunal materials from HEA-455 were likewise too fragmentary to identify, and the lack of identifying markers limited attempts to categorize specimens even to element. Two were bird-bone fragments from a modern context and several were fragmentary remains of mammalian teeth; however, these specimens were too fragmented to identify them beyond class.

Table 2. Taxonomic identification of faunal remains.

Element	**Class**	**Order**
Rib facet* (2)	Mammalia	-
Sesamoid	Mammalia	-
Vertebra* (2)	Mammalia	-
Astragalus* (2)	Mammalia	Artiodactyla
Metapodial*	Mammalia	Artiodactyla
Pisiform (2)	Mammalia	Artiodactyla
Medial phalanx*	Mammalia	Artiodactyla
Terminal phalanx*	Mammalia	Artiodactyla
Intermediate carpal*	Mammalia	Artiodactyla
Distal condyle of femur*	Mammalia	Artiodactyla
Radius*	Mammalia	Rodentia

*Faunal specimen is a fragment.

Fragmentation

The faunal assemblage from site HEA-499 consists of approximately 10,600 specimens, all less than 7 mm in size. About 73% of the faunal specimens were in the size range of 2-4 mm, 22.5% were 4-6.3 mm, and 4.5% were > 6.3 mm in size (Figure 5, Table 2). A similar pattern was seen in the faunal remains from HEA-455, which consist of approximately 600 bone pieces, with 66.4% at 2-4 mm, 24.5% at 4-6.3 mm, and 9% at > 6.3 mm (Figure 5, Table 2). Each faunal assemblage is highly fragmented, with similar distributions between the different size categories; however, a Chi-square test to test the distribution of fragment sizes indicated a significant difference between the two sites ($\chi 2 = 29.00$, df = 2, p-value = 0.001). The highly fragmented nature of the assemblages is likely due to friability brought about through heat and burning within a fire (Stiner et al. 1995). The difference documented between the two assemblages indicates the distribution of size categories was not the same at both sites, which could be due to the difference in sample sizes, sampling bias, or preservation bias.

Table 3. Size category by site.

Size Categories	HEA-455	HEA-499	Total
2-4 mm	390	7744	8134
4-6.3 mm	144	2390	2534
>6.3 mm	*(+)53	*(-)473	526
Total	587	10607	11194

*Z-score deviated from random; (-) Z-score was lower than expected by chance; (+) Z-score was higher than expected by chance

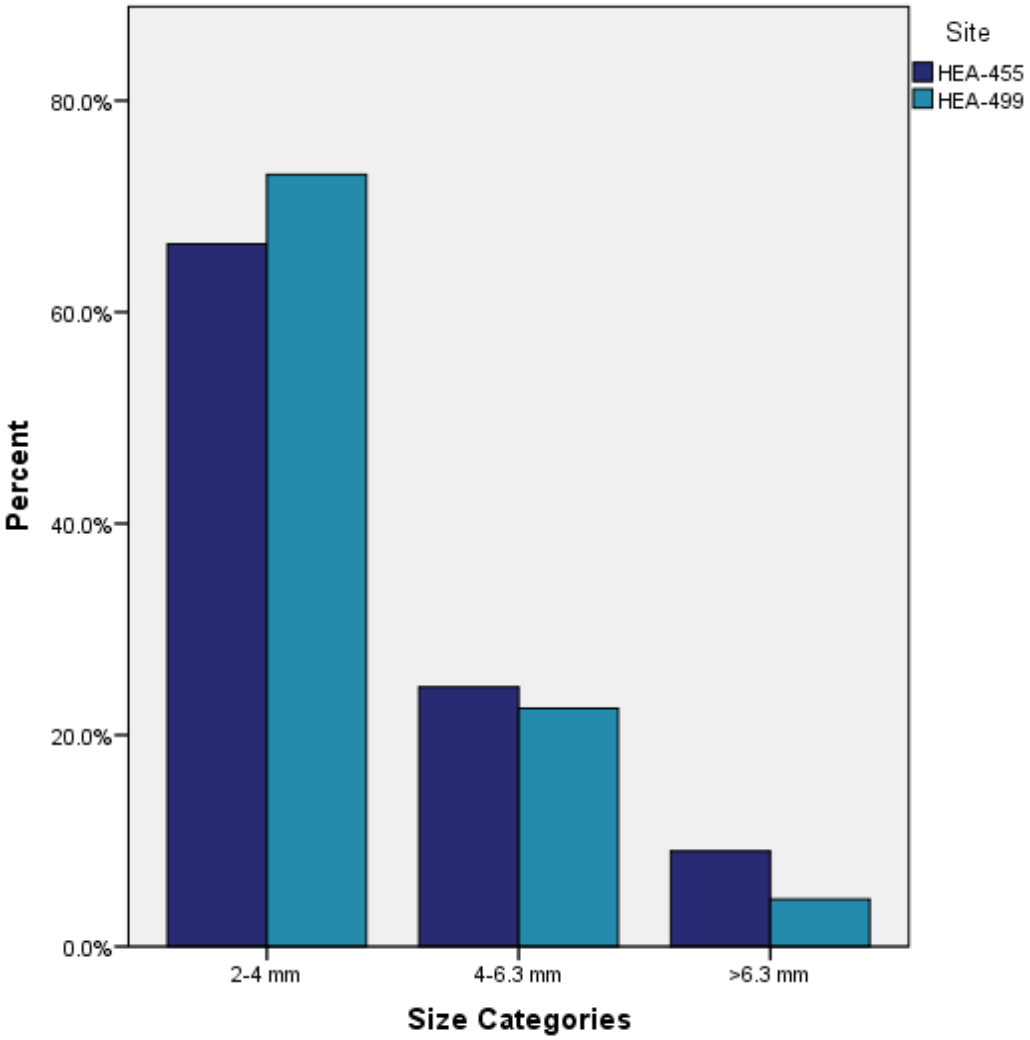

Figure 5. Distribution of bone fragments by size category per site.

