Where is the Beef?
Aurochs Exploitation in Neolithic Northeast China

by

Zhe Zhang

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Department of Anthropology
University of Alberta

Abstract

Houtaomuga site is located at the embankment of Lake Xinhuangpao in Da'an County of northeast China. Excavations from 2011 to 2015 revealed an occupation ranging from the early Neolithic period to late Liao Dynasty. This dissertation will focus on an unusual feature from the late Neolithic period at the site, the 5500-year-old G2 trench, with its many aurochs, as well as related house structures, in order to make a detailed analysis of faunal remains, to reconstruct the construction and deposition process for the G2 trench, and to better understand this Neolithic economy. The results will also allow investigation of social constructs and ideologies at Houtaomuga.

Aurochs are the dominant species in the G2 trench, and their large numbers suggest that they were a significant terrestrial meat resource. Genetic analyses of ancient DNA from the G2 aurochs indicate that they were wild animals, but they had reduced body sizes. There was also a selective slaughtering pattern. These factors suggest that the G2 aurochs came from a population that may have been somewhere along the range between fully wild and fully domesticated animals.

I present data on the species present in G2 trench and house structures at Houtaomuga, the distribution of animal species and elements, butchering and cooking practices, scavenger damage to the bones, and postdepositional weathering patterns. I also engaged in a spatial analysis to clarify the function of the G2 trench. On the basis of this evidence, along with the clustering in radiocarbon dates, I argue that the faunal remains in the G2 trench resulted from one or a few episodes of mass procurement, followed by one or a few depositional events that occurred in a short time. I also suggest that the Houtaomuga inhabitants engaged in large-scale feasting, and that the G2 trench was built for symbolic and social reasons rather than for purely functional purposes.

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Chapter 1: Introduction

Animals, as we have seen in various prehistoric and historic cultures in China, have played a major role in all aspects of pre-modern societies, as providers of food, raw materials for crafting, traction for agriculture and, symbolically, representing specific social and political meanings. The earliest zooarchaeological research in China started in the early 20th century, marked by the publication of *On the Mammalian Remains from the Archaeological Site of Anyang (Chardin and Young 1936)*. Since then, many scholars (either zoologists who were interested in archaeology or archaeologists who realized the necessity of studying faunal assemblages in the interpretation of human behaviour) have dedicated their lives to the development of zooarchaeology. Without a doubt, zooarchaeology has become an essential part of modern Chinese archaeology. The study of animal remains has contributed minimally, however, to the understanding of social interactions and political ideology in pre-historic China since most scholars have merely emphasized the economic function of animals. Using the results of zooarchaeological analysis of animal bone groups from Houtaomuga, a site which was occupied from the early Neolithic to the Iron Age, this study attempts to elucidate the economic and social role of animals in Neolithic China.

1.1 Houtaomuga site

The site of Houtaomuga in Da'an County, Jilin province (northeastern China), is located on a long and narrow hill on the southeast shore of Lake Xinhuang (Figure 1.1). The site has a total surface area of 1,410,000 m^2 and shows a high density of finds across an area of 550,000 m^2. It was occupied for a lengthy period of time that can be divided into seven cultural stages based on radiocarbon dates and pottery typology, ranging from the Neolithic Age to the Liao and Jin Dynasties. Kunikita et al. (2017) found that Houtaomuga's Neolithic occupation began 13000 years ago and can be divided into four phases ending at 5000 cal yr BP. Phase IV will be the focus of this dissertation. The site was first investigated in 1957, and major excavations were carried out again from 2011 to 2015. All artifacts were collected and recorded by stratigraphic units, and all soil was screened for microliths, and small animal remains. Many pot sherds, lithics and animal bones were discovered at this site.