Burned Bones

Evidence of burning was prevalent throughout both faunal assemblages, with the majority of both assemblages presenting some degree of burning. Of the collected bone fragments from HEA-499, 80.8% were fully calcined, 10.5% were more than 50% calcined, 6.3% were less than 50% calcined, 2.1% were carbonized to a certain degree (fully carbonized, > 50% or < 50% carbonized), and 0.3% were not burned (Figure 6, Table 4). Of the collected bone fragments from HEA-455, 68.8% were fully calcined, 23% were more than 50% calcined, 3.1% were less than 50% calcined, 2% were carbonized to a certain degree, and 3.1% were not burned (Figure 6, Table 4). Calcination of bones is the most common degree of burning intensity identified in the two faunal assemblages. A Chi-square test, conducted to test the distribution of burn level categories between the two assemblages, indicated a significant difference ($\chi 2$ = 212.80, df = 6, p-value = 0.001). This difference shows that the distribution of the level of burning between the two sites was not the same.

To investigate whether a significant relationship between bone fragment size and level of burning is present in the two assemblages, a Pearson's Chi-square test of independence was conducted for both sites. The results indicate a significant association between size of fragments and degree of burning (HEA-499: $\chi 2$ = 406.307, df = 12, p-value = 0.001, phi-coefficient = 0.196; HEA-455: $\chi 2$ = 154.699, df = 12, p-value = 0.001, phi-coefficient = 0.513) (Figures 7 and 8, Tables 5 and 6). These results indicate that taphonomically, a significant relationship exists between bone fragment size and the level of burning identified in the remains.

Table 4. Degree of burning by site.

Degree of Burning	HEA-455	HEA-499	Total
0	*(+)18	*(-)29	47
1	*(+)6	32	38
2	3	54	57
3	*(-)3	141	144
4	*(-)18	669	687
5	*(+)135	*(-)1110	1245
6	*(-)404	8572	8976
Total	587	10607	11194

*Z-score deviated from random; (-) Z-score was lower than expected by chance; (+) Z-score was higher than expected by chance

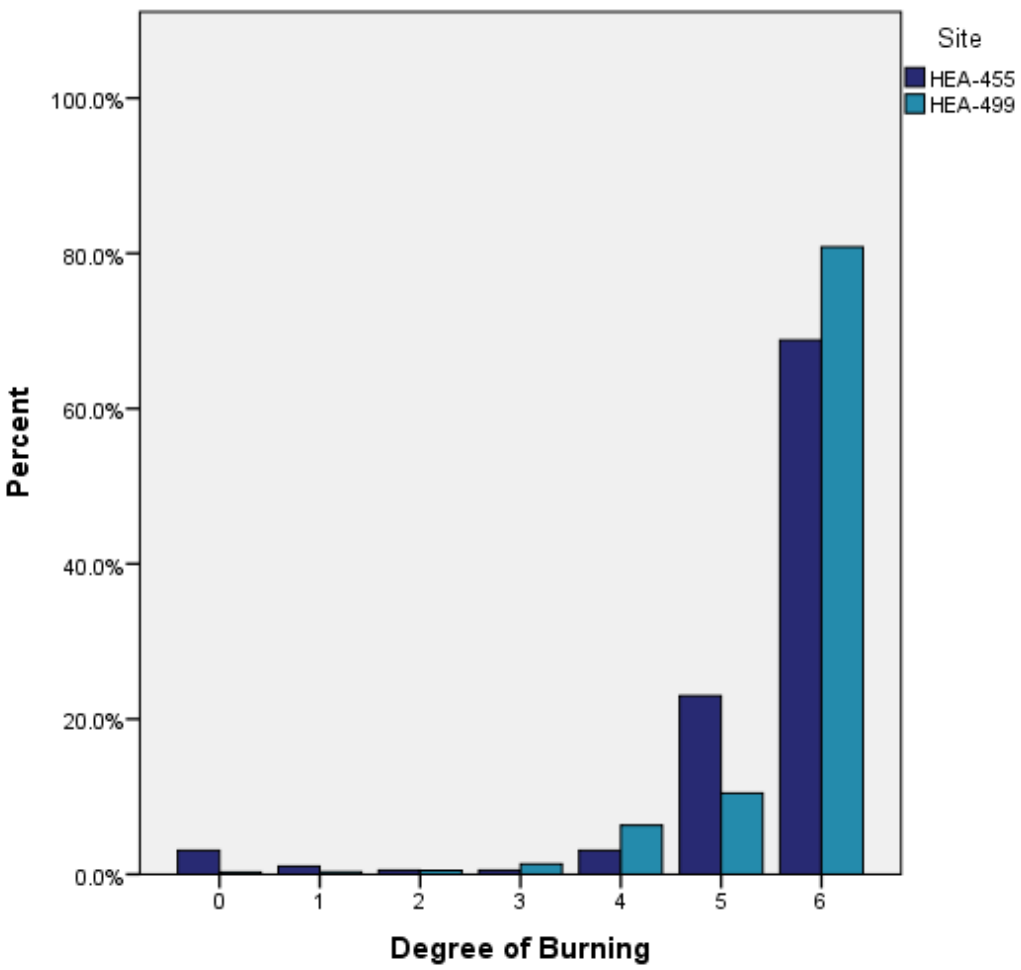

Figure 6. Distribution of bone fragments by level of burning per site.

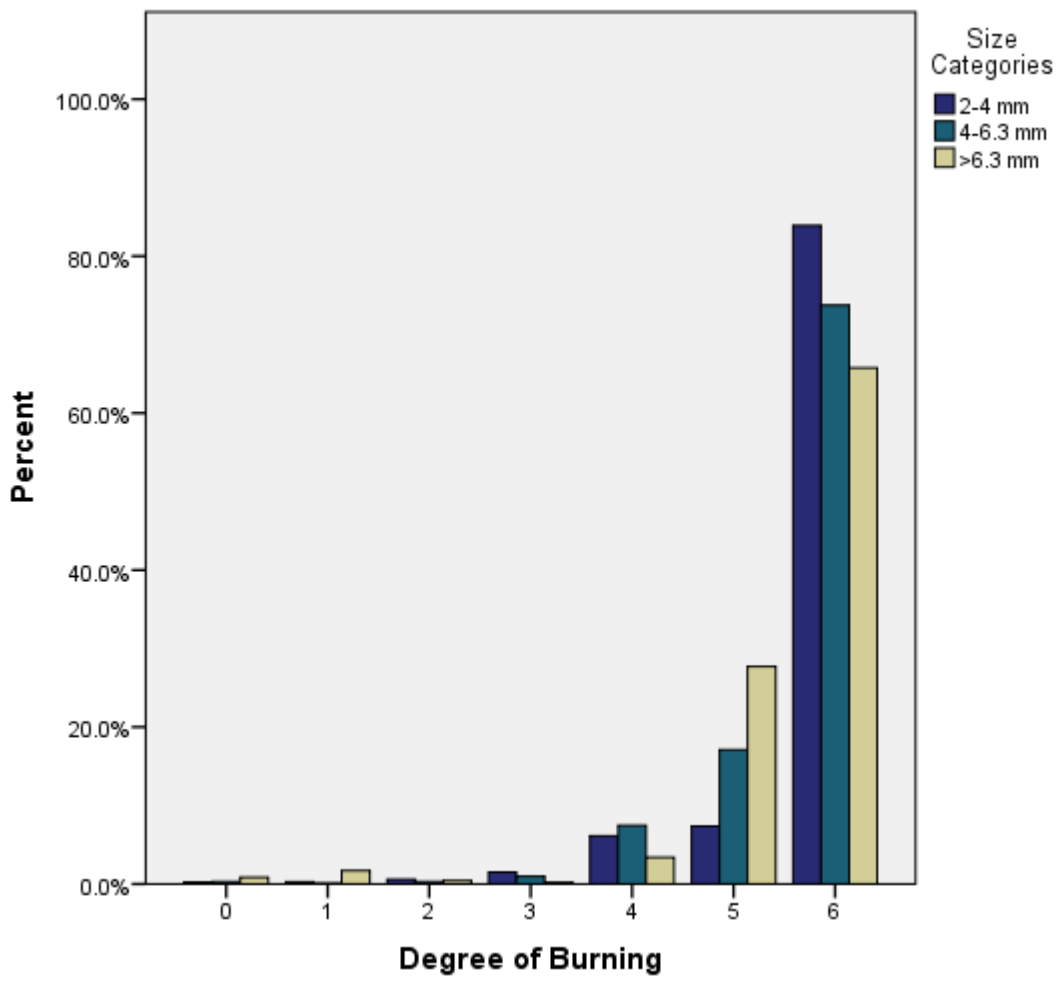

Figure 7. Degree of bone burning per size category for HEA-499.

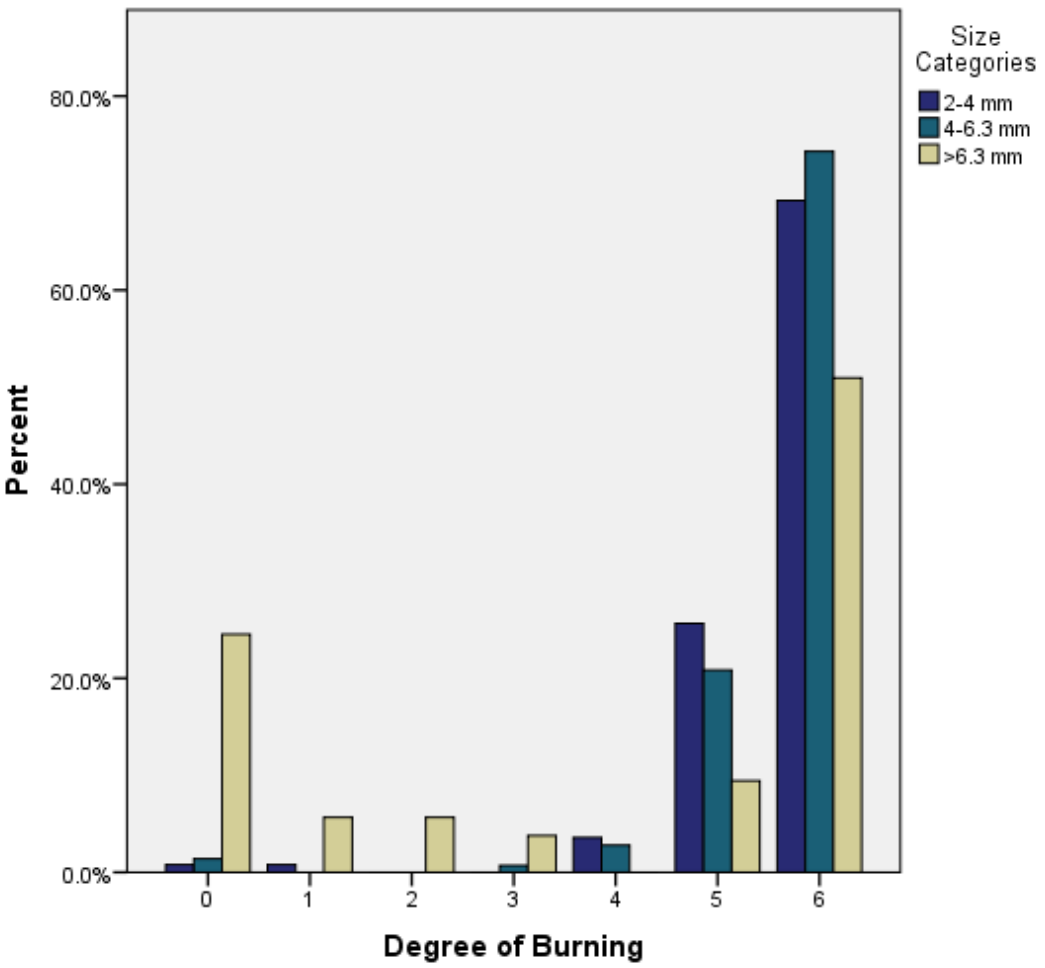

Figure 8. Degree of bone burning per size category for HEA-455.