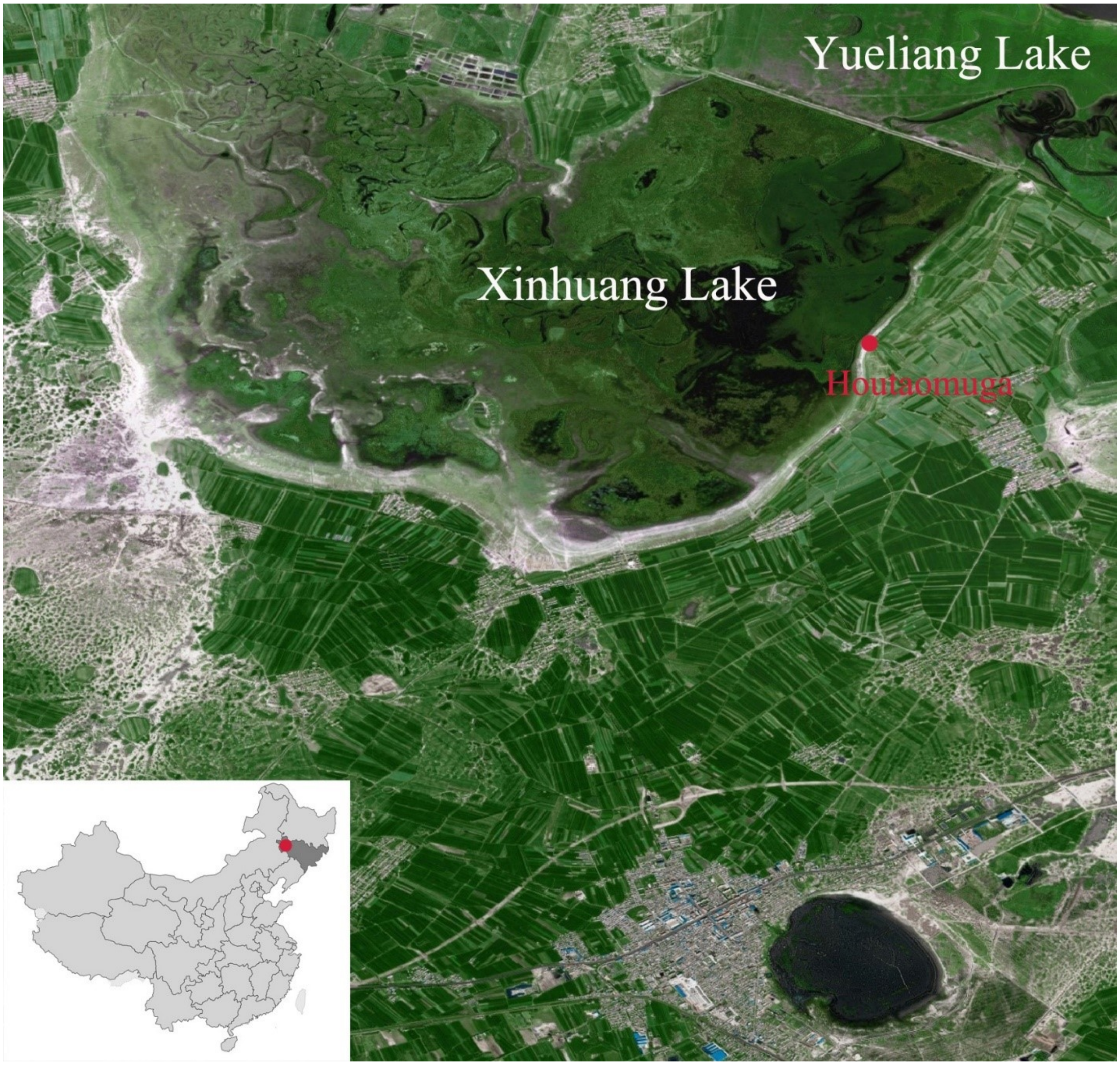


Figure 1.1 Location of Houtaomuga.

The site was divided into four quadrants (Figure 1.2). From 2011 to 2012, a joint archaeological team that was formed by archaeologists from the Research Center for Chinese Frontier Archaeology (RCCFA) of Jilin University and the Archaeological Institute of Jilin Province (AIJP) unearthed about 2355 m^2 of the third quadrant (III) and the fourth quadrant (IV) (RCCFA and IAJL2016). In 2012, the excavators discovered a special trench (G2) in the north of IV full of aurochs' bones in very high density. Many bones were in articulation when they were uncovered. The G2 trench belongs to the fourth phase, which is the last phase of the Neolithic period at this site and is associated with the Haminmangha culture. In later excavations from 2013 to 2015, a more complete site layout was unearthed, revealing that the G2 trench was part of a large circular structure.

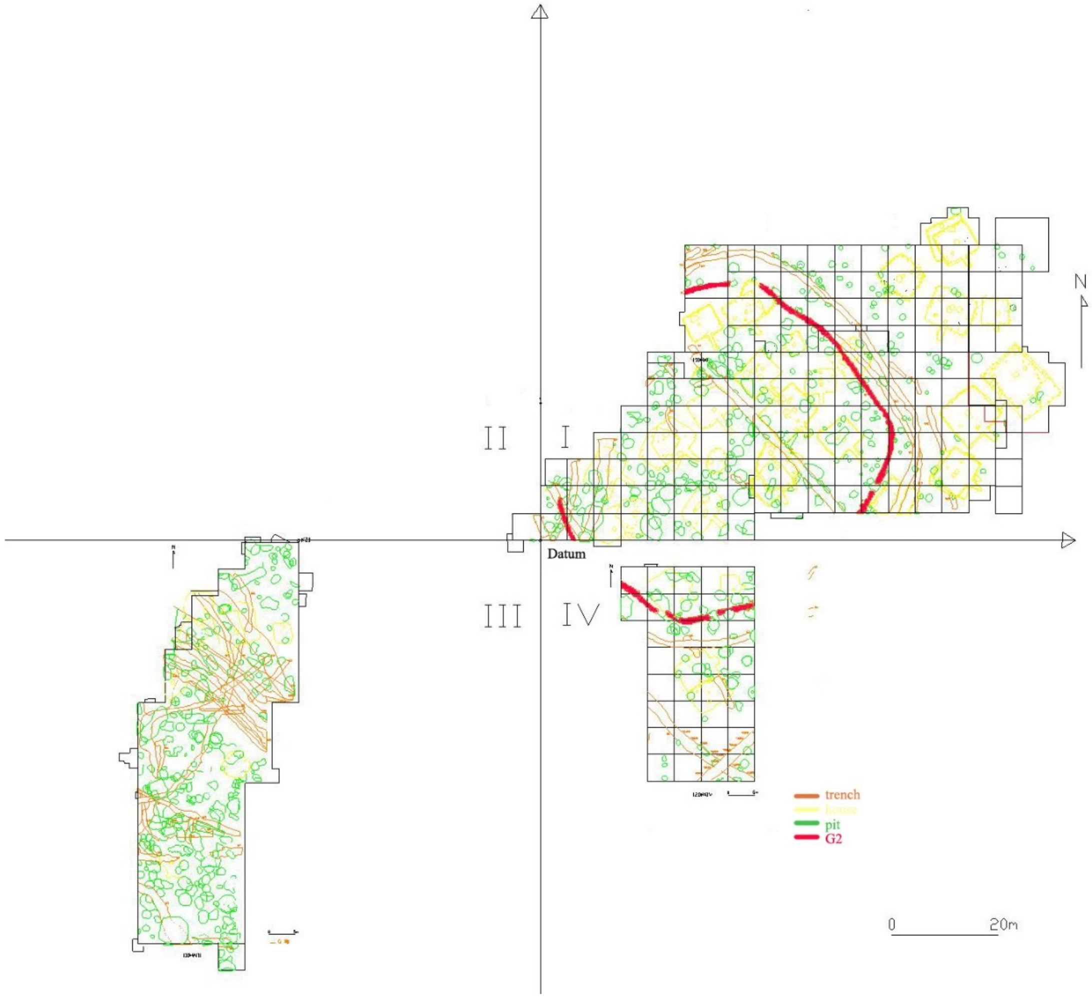


Figure 1.2 Plan map of the excavation area at Houtaomuga. The G2 trench is marked in red.

The faunal remains were dominated by aurochs bones, which came from G2 trench in excavation areas I and IV. In the excavation area IV, the G2 trench was first uncovered in an arc-shape in 2012 (Figure 1.3). The highly concentrated bone deposition is unique in northeast China, and it stimulated my curiosity to discover what had happened there. In the subsequent excavation from 2013-2015, another ditch, which was assigned a feature name as G1, represented a similar deposition in quadrant I (Figure 1.4). Excavators later identified that G2 in quadrant IV and G1 in quadrant I are part of the same trench that circled the whole village, separating the house features into interior and exterior houses. Therefore, in the following study, "G2" will be used to refer to G1 from quadrant I together with G2 from quadrant IV for clarity. The zooarchaeological material, including the assemblage from the G1 and G2 trench, and the contemporary house features, is studied here to obtain information about Neolithic life in Houtaomuga, but most particularly to better understand what led to such a concentration of aurochs bones.

Figure 1.3 An aerial map of the excavation area in quadrant IV with the location of the G2 trench.

Figure 1.4 An aerial map of the excavation area in quadrant I with the location of G1(G2) trench.

1.2 Research objectives and postulates

The specific objectives of this dissertation are:

To determine if patterns in the aurochs bones deposited at G2 represent the mass procurement of these animals at Houtaomuga, or more individual hunting efforts, and to determine if the large number of animals involved came from feasting activities. How can we detect such distinctions from a zooarchaeological perspective?

Sites with a large number of ungulate bones have been discovered in many parts of the world, and archaeologists have long been interested in interpreting site formation processes connected with whether a bone accumulation resulted from mass procurement or not. Thus, this is the first question that must be considered in this study. The examination and analysis of faunal remains, particularly of aurochs bones, will reveal the formation processes for the circular ditch and aid in reconstructing animal consumption at Houtaomuga.

In addition to the information from the aurochs bone assemblage, securing radiocarbon dates from bone samples from G2 will also provide critical interpretive evidence. For example, Bayesian modelling of the radiocarbon dates should indicate a brief time range if G2 was the consequence of a single or a few temporally related episodes of mass procurement. Correspondingly, we would expect a wider range of radiocarbon dates if the bones in the G2 trench accumulated over a longer period, involving many small procurement events.

To explore where the aurochs originated. Did aurochs management or domestication happen here? What role did aurochs play in the daily diet of Houtaomuga inhabitants?

There is a broadly accepted view that domestic cattle were introduced to China sometime around 6,000 to 5,500 years ago, eventually becoming a significant livestock species in Northern China around 4,500 years ago. The discovery of a large amount of aurochs remains at Houtaomuga raises the possibility that human control or management of these bovids may have begun in northeast China.

Stable isotope analysis of human and animal bones has played a prominent role in the assessment of diet and forage strategies because it provides direct evidence of the relative dietary contribution of certain food classes. Animal bones (aurochs, deer, and dog) from the G2 trench were selected for carbon and nitrogen stable isotope measurement to investigate the possible human influence on animal diets.

To explore why people built this trench. Did patterns of food consumption (whether feasting events or daily consumption over longer periods of time) reflect an intensely hierarchical *division of society, such that the settlement was spatially organized in concentric gradients with elites occupying the space enclosed by the trench?*

If dietary reconstruction reveals variation between materials recovered inside and outside the trench, it may indicate the trench acted as the spatial boundary for a social division. This would further suggest that distinctions in food consumption were a prime means of marking social boundaries.

1.3 Cattle Domestication in China

There are many studies concentrating on the process of domestication of cattle in China, specifically around the question of whether China was an independent location for cattle domestication (Lu et al. 2017; Lv 2007; Mannen et al. 2004; Yu 2015; Zhou 1984). Most zooarchaeologists and geneticists have concluded that modern domesticated cattle derived from the extinct aurochs (*Bos primigenius*). There were two episodes of domestication: one involving *Bos taurus* in the Near East around 8,000-10,000 years ago and one involving *Bos indicus* in South Asia roughly 7,000 years ago (e.g., Ajmone-Marsan et al. 2010; Bradley and Magee 2006; Loftus et al. 1994; MacHugh et al. 1997; Mannen et al. 2004). In earlier research, domesticated cattle in China were believed to have descended from late Pleistocene aurochs populations (Zhou 1984). The identification of haplogroup T4, which is a unique divergent compared to the haplogroups T1, T2, and T3 found in Europe and Africa, provided evidence of an independent mitochondrial origin in Asian cattle (Mannen et al. 2004). Zhang et al. (2013) discovered an aurochs mandible dated to 10,660 calibrated years BP in northeast China and provided new evidence for the theory of indigenous cattle domestication. They observed symmetrical hyper-attrition of teeth on the M1 and P4 from both sides of the mandible, and inferred that was caused by the repeated chewing of hard objects, such as crib-biting. They considered this as evidence of human-intensive management of aurochs.

However, Lv et al. (2014) claimed that the extreme wear on the lower P4 and M1 can also occur in other large ungulates in old age, from the long-term grinding of over-erupted opposing teeth on the maxilla. Therefore, they insisted that hyper-attrition on the mandible cannot be considered as evidence only of human-intensive management (Lv et al. 2014). Recent genetic studies have also opposed the theory of local cattle domestication. Achilli et al. (2008) proposed that the derived clade of haplogroup T4 probably shared a same or closely related genetic source with T3, and all T haplogroups have a single origin in the Fertile Crescent. The mitochondrial DNA analysis on 53 cattle individuals from five archaeological sites aged between 4500 and 2300 years in northern China showed the predominance of haplogroup T3, which indicates that Chinese domestic cattle originated from the Near East and were introduced into Northern China around 4,500 - 3,900 ago (Cai et al. 2014).

The evidence from biometry and genetic analysis indicates that cattle were introduced to China sometime around 6,000 to 5,500 years ago (Cai et al. 2014; Yu 2015). It is highly possible that cattle, first domesticated in the Fertile Crescent, travelled to China and either reached the Tianshan Mountain range via the Inner Asian Mountain Corridor or entered east of the Mongolian Plateau through the vast Eurasia Steppe (Yu 2015).

1.4 Mass Procurement

Mass procurement is often defined as capturing or killing of a number of animals in a single event. Sites with large numbers of ungulate bones have been discovered in many locations across the world, and archaeologists have long had an interest in interpreting this phenomenon, especially whether it is a mass procurement episode or not (Bar-Oz et al. 2011; Dewar et al. 2006; Frison and Reher 1970; Hill 2002; Todd et a. 1992). Although such places have been found across the world, bison bonebeds in North America are among the most famous.