Table 5. Degree of burning per size category for HEA-499.

Degree of Burning	2-4 mm	4-6.3 mm	>6.3 mm	Total
0	18	7	4	29
1	21	3	8	32
2	45	7	2	54
3	117	23	1	141
4	475	178	16	669
5	570	409	131	1110
6	6498	1763	311	8572
Total	7744	2390	473	10607

Table 6. Degree of burning per size category for HEA-455.

Degree of Burning	2-4 mm	4-6.3 mm	>6.3 mm	Total
0	3	2	13	18
1	3	0	3	6
2	0	0	3	3
3	0	1	2	3
4	14	4	0	18
5	100	30	5	135
6	270	107	27	404
Total	390	144	53	587

DISCUSSION

The faunal remains from HEA-455 and HEA-499 are highly fragmented, with an overwhelming majority of both assemblages having bones between 2-4 mm in size and calcined to some degree. For this reason, taxonomic identification was limited to only ten specimens to order out of about 10,600 for the assemblage from HEA-499, and no taxonomic information being gleaned for the assemblage from HEA-455.

Taxonomic information was relatively lacking; however, the material that was identified provides suggestions regarding how the local landscape was utilized. Based on the sizes of the identifiable elements from HEA-499, and the types of Artiodactyla species that inhabit the Upper Susitna River area, they likely represent caribou remains. Especially during migratory events in the spring and early fall, caribou would have been a reliable resource utilized by middle Holocene people. There is not enough information to determine seasonality of site use for either site; however, there is still potential for determining such information given that much of the two sites are only minimally excavated. Continued excavations could provide more identifiable remains and allow for further meaningful analyses to be conducted. Nonetheless, the extensive amount of bone in the sites' features suggests intensive processing of hunted game – including seasonally available resources such as caribou. More detailed information of this sort could contribute to current discussions regarding shifts in subsistence practices during the middle to late Holocene in central Alaska, and current discussions regarding the origins of Native Athabaskan populations in central Alaska.

Considering the overwhelming percentage of bone fragments from both HEA-455 and HEA-499 that were calcined to some degree, as well as the association between many of the fragments with cultural hearths, it can be determined that direct human activities created the faunal assemblages at both sites. Natural fires produce charring and carbonization of bones, and rarely (if at all) produce intensely calcined bones (Bennett 1999; Connor et al. 1989; Stiner et al. 1995). Thus, not only were the bones not burned in a natural fire, it is very unlikely that they were burned from an overlying hearth from a separate occupation. Experimental fires in which bones were buried at varying depths in sediments and soils have demonstrated that heat from an overlying hearth could produce carbonization, but not calcination of the underlying bone (Bennett 1999; Stiner et al. 1995). Although a wide range of human activities could have produced the fragmented burned bone assemblages (e.g. trampling at a well-occupied site by humans, cooking and roasting, discarding of bones into the fire after a meal, bones used as fuel for fires, or pounding of bones to obtain grease or marrow), the final activity discernable from both assemblages was the direct burning of bone in a hearth.

Cooking and roasting of meat on bones is an activity that is generally to have occurred at prehistoric hunter-gatherer sites that contain faunal remains. Direct evidence of this activity is difficult to determine, yet the presence of charring on the distal and proximal ends and edges of bones could represent possible roasting activities (Gifford-Gonzalez 1989). Considering that the majority of both faunal assemblages were calcined to some degree, cooking activities that included roasting were probably not the processes that directly formed the final stage of the assemblages. This does not mean that cooking

activities did not occur at the site, only that roasting was not the final process that created the fragmentary calcined bones. Cooking activities could have occurred in other ways. Bone pounding to obtain grease and marrow has been documented ethnographically, and particularly in the study area by the Western Ahtna (Binford 1978; de Laguna and McClellan 1981; Leechman 1951; Vehik 1977). Any taphonomic indications from fracture patterns to indicate deliberate cracking of long bones for marrow extraction would have been eliminated from the burning process, which not only alters the surface of bones, but also further fragments bones when burned until calcined. However, it may be possible to identify blunt-force fractures if the bones are not burned to the degree of highly calcined (Hermann and Bennett 1999).

Bone as a source of fuel for fires has been proposed in Paleolithic contexts to explain fire use in situations where wood may be scarce, and as such, experimental hearths have been constructed to test the use of bone as fuel (Costamagno et al. 2005; Mentzer 2009; Thery-Parisot 2002). Documenting bone-fuel use in the contexts of the two sites considered here from the Susitna River valley would be difficult, as finding bone that was heavily burned and fragmented in a hearth could be the culmination of several different activities. Rather than acting as a fuel source, animal remains could have been tossed into the fire as a means of discarding waste, as documented ethnographically among the Western Ahtna. Another possibility is that the discard of bone waste into a fire could have served a dual purpose of waste disposal along with providing additional fuel to the hearth. It has been shown in experimental situations that

adding bone to an already established fire prolongs the life of the hearth (Costamagno et al. 2005).

Burning bones in a fire weakens the structure of the bone, and makes it much more likely to fragment (Costamagno et al. 2005; Johnson 1989; Knight 1985; McKinley 1994; Stiner et al. 1995). While the burning process does fragment the bone itself, further reduction of bone fragments into even smaller pieces could have occurred through soil compaction from trampling by humans at a well-occupied site (Stiner et al. 1995). Trampling could also have occurred from other animals. As previously mentioned, the Nelchina caribou herd is known to migrate through the area. Other taphonomic processes that could have altered the faunal assemblages from both sites over time are leaching from acidic soils, solifluction, and freeze/thaw actions.