The earliest systematic excavations and investigations began at the Emigrant bison drive site (Brown 1932), kill sites in Montana (Lewis 1941), and Wettlaufer's 1949 work at Head-Smashed-In, followed by Forbis's 1960s work at both Head-Smashed-In and Women's Buffalo Jump (see Brink 2008:19). In the 1970s, Frison began extensive work in Wyoming, including at the Casper Site and Glenrock Buffalo Jump. His research often concentrated on bison season of death, butchering processes and lithic assemblages in bone beds. Based on animal ages at the time of death at several Paleoindian bison kills (including the Casper, Horner, Finley, and Hawken sites), Frison inferred the seasonality of communal bison procurement as late fall or early winter. This seasonal hunting was important in preparing for storage of both meat products and hide, for the long and bitter winter (Frison 1978). By the 1980s, researchers concentrated more on bison ecology, from historical documents that focused on the annual cycle of bison seasonal movement patterns (Bamforth 1987; Epp 1988; Morgan 1980). In the 1990s, bison bone beds that had been excavated earlier were re-investigated with new technologies and methods (Hofman and Todd 1997; Johnson and Holliday 1997; Niven and Hill 1998). Although researchers still concentrated on age estimation, bison death season and butchering strategies, bone surface modification and fracture patterns which related to taphonomic processes were also evaluated by researchers (Hill and Hofman 1997; Quigg 1997; Todd and Rapson 1999).

Recently, unlike the previous studies which primarily focused on the generation and meaning of mortality distribution, Lubinski (2013) has argued that multiple lines of evidence for mass procurement should be interpreted in faunal assemblages. He divided them into four categories: 1) a threshold number of prey species bones (the target prey species should constitute a majority [>50%] of faunal remains in the collection); 2) human caused mortality (direct evidence of human caused death, such as projectile points embedded in bone, or indirect indicators, like high rates of green fracture owing to human behavior; 3) evidence for a single depositional episode (e.g., assessing surface modification of bones, especially the weathering stage, that would be expected for a single deposit event; 4) evidence for a single mortality event (e.g., a narrow mortality season or an age distribution close to a living population structure (Lubinski 2013). Each category has several detailed forms of evidence that should be considered in analysis of such assemblages.

1.5 Animals, feasts, and the construction of communal politics

1.5.1 Feasts and commensal politics

Feasts are a significant aspect of social life for different societies, both past and present. An expanding body of scholars has argued that detecting feasting practices in the archaeological record is important for understanding kinship, social status and intercommunity relationships.

Mauss (1967) was among the first to consider the social and political significance of feasts. He proposed that gift giving at feasts is not free of self-interest. Rather, showing one's superiority by gift giving is a way of establishing a hierarchy in interpersonal relations. Further, he demonstrated that the donor gains prestige by transforming the recipient into a debtor if the gift cannot be repaid in an equivalent value. Like Mauss, many anthropologists and sociologists believe that unilateral giving eventually leads to an increase of power and prestige for the donor. However, the situation in modern China has the opposite connotation. Yan (1993) studied the relationship between the flow of gifts and social networks in a Chinese village based on his field work in Xiajia, Heilongjiang Province; he suggested that gift receiving rather than gift giving is regarded as a symbol of prestige.

It was not until the 1990s that archaeologists started to recognize the importance of feasts in political and social development. Wiessner (2001) studied the feasts among the Enga, a highland horticultural society from Papua New Guinea, and found that big-men gained prestige through organizing impressive feasts, especially large, sacred feasts. Furthermore, acquiring significant prestige not only offered big-men the license to excel inside the group, but also had an impact on intergroup relationships: prestige keeps big-men alive in frequent warfare because they are too important to be killed. Additionally, feasts also provided the opportunity to alter norms and values by importing new cults and ritual experts from other groups, or by rearranging new cult procedures to communicate with ancestors. Clark (2001) observed that the feast is a means to reinforce group solidarity among the Akha, a transegalitarian society in Thailand. All the elder males representing the various lineages in the village were in attendance at a wedding feast, which implied and confirmed their friendship and cooperation, while their absence was treated as a clear statement of disassociation. Other than the social and political benefits that were obtained through feasting, Hayden (2014) proposed that feasting, which requires a large amount of surplus, is probably the predominant motivation for the development of food production and the domestication of plants and animals.

Based on an extensive body of archaeological and ethnographic research, scholars attempt to define feasts in a number of different ways. Dietler (2001) focused on the symbolic meaning behind feasts that could distinguish them from everyday activities; thus, he defines feasts as “a form of public ritual activity centred around the communal consumption of food and drink.” Hayden (2001, 2014) proposed a broader definition of a feast as “any sharing between two or more people of a meal featuring some special foods or unusual quantities of foods hosted for a special purpose or occasion." He suggested that the word "ritual" is too obscure and could lead to misunderstandings because ritual activities would exclude many events generally viewed as feasting such as solidarity dinners, work feasts, puberty feasts, and wedding parties. Although the definition of feasting varied from author to author, food (including drink) is always the pivotal part of the whole activity.

1.5.2 Animals as food and status

No matter what the purpose is, food and drink are always necessary for feasts. In other words, a feast cannot be considered a feast without the consumption of food and drink. In the Akha society of northern Thailand, Clark (1999, 2001) observed that chicken, pig, cattle and water buffalo all played a prominent role in the feasting, particularly cattle and water buffalo, which were only used at the most important feasts because of their high value in the economy. In Indonesia, Tana Toraja also has a similar regulation, in which water buffaloes, in particular, are reserved for the most lavish of feasts, while pigs and chickens are slaughtered at a wider variety of feasts (Adams 2001). However, not all food is suitable for feasting, and there are some basic rules in food selection. Products that are costly to produce and labour-intensive, and animal species that are difficult to acquire have a higher possibility of being consumed in feasts (Blackburn 1986; Foster 1990; Hayden 2001; Wiessner 2001).

Animals not only appeared as food in feasts, but also delivered social and political implications in various ways. In pastoral societies, wealth is nearly always defined and measured in cattle and other large livestock as people have a steady demand for them (Russell 1998, 1999). In South Sudan, cattle are a great treasure for the Nuer not only because their daily life is largely dependent on milk from the herds, but also because of their deeper significance to the Nuer.

Males who have passed through the rite of initiation to manhood must take an ox-name from their cattle in addition to the personal names they are given soon after birth; therefore, a man would be accused of wastefulness if he were to slaughter cattle unnecessarily for sacrifices and feasts (Evans-Pritchard 1956). Maasai people, who inhabit northern, central and southern Kenya and northern Tanzania, generally hold the feast of the Great Ox for elders to celebrate their transition to elderhood. In those feasts, meat from different parts of a butchered ox is distributed to groups of different statuses (Spencer 1988). For example, the best cuts and "extremely sweet" parts, such as the tongue and flank, often go to elders, while the worst cuts are always allocated to women. Maasai men argue that women are quite undiscriminating and cannot know the value of what they have never tasted (Spencer 1988). Meat also serves to identify the gender, wealth, power, and rank of participants in the feasts when animals are donated or slaughtered in Turkana in northwest Kenya (Lokuruka 2006).

1.5.3 Feasting in Early China

Various historical documents from early China indicate the great importance of food and feasting to the early state, and that ritual sacrifice was the symbol of the legitimation of power and authority of the ruler. In the frequently cited text from *Zuo Zuan* (The Zuo Tradition or The Commentary of Zuo), the two primary affairs for a state are warfare and sacrifice. Bronze vessels were difficult to make and get in the early period and were only used by the elite, so they generally represented ruling power and prestige in the sacrifice.

In addition to bronze vessels, animal sacrifice was another claim to power and status. The *Li Ji* (Book of Rites) is a collection of texts describing the social forms, administration, and the ceremonial rites of the Zhou dynasty. Although compiled in the early Han period, it is believed to faithfully reflect social and ritual practice in the Zhou. In chapter three, it describes the different animals that were used in the ritual: “In sacrificing at the altars to the spirits of the land and grain, the son of Heaven used in each case a bull, a ram, and a boar; the princess, (only) a ram and a boar” (Li Ji. Trans. James Legge 1885, P226). It also proposed the regulation of animal sacrifice in great detail:

> If the sacrifice were a great one, consisting of the three victims, then the portion sent was the left quarter of the ox, divided into nine pieces from the shoulder. If the sacrifice were the smaller, the portion sent was the left quarter, divided into seven pieces. If there were but a single pig, the portion was the left quarter, divided into five portions. (P81)

Animal species, elements, side and portion were all stipulated in a strict manner, and acted as the manifestation of political power and social position.

Although most of the historic documents described the manner and regulation of feasting in the Shang and Zhou dynasties, archaeological studies have suggested that the tradition of sharing food and drink in a communal event, particularly in the activity of mourning deceased in a ritualized space, is much earlier and rooted in the Neolithic in China. Underhill (2000) sees Dawenkou cemetery as containing evidence of marked social change and believes that family members invested more pottery vessels for funeral feasting to feed more mourners and to express more respect to the deceased. The most labour-intensive form of pottery vessel, the long-stemmed cup, was a way of displaying wealth during funerals. Later, she expands this study to sites from the Dawenkou and Yangshao Regional Phases in Shangdong province. From her results, she argues that, during the Late Dawenkou Regional Phase, the quantity and diversity of food vessels increased dramatically in both western and eastern Shandong (Underhill 2002). Fung (2000) also worked with the data from Dawenkou culture. However, except for the investigation of changes in pottery vessel frequency over time, he focused on the spatial patterning of grave-goods within Dawenkou burials. He observed that there was a change in the way the majority of stemmed drinking vessels were placed in graves. There was an explicit symbolic distinction between goblets that were placed around the perimeter of a grave, and those placed near the corpse and parallel to it. Fung (2000) interpreted the former as a sacrifice for the deceased, while the latter as the drinking vessels that served mourners at the graveside.

Almost all the research about the archaeological evidence of feasting in China is associated with graveside feast and pottery vessels (Fung 2000; Lee and Zhu 2002; Nelson 2003; O'Connor 2015; Reinhart 2011; Underhill 2000, 2002). Some scholars even argue that compared to relations with their living counterparts, forming alliances with the deceased or ancient ancestors was more powerful and desirable in early Chinese society (Nelson 2003). The discovery of ditch G2 in Houtaomuga, however, evidently indicated that communal food sharing was much more complex than previously imagined. It also highlighted the important role of animals and implied a possible approach to distinguish feasting in ancient China. In this dissertation, I will provide new insights into identifying and understanding feasting practices in early China from the perspective of zooarchaeology.

Chapter 2: Background Information for Northeastern China

2.1 Introduction

This research will focus on the formation processes and function of G2 at Houtaomuga; I will attempt to obtain a better understanding about the changes and developments in the settlement structure and social complexity in northeastern China. Therefore, it is necessary to review the previous archaeological research within this region (see Figures 2.1 and 2.2).

Figure 2.1 Distribution of culture areas and positions of Houtaomuga and Haminmangha mentioned in the text. (1) The West Liao River Valley; (2) The South Songnen Plain.

Many of the earliest publications on Chinese prehistory focused on descriptive analyses of pottery and the creation of culture types based on these typologies (Andersson 1923; Gernet 1968). In more recent times, the development of technologies for analyzing ancient plant remains as well as an increasing focus on the study of faunal remains from archaeological sites has contributed to a more holistic perspective on the shift from economies based on mobile hunting and gathering in the Paleolithic to more sedentary and village-based settlement patterns in the Neolithic period.

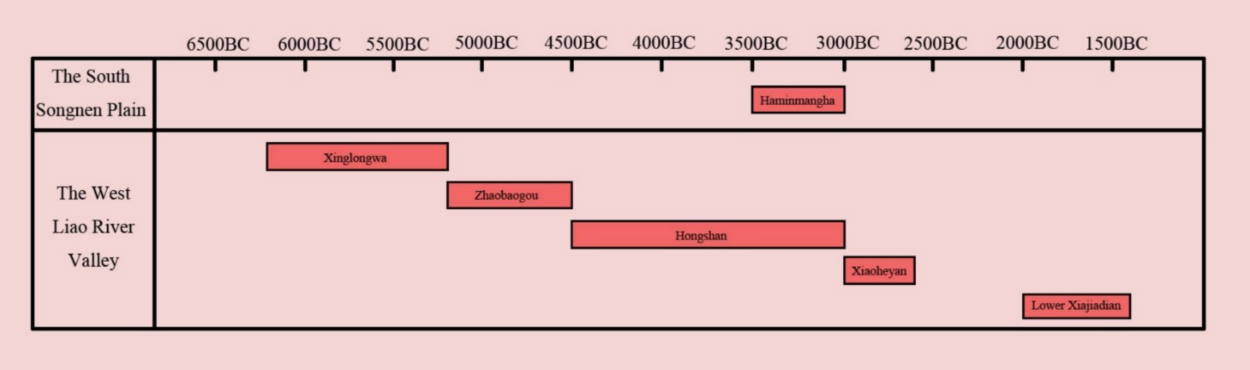


Figure 2.2 A timeline of cultures discussed in the text.