Regardless of which taphonomic processes led to the formation of the highly fragmented calcined bone assemblages, a significant association between size of the bone fragments and degree to which the bones were burned/calcined/carbonized was found for both sites. This is to be expected because burning bones to the point that they become calcined weakens the structure of the bone. Calcined bone fragments are even more likely to fragment into smaller pieces, limiting interpretations regarding possible relationships of size and degree of burning. A bone fragment of decent size that is calcined partially could fragment into even smaller pieces, either from excavation activities, transport to the lab after excavation, or during subsequent analyses. This results in smaller bone fragments, thus skewing possible interpretations regarding

distributions of the size of fragments and the degree of burning represented on the fragments.

Nevertheless, calcined bones dominate both faunal assemblages, which has been interpreted as a clear indicator of human site maintenance activities, i.e. the disposal of bones into hearths during the middle Holocene in the Susitna River valley by prehistoric hunter-gatherers. Preservation biases have to be considered in regards to faunal assemblages dominated by calcined fragments. Knight (1985) demonstrated that calcined bones are more resistant to deterioration in acidic conditions than regular bone by experimentally testing both calcined and unburned bones in acid-buffer solutions. These tests indicated that regular bone deteriorated at a more rapid pace than calcined bone. Differences in preservation of calcined versus unburned bones in acidic solutions has certain implications when considering faunal remains from Alaska, and could explain why the majority of faunal assemblages in the state are burned fragmented remains, why earlier prehistoric sites are relatively lacking in identifiable faunal remains, and why later historic Paleoeskimo and Thule sites contain better-preserved faunal assemblages.

Investigation of distribution patterning between the two sites for size categories and degree of burning indicated that a significant difference exists between the two faunal assemblages for each variable. The Chi-square test was conducted to determine if similarities and/or differences could be detected between HEA-455 and HEA-499. Similarities in the distribution of size categories, and separately degree of burning, between the two sites could have suggested comparable site maintenance activities;

however, the significant difference indicated by the Chi-square test shows that multiple factors need to be considered. The comparison of two hearths is a small sample size, and a future analysis of multiple hearths in both similar and different temporal contexts could determine if patterns seen using these two variables can add to discussions of subsistence behaviors. Sampling bias based on the difference in size of the faunal assemblages could have influenced the results, which could be reconciled by using assemblages of similar size.

HEA-455 and HEA-499 are both middle Holocene hunter-gatherer sites located along the Susitna River roughly 15 km from one another. Both sites contained highly fragmented burned and calcined bones. It is possible that site maintenance activities, including the discard of bones into hearths, were similar at each location; however, sampling biases need to be mediated before this distinction can clearly be made for these two sites. Whether the bones were discarded in hearths as a means to dispose of waste, to maintain a fire by adding another fuel source, or both, is difficult if not impossible to determine; however, we can reliably conclude that bones were deliberately added to an intensely burning fire in the hearths. Due to the degree of fragmentation, other human activities such as rendering of grease and fat from bones or splitting of long bones for marrow extraction cannot be ruled out; however, processing activities of hunted game did take place at HEA-455 and HEA-499. Intensive processing of hunted game, likely caribou, evident at these two sites highlights the complicated nature of determining when shifts in subsistence strategies from logistical to residential mobility occurred. The preservation of bone material at these two sites suggests the potential of the study area to

address questions regarding shifts in subsistence practices from the middle to late Holocene in central Alaska.

CONCLUSIONS

In summary, despite the limited taxonomic information, taphonomic and zooarchaeological analysis of the faunal assemblages from HEA-455 and HEA-499 show that 1) intensive processing of hunted game occurred at both sites; and 2) direct human activities created the faunal assemblages at both sites through intentional placement of bones in hearths.

By thoroughly analyzing fragmented and burned faunal remains, this study shows it is possible to create a clearer picture of middle Holocene hunter-gatherer land use and subsistence practices within Interior Alaska. Poor faunal preservation poses a significant problem to studying subsistence practices of Alaskan prehistoric populations; therefore, it is important to include analyses of what is available to supplement those ideal situations in which faunal remains do preserve well. Although taxonomic identifications were limited, the identified fauna at HEA-499 highlights the potential for this record to provide materials useful for investigating hypothesized shifts in subsistence practices and resource acquisition from the middle to late Holocene in Interior Alaska, and to determine if seasonally available resources were more intensively utilized during the late Holocene than during the middle Holocene. Delineating when ethnographic Western Ahtna subsistence patterns emerged in the Upper Susitna River area could provide insight into how subsistence activities in the region changed over time, especially if residential mobility and a focus on seasonally abundant resources emerged during the middle rather than the late Holocene.

Clear cut subsistence behaviors and activities are difficult to determine simply from burned fragments of bones; however, it has been determined that bones were coming into direct contact with the fire of a hearth for a prolonged period of time to create the heavily calcined assemblages at HEA-455 and HEA-499. This suggests that during the middle Holocene, hunter-gatherers in the Susitna River valley were deliberately disposing of bone in fires, but for what purpose is beyond the scope of this study. Other subsistence-based activities were not visible or obtainable, as the high degree of burning that led to the formation of these assemblages likely erased the possible prior presence of other identifiable surface modifications that occurred.

Subsistence patterns reflecting different site activities at Alaskan prehistoric sites from the late Pleistocene to the late Holocene could be further elucidated if fragmented and burned fauna were included in regular analyses. Limitations in interpretation of fragmented and burned faunal assemblages, however, need to be considered for any future analyses. Sampling biases are likely to have strong influences in these assemblages, as these sites were excavated as part of a larger survey project. Preservation biases need to be accounted for as well, as calcined bones are more likely to preserve in acidic soils; yet, calcined bone fragments are more likely to fragment into smaller fragments from excavation, to transport, to handling during analysis. Along those lines, interpretations of subsistence behaviors based on highly fragmented and burned faunal remains are limited by the fact that we are only seeing the final activities that led to the formation of these assemblages. Signs of butchering, cooking, and other processing activities are likely to be erased during the final activity of burning bones in

hearths. Future research could be aimed at expanding excavations at both sites, as well as at other sites in the study area, to examine faunal resource use across the sites and between sites, and to mediate any sampling biases that limited interpretations of the patterns of distribution of size and degree of burning of the fragments at each site.

REFERENCES

Alperson-Afil, N., D. Richter, N. Goren-Inbar (2007) Phantom Hearths and the Use of Fire at Gesher Benot Ya'aqov, Israel. *PaleoAnthropology* 1-15.

Asmussen, B. (2009) Intentional or Incidental Thermal Modification? Analyzing Site Occupation Via Burned Bone. *Journal of Archaeological Science* 36:528-536.

Behrensmeyer, A. K. (1978) Taphonomic and Ecologic Information from Bone Weathering. *Paleobiology* 4(2):150-162.

Bennett, J. L. (1999) Thermal Alteration of Buried Bone. *Journal of Archaeological Science* 26:1-8.

Betts, M. W. (2004) *A Multicontextual Approach to Zooarchaeology: Procurement Strategies in the Mackenzie Delta Region, Western Canadian Arctic*. Unpublished PhD dissertation, University of Toronto, Toronto.

Bigelow, N. H., and M. E. Edwards (2001) A 14,000yr Paleoenvironmental Record from Windmill Lake, Central Alaska: Lateglacial and Holocene Vegetation in the Alaska Range. *Quaternary Science Reviews* 20:203-215.

Binford, L. (1978) *Nunamiut Ethnoarchaeology*. Academic Press, New York.

Bishop, Y., S. E. Fienberg, and P. W. Holland (2007) *Discrete Multivariate Analysis: Theory and Practice*. Springer, New York.

Bowers, P. M. (1980) *The Carlo Creek Site: Geology and Archaeology of an Early*

Holocene Site in the Central Alaska Range. Occasional Paper No. 27, Anthropology and Historic Preservation, Cooperative Park Studies Unit, University of Alaska, Fairbanks.

Brain, C. K. (1993) The Occurrence of Burnt Bones at Swartkrans and their Implications for the Control of Fire by Early Hominids. In *Swartkrans: A Cave's Chronicle of Early Man*, edited by C. K. Brain, pp. 229-242. Tranvaal Museum Monograph, no.8, Pretoria.

Brain, C. K., and A. Sillen (1988) Evidence from the Swartkrans Cave for the Earliest Use of Fire. *Nature* 336:464-466.

Cain, C. R. (2005) Using Burned Animal Bone to Look at Middle Stone Age Occupation and Behavior. *Journal of Archaeological Science* 32:873-884.

Castillo, R. F., D. H. Ubelaker, J. A. L. Acosta, and G. A. Canadas de la Fuente (2013) Effects of Temperature on Bone Tissue. Histological Study of the Changes in the Bone Matrix. *Forensic Science International* 226:33-37.

Clark, D. W. (1992) The Archaic in the Extreme Northwest of North America. *Revista de Arqueologia Americana* 5:71-99.

Clark, J. L., and B. Ligouis (2010) Burned Bone in the Howieson's Poort and Post-Howieson's Poort Middle Stone Age Deposits at Sibudu (South Africa): Behavioral and Taphonomic Implications. *Journal of Archaeological Science* 37:2650-2661.

Connor, M., K. P. Cannon, and D. C. Carlevato (1989) The Mountains Burnt: Forest

Fires and Site Formation Processes. *North American Archaeologist* 10(4):293-310.

Costamagno, S., I. Thery-Parisot, J. P. Brugal, and R. Guibert (2005) Taphonomic Consequences of the Use of Bone as Fuel. Experimental Data and Archaeological Applications. In *Biosphere to Lithosphere*, edited by Terry O'Connor, pp. 51-62. 9th ICAZ Conference, Durham.

Darwent, C. M. (1995) *Late Dorset Faunal Remains from the Tasiarulik Site, Little Cornwallis Island, Central High Arctic, Canada*. MA thesis, Simon Fraser University, Burnaby.

(2001) *High Arctic Paleoeskimo Fauna: Temporal Changes and Regional Differences*. PhD dissertation, University of Missouri, Columbia.

Darwent, C. M., and J. C. Foin (2010) Zooarchaeological Analysis of a Late Dorset and an Early Thule Dwelling at Cape Grinnell, Northwest Greenland. *Geografisk Tidsskrift* 110:315-336.

de Laguna, F., and C. McClellan (1981) Ahtna. In *Handbook of North American Indians*, Vol. 6, *Subarctic*, edited by J. Helm, Smithsonian Institution, Washington, DC.

Derry, D. E. (1975) Later Athapaskan Prehistory: A Migration Hypothesis. *Western Canadian Journal of Anthropology* 5:134-147.

Dixon, E. J. (1985) Cultural Chronology of Central Interior Alaska. *Arctic Anthropology* 22(1):47-66.

Dixon, E. J., W. Andrefsky, C. J. Utermohle, G. S. Smith, and B. M. Salleby (1985)

Susitna Hydroelectric Project, Vols. 1-3. Report submitted to Alaska Power Authority by University of Alaska, Fairbanks.

Gifford-Gonzales, D. (1989) Ethnographic Analogues for Interpreting Modified Bones: Some Cases from East Africa. In: *Bone Modification,* edited by M. H. Sorg and R. Bonnichsen, pp. 179-246. Center for the Study of the First Americans, University of Maine, Orono.

Goldberg, P., H. Dibble, F. Berna, D. Sandgathe, S. McPherron, and A. Turq (2012) New Evidence on Neandertal Use of Fire: Examples from Roc de Marsal and Peche de l'Aze IV. *Quaternary International* 247:325-340.

Goren-Inbar, N., N. Alperson, M. Kislev, O. Simchoni, Y. Melamed, A. Ben-nun, and E. Werker (2004) Evidence of Hominin Control of Fire at Gesher Benot Ya'aqov, Israel. *Science* 304:725-727.

Gotfredsen, A. B. (2010) Faunal Remains from the Wollaston Forland-Clavering Ø Region, Northeast Greenland-Thule Culture Subsistence in a High Arctic Polynya and Ice-edge Habitat. *Geografisk Tidsskrift* 110:175-200.

Hanson, M., and C. R. Cain (2007) Examining Histology to Identify Burned Bone. *Journal of Archaeological Science* 34:1902-1913.