Within the archaeological literature, the prehistoric period in China is often addressed with northern and southern China as separate units (Liu and Chen 2012). While this division does not necessarily reflect the complexity of interaction across China during this time, it provides a way in which a vast landscape can be more succinctly analyzed and more effectively ordered in an archaeological sense (Fargo 2014). However, some subareas in northern and southern China were ignored in favour of an emphasis on the flourishing cultures along the Yellow River and Yangtze River (Lawler 2009; Lee 2002; Olsen 1987; Wang 2006). Northeastern China, also called Dongbei or Manchuria by some researchers, is one of these subareas that lacks comprehensive study in this context.

Northeastern China is bounded by the Greater Xing'-an Mountains to the west, the Lesser Xing'an Mountains to the north, and the Changbai Mountains to the east, separating China from Korea and Russia (Liu and Chen 2012) (Figure 2.1). The modern climate is cold and dry in the winter, and dry and very windy in the spring. Summers are relatively short and hot, with temperatures dropping rapidly during the autumn. The average temperatures in this area are between -11℃ and -15℃ during January and 20℃ - 23℃ in July (Kong et al. 1991). Most precipitation occurs in summer, with 70% of the average 350-450 mm falling between June and August (Kong et al. 1991; Wang 1990). Fluctuations of up to 25% in yearly precipitation are common throughout the area (Tian and Shi 1997). The northern part of the Northeast Plain, which is bitterly cold in winter, is marginal for farming, whereas the southern part, especially the Liao River valley, is milder (Tregear 1980, 2017). Some early Neolithic villages have been found in the Liao River region, marking it as one of the earliest regions of sedentary communities in China. In addition, an independent cultural sequence was developed in this region that differs from that of the Yellow River valley (Liu and Chen 2012).

2.2 Setting the stage

A brief overview of the culture sequence is described in this section to set up an archaeological framework for interpreting the archaeological record at the Houtaomuga site.

2.2.1 The Xinglongwa and Zhaobaogou Culture

The Xinglongwa (ca. 6200 – 5200 BC) and Zhaobaogou (ca. 5200 – 4500 BC) cultures represent the early Neolithic stage in Northeast China. About 100 sites of the Xinglongwa culture have been found, distributed mostly in the hilly Liaoxi region, in today's southeastern Inner Mongolia, western Liaoning, and northern Hebei (Liu and Chen 2012). The Zhaobaogou culture succeeded the Xinglongwa culture, and nearly 100 sites have been reported, while only a few dozen sites have been excavated. These sites represented the development of sedentary living, ceramic production, and the use of domesticated plants and animals. The most thoroughly excavated sites are Xinglongwa and Zhaobaogou in Aohan Banner, Baiyinchanghan in Linxi County, and Chahai in Fuxin. Excavations at habitation sites represented the earliest villages in this area, and led investigators to suggest that most were planned before construction. They featured square semi-subterranean houses arranged in rows, at more or less equal distances from each other (Linduff et al. 2004). Most house features were 50-80 m^2 in size, with some as large as 100 m^2. Storage pits were found both inside and outside houses, and human burials have occasionally been found underneath the house floors (Figure 2.3). Some of the earliest sites were surrounded by a narrow ditch (Linduff et al. 2004). At Xinglongwa and Baiyinchanghan, for example, these ditches are 0.55 – 1.00 m deep and 1.5 –2.00 m wide (Guo et al. 1991; Zhongguo 1985).

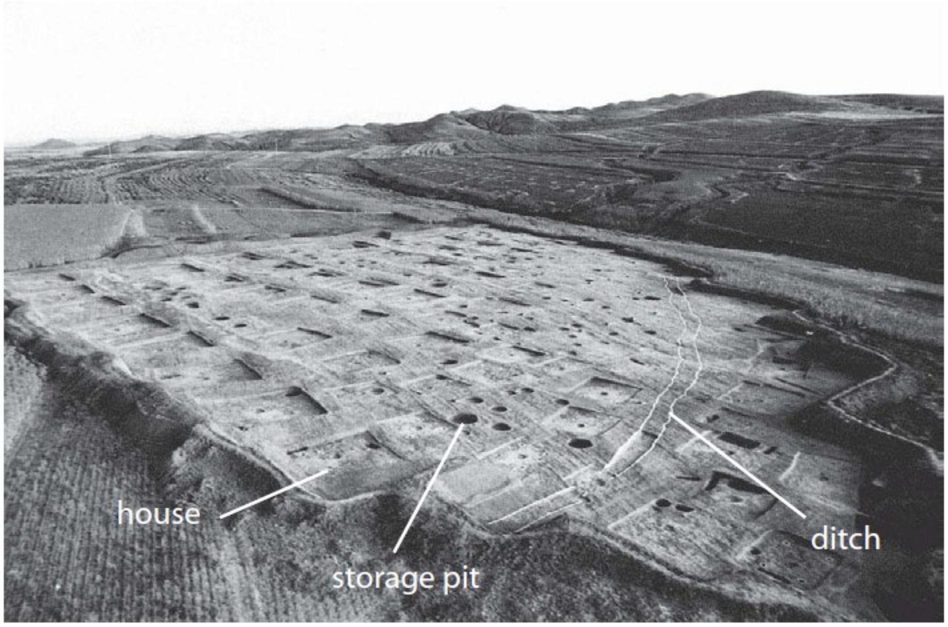


Figure 2.3 The settlement layout of the Xinglongwa site (after Liu and Chen 2012).