Harper, P. (2009) *Caribou Management Report of Survey and Inventory Activities 1 July 2006-30 June 2008*. Alaska Department of Fish and Game, Juneau, Alaska.

Hemming, J. E. (1971) *The Distribution and Movement Patterns of Caribou in Alaska*. Alaska Department of Fish and Game, Game Technical Bulletin No. 1.

(1975) Population Growth and Movement Patterns of the Nelchina Caribou Herd. *Proceedings of the First International Reindeer and Caribou Symposium* 162-179. University of Alaska, Fairbanks.

Herrmann, N. P., and J. L. Bennett (1999) The Differentiation of Traumatic and Heat-related Fractures in Burned Bone. *Journal of Forensic Sciences* 44(3):461-469.

Hodgetts, L. M., M. A. P. Renouf, M. S. Murray, D. McCuaig-Balkwill, and L. Howse (2003) Changing Subsistence Practices at the Dorset Paleoeskimo Site of Phillip's Garden, Newfoundland. *Arctic Anthropology* 40:106-120.

Hollander, M., D. A. Wolfe, and E. Chicken (2014) *Nonparametric Statistical Methods*. John Wiley & Sons, Hoboken.

Holmes, C. E. (1996) Broken Mammoth. In *American Beginnings: Prehistory and Paleoecology of Beringia*, edited by F. West, pp. 312-318. University of Chicago Press, Chicago.

Holmes, C. E., R. VanderHoek, and T. Dillehay (1996) Swan Point. In *American Beginnings: Prehistory and Paleoecology of Beringia*, edited by F. West, pp. 319-323. University of Chicago Press, Chicago.

Howse, L. (2008) Late Dorset Caribou Hunters: Zooarchaeology of the Bell Site, Victoria Island. *Arctic Anthropology* 45:22-40.

Irving, W. N. (1957) An Archaeological Survey of the Susitna Valley. *Anthropological Papers of the University of Alaska* 6(1):37-52.

Ives, J. W. (1990) *A Theory of Northern Athapaskan Prehistory*. University of Calgary Press, Calgary.

Johansen, T. B. (2012) *A Zooarchaeological and Ethnographic Investigation of Subsistence Change through Time at Iita, Northwest Greenland*. PhD dissertation, University of California, Davis.

Johnson, E. (1989) Human Modified Bones from Early Southern Plains Sites. In *Bone Modification*, edited by R. Bonnichsen and M. Sorg. pp. 431-471, Center for the Study of the First Americans, University of Main, Orono.

Karkansas, P., R. Shahack-Gross, A. Ayalon, M. Bar-Matthews, R. Barkai, A. Frumkin. A. Gopher, and M. C. Stiner (2007) Evidence for the Habitual Use of Fire at the End of the Lower Paleolithic: Site-Formation Processes at Qesem Cave, Israel. *Journal of Human Evolution* 53:197-212.

Ketz, J. A. (1982) *Paxson Lake: Two Nineteenth Century Ahtna Sites in the Copper River Basin, Alaska*. MA thesis, University of Alaska, Fairbanks.

Knight, J. (1985) *Differential Preservation of Calcined Bone at the Hirundo Site, Alton, Maine*. MA thesis, Department of Quaternary Studies, University of Maine, Orono.

Leechman, D. (1951) Bone Grease. *American Antiquity* 16(4):355-356.

Lefevre, C., D. G. Corbett, D. West, and D. Siegel-Causey (1997) A Zooarchaeological Study at Buldir Island, Western Aleutians, Alaska. *Arctic Anthropology* 34(2):118-131.

Lefevre, C., D. West, and D. G. Corbett (2011) Zooarchaeological Analysis at ADK-011, Adak Island, Central Aleutian Islands, Alaska. *Arctic Anthropology* 48(2):69-82.

Lofthouse, S. E. (2003) *A Taphonomic Treatment of Thule Zooarchaeological Materials from Diana Bay, Nunavik*. MA thesis, McGill University, Montreal.

Lyman, R. (1984) Bone Density and Differential Survivorship of Fossil Classes. *Journal of Anthropological Archaeology* 3:259-299.

(1994) *Vertebrate Taphonomy*. Cambridge University Press, Cambridge.

Marean, C. W. (1991) Measuring the Post-depositional Destruction of Bone in Archaeological Assemblages. *Journal of Archaeological Science* 18:677-694.

McKinley, J. (1994) Bone Fragment Size in British Cremation Burials and its Implications for Pyre Technology and Ritual. *Journal of Archaeological Science* 21:339-342.

Meadow, R. H. (1980) Animal Bones: Problems for the Archaeologist Together with Some Possible Solutions. *Paleorient* 6:65-77.

Mentzer, S. M. (2009) Bone as a Fuel Source: The Effects of Initial Fragment Size Distribution. In: *Fuel Management during the Palaeolithic and Mesolithic Periods*, edited by I. Thery-Parisot, S. Costamagno, and A. Henry pp. 53-64. BAR International Series 1914, Lisbon.

(2014) Microarchaeological Approaches to the Identification and Interpretation of Combustion Features in Prehistoric Archaeological Sites. *Journal of Archaeological Method and Theory* 21:616-668.

Moss, M. L., and P. M. Bowers (2007) Migratory Bird Harvest in Northwestern Alaska: A Zooarchaeological Analysis of Ipiutak and Thule Occupations from the Deering Archaeological District. *Arctic Anthropology* 44:37-50.

Murray, P. (1980) Discard Location: The Ethnographic Data. *American Antiquity* 45(3):490-502.

Nicholson, R. A. (1993) A Morphological Investigation of Burnt Animal Bone and an Evaluation of its Utility in Archaeology. *Journal of Archaeological Science* 20:411-428.

Nowacki, G. J., P. Spencer, M. Fleming, T. Brock, and T. Jorgenson (2001) *Ecoregions of Alaska and Neighboring Territories*. U.S. Geological Survey Open-File Report 02-297.