The ceramic vessels of Xinglongwa culture were simple in form, dominated by bucket-shaped pots, and made of coarse, sand-tempered clay (Linduff et al. 2004). They were relatively soft and uneven in color, suggesting poor control over firing conditions. The vessels were all hand-made, mostly by coiling. During the Zhaobaogou period firing techniques slightly improved and pottery, although usually simple in shape, became more varied (Linduff et al. 2004). The most common decorations were impressions and incisions, especially of a “Z” motif.

Flaked stone, ground stone, and bone tools were commonly found at Xinglongwa sites. Functional interpretation of these tools was based strictly on their shapes, leading to categories such as hoes, axes and grinding stones for morphological types (Liu and Chen 2012).

2.2.2 The Hongshan and Xiaoheyan Culture

The Hongshan culture was the first complex society to develop in northeastern China. It was first discovered in the early 20th century, and many archaeological excavations and surveys have since been devoted to its investigation. Most Hongshan sites date to between ca. 4500 and 3000 BC and are found across western Liaoning province and the southeastern part of Inner Mongolia (Liu and Chen 2012).

Hongshan culture is known mainly from the discoveries of monumental-scale ritual structures, elaborate burials, and sophisticated jade artifacts. The most intensive investigations focused on Hongshan monuments and graves while few domestic sites of this period were excavated and studied.

Hongshan indicated the emergence of societies with social inequalities and organized, skilled labour forces. The attributes of ceramics—including texture, shape, and decoration, were carefully studied and were the foundation of building the chronology between cultures.

Among the few domestic features so far discovered, researchers have identified circular storage pits and rectangular houses, some semi-subterranean and others at ground level (Linduff et al. 2004). Some sites were also surrounded by trenches. The Xitai site, for example, was divided into north and south regions by a moat, and 17 house features were found at the site (Zhu

2003). The Hongshan graves that have been recovered are usually large stone piles or "cairns." At locality II of Niuheliang, the largest cairn is 35 m long. They are constructed with stone walls and filled with earth and rubble. At Niuheliang the large graves are associated with the nearby "Goddess Temple" where the excavation of a large platform revealed a multi-chambered structure 25 m long and 2 - 9 m wide (Liaoningsheng 1986).

Hongshan ceramics contain abundant sand temper. The walls of the vessels are thick, many decorated with a "Z" motif. Delicate jade artifacts including *huang* (semi-lunar shaped pendants), *bi* (circular objects), and some animal shaped objects indicate an advanced technology in crafting. They are often discovered in burials and ritual sites (Linduff et al. 2004),

There is no doubt that farming activities increased in the Hongshan subsistence economy; this conclusion is based on the presence of domesticated pigs and millet at several Hongshan sites, and the fact that the high density of Hongshan settlements could be supported only by intensified agriculture (Liu and Chen 2012). On the other hand, recent stable isotopic analyses of human bones from the Xinglongwa site showed that the Hongshan people were likely to have relied on broad-spectrum subsistence strategies, although agriculture now played a much more critical role than ever before in this region (Zhang et al. 2003).

The Hongshan culture collapsed at approximately 3000 BC, resulting in a dramatic decline in population and sparse settlement in the subsequent period (Figure 2.4). Some researchers have proposed that this abrupt transition occurred because of decreased precipitation at the time, when summer monsoons weakened (An et al. 2000). On the contrary, other researchers have insisted that excessive farming may have caused desertification of this fragile landscape, contributing to a decline in agricultural productivity (Liu and Chen 2012). The collapse of Hongshan complex society may have been related to multiple factors, including climatic fluctuation, overexploitation of land, and social responses to external challenges.