Outram, A. K. (1999) A Comparison of Paleo-Eskimo and Medieval Norse Bone Fat Exploitation in Western Greenland. *Arctic Anthropology* 36(1/2):103-117.

Pitcher, K. W.

(1984) *Susitna Hydroelectric Project 1983 Annual Report, Big Game Studies*, Volume IV, *Caribou*. Report submitted by Alaska Department of Fish and Game to Alaska Power Authority.

Plaskett, D. C. (1976) *Nenana River Gorge Site HEA-62: Preliminary Report on Archaeological Investigations 1975*. Technical Report to Geist Fund, University of Alaska, Fairbanks.

Potter, B. A. (2005) *Site Structure and Organization in Central Alaska: Archaeological Investigations at Gerstle River*. PhD dissertation, University of Alaska, Fairbanks.

(2007) Models of Faunal Processing and Economy in Early Holocene Interior Alaska. *Environmental Archaeology* 12(1):3-23.

(2008a) Radiocarbon Chronology of Central Alaska: Technological Continuity and Economic Change. *Radiocarbon* 50(2):181-204.

(2008b) Exploratory Models of Intersite Variability in Mid to Late Holocene Central Alaska. *Arctic* 61(4):407-425.

(2008c) A First Approximation of Holocene Inter-Assemblage Variability in Central Alaska. *Arctic Anthropology* 45(1):89-113.

Powers, W. R., R. D. Gurthrie, and J. F. Hoffecker (1983) *Dry Creek: Archaeology and Paleoecology of a Late Pleistocene Alaskan Hunting Camp*. National Park Service, Alaska Regional Office, Anchorage.

Reckford, H. (1983) *Where Raven Stood: Cultural Resources of the Ahtna Region*. Cooperative Park Studies Unit, University of Alaska, Fairbanks.

Reger, R. D., and T. K. Bundtzen (1990) *Multiple Glaciation and Gold-Placer Formation, Valdez Creek Valley, Western Clearwater Mountains, Alaska*. Division of Geological and Geophysical Surveys, Professional Report 107, Anchorage.

Ruff, C. B. (1983) The Contribution of Cancellous Bone to Long Bone Strength and Rigidity. *American Journal of Physical Anthropology* 61:141-143.

Shen, C., W. Yi, Y. Yang, Y. Sun, C. Jin, T. Liu, and B. Cai (2004) Concentrations of "Elemental Carbon" in Samples from the Peking Man Site at Zhoukoudian and the Possibility of their Application in the Development of Evidence for the use of Fire by Humans. *Chinese Science Bulletin* 49:612-616.

Shipman, P., G. Foster, and M. Schoeninger (1984) Burnt Bones and Teeth: An

Experimental Study of Color, Morphology, Crystal Structure and Shrinkage. *Journal of Archaeological Science* 11:307-325.

Shirar, S. (2009) Subsistence and Seasonality at a Late Prehistoric House Pit in Northwest Alaska. *Journal of Ecological Anthropology* 13(1):6-25.

Skeete, L. K. (2008) *An Analysis of Faunal Remains from the Susitna Hydroelectric Project*. MA thesis, Department of Anthropology, University of Alaska, Fairbanks.

Stiner, M. C., S. L. Kuhn, S. Weiner, and O. Bar-Yosef (1995) Differential Burning, Recrystallization, and Fragmentation of Archaeological Bone. *Journal of Archaeological Science* 22:223-237.

Taylor, R. E., P. E. Hare, and T. D. White (1995) Geochemical Criteria for Thermal Alteration of Bone. *Journal of Archaeological Science* 22:115-119.

Thery-Parisot, I. (2002) Fuel Management (Bone and Wood) during the Lower Aurignacian in the Pataud Rock Shelter (Lower Palaeolithic, Les Eyzies de Tayac, Dordogne, France). Contribution of Experimentation. *Journal of Archaeological Science* 29:1415-1421.

Tremayne, A. H. (2011) An Analysis of Faunal Remains from a Denbigh Flint Complex Camp at Matcharak Lake, Alaska. *Arctic Anthropology* 48:33-53.

Vehik, S. C. (1977) Bone Fragments and Bone Grease Manufacturing: A Review of their Archaeological Use and Potential. *Plains Anthropologist* 22(77):169-182.

Von Endt, D. W., and D. J. Ortner (1984) Experimental Effects of Bone Size and Temperature on Bone Diagenesis. *Journal of Archaeological Science* 11:247-253.

Wendt, M. (2013) *Integrating Climate Change with Human Land Use Patterns: Archaeology of Butte Lake Northeast*. MA thesis, Department of Anthropology, University of Alaska, Fairbanks.

White, E. M., and L. A. Hannus (1983) Chemical Weathering of Bone in Archaeological Soils. *American Antiquity* 48(2):316-322.

Wygal, B. T. (2010) Prehistoric Upland Tool Production in the Central Alaska Range. *Alaska Journal of Anthropology* 8(1):107-119.

Wygal, B. T., and T. Goebel (2012) Early Prehistoric Archaeology of the Middle Susitna Valley, Alaska. *Arctic Anthropology* 49(1):45-67.

Yellen, J. E. (1977) Cultural Patterning in Faunal Remains: Evidence from the !Kung Bushmen. In *Experimental Archaeology*, edited by D. Ingersoll, J. E. Yellen, and W. Macdonald, pp. 271-331, Columbia University Press, New York.

Yesner, D. (1996) Human Adaptation at the Pleistocene-Holocene Boundary (Circa 13,000 to 8,000 BP) in Eastern Beringia. In *Humans at the End of the Ice Age: The Archaeology of the Pleistocene-Holocene Transition*, edited by L. Straus, B. Erikson, J. Erlandson, and D. Yesner, pp. 255-276. Plenum Press, New York.

Zhong, M., C. Shi, X. Gao, X. Wu, Y. Chen, S. Zhang, X. Zhang, and J. Olsen (2014) On the Possible Use of Fire by *Homo erectus* at Zhoukoudian, China. *Chinese Science Bulletin* 59:335-343.