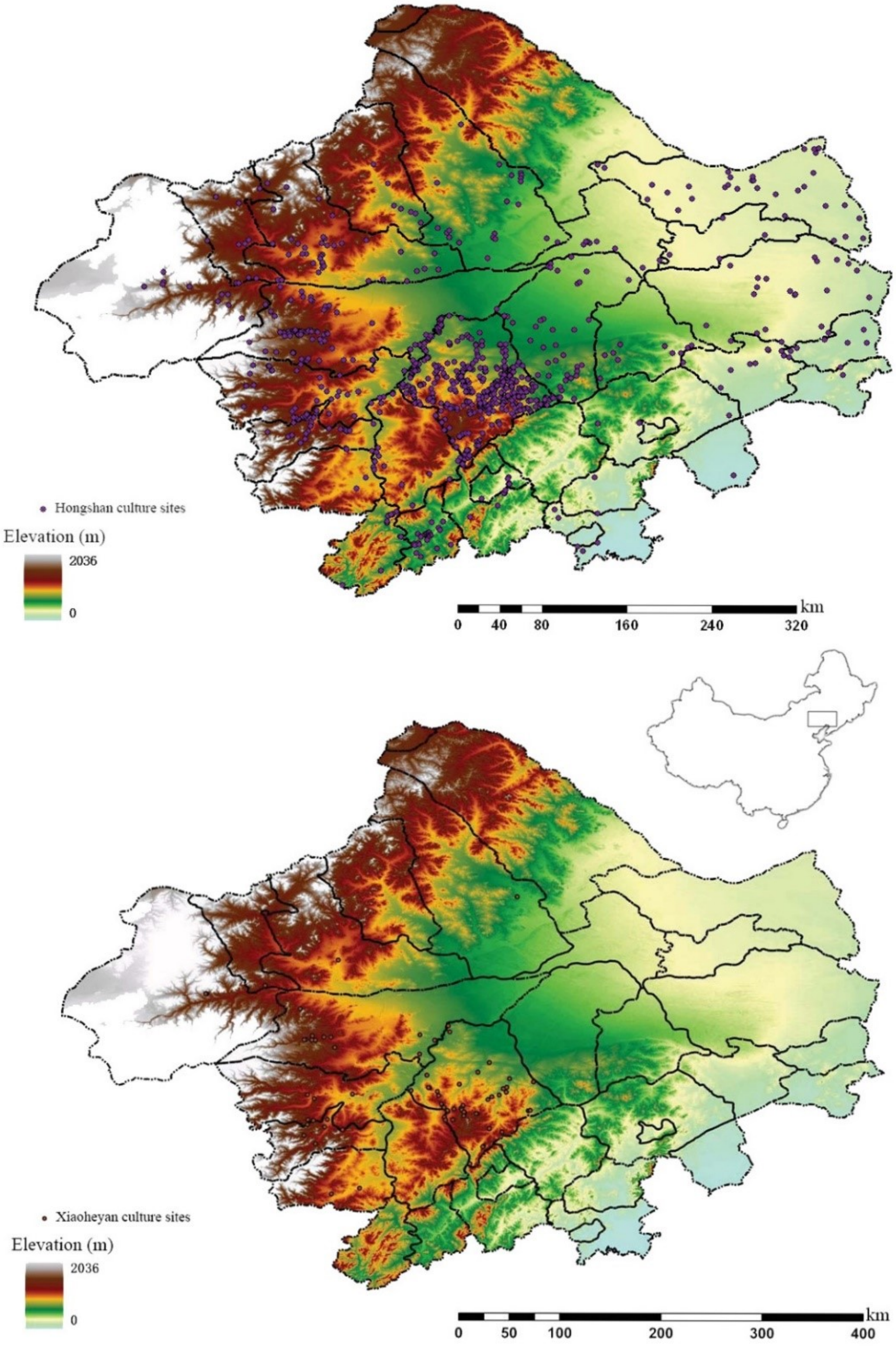


Figure 2.4 Map showing distribution of archaeological sites during Hongshan (top) and Xiaoheyan (bottom) periods in the west Liao River Valley (Liu 2012).

The chronological gap between the end of the Hongshan period and the beginning of the Lower Xiajiadian period was an issue of debate among Chinese archaeologists during the 1970s and 1980s. In an attempt to interpret the cultural discontinuity between these two periods, some scholars believed that Hongshan was an indigenous culture while the Lower Xiajiadian was associated with migratory waves coming from the south or southwest (Tian 1992). The chronological gap between the Hongshan and Lower Xiajiadian period was filled by the Xiaoheyan culture with the excavation of Baiyinchanghan (ICRAIM 2004). The Baiyinchanghan site provided two lines of evidence. First, the strata which contained an archaeological assemblage from the Xiaoheyan culture was deposited between the Hongshan and Lower Xiajiadian layers. Secondly, the similar ceramic shapes (ICRAIM 2004), such as tripod legs, and the overlapping distribution area provided additional evidence that the Hongshan culture was succeeded by the Xiaoheyan culture (Suo and Li 2008). Radiocarbon dates also indicated the Xiaoheyan culture developed at the end of or after the collapse of the Hongshan (Du 2014; Suo and Li 2008) (Table 2.1).

Table 2.1 Radiocarbon results from the Hongshan and Xiaoheyan cultures (Suo and Li 2008; Du 2014).

	Site	Sample ID	Feature	Sample Type	14C (BP)	Date cal BP (68.2%)
Hongshan Culture	Xinglongwa	ZK-1394	F133③	Wood Charcoal	5865 ± 90	6525 ± 100
		ZK-2064	F142①	Wood Charcoal	5735 ± 85	6395 ± 190
		ZK-3074	F106②	Wood Charcoal	5425 ± 53	N/A
	Dongshanzui	BK-82	Rock structure	Wood Charcoal	4895 ± 70	5485 ± 100
	Niuheliang	ZK-1355	N2Z1	Wood Charcoal	4995 ±110	5600 ± 135
		ZK-1351	N1F1	Wood Charcoal	4970 ±80	5575 ± 110
		ZK-1354	N1F1	Wood Charcoal	4605 ± 125	5145± 155
	Wudaowan	ZK-1180	M1	Human Bone	4455 ± 85	4965± 80
	Xiaodongshan	N/A	F8	Wood Charcoal	5430 ± 80	N/A
	Jinggouzi	BK2003067	F1③	Wood Charcoal	5160 ± 55	N/A
Xiaoheyan Culture	Shipengshan	ZK-0542	M35	Bone Charcoal	3640 ± 120	3955 ± 135
		ZK-0740	M54	Human Bone	3785 ± 100	4135 ± 120
		WB82-08	M76	Wood	4345 ± 80	4830 ± 180
	Halahaigou	N/A	M36:1	Human Bone	4920 ± 40	N/A
		N/A	M36:2	Human Bone	4850 ± 35	N/A
		N/A	M33:2	Human Bone	4860 ± 35	N/A
		N/A	M41	Human Bone	4925 ± 40	N/A
		N/A	M45:3	Human Bone	4780 ± 40	N/A
	Xueshan	WB82-58	T225H11	Wood Charcoal	4880 ± 90	N/A

Since little excavation of Xiaoheyan sites has occurred, its settlement pattern and ceramic assemblage are poorly understood (Linduff et al. 2004). The subsistence economy was primarily hunting-gathering, as indicated by the absence of reaping knives and the presence of hunting-gathering tools, such as arrowheads and microblades (Li and Chen 2012).

2.2.3 Lower Xiajiadian Culture

The Lower Xiajiadian culture (ca. 2200-1600 BC) was named after an excavation site at Xiajiadian in Chifeng, Inner Mongolia, revealing a stratigraphic sequence of two distinctive Bronze Age cultures, namely Lower Xiajiadian and Upper Xiajiadian. The Lower Xiajiadian is marked by a dramatic increase in the number and size of sites and the appearance of labour - intensive defence systems comprising large stone or brick walls. Some of the more significant sites have two such walls separated by a trench (Shelach 1998). Lower Xiajiadian houses were round or square-shaped and were built on either the ground level or were subterranean (Figure 2.5).

Agriculture seems to have been the dominant subsistence mode, although pastoralism had already played an important role. The technology of making ceramic vessels developed significantly, reflecting the widespread use of the fast wheel and the achievement of high firing quality. More complex vessels, such as *li*, *yan*, and *ding* tripods and pedestal vessels (*dou*) were relatively common (Linduff et al. 2004).

Figure 2.5 A walled Lower Xiajiadian site at Erdaojingzi in Chifeng, Inner Mongolia (after Cao and Sun 2009).

2.2.4 Haminmangha Culture

The Haminmangha Culture is a newly identified Neolithic culture in the south Songnen Plain. Although some artifacts that belonged to the Haminmangha culture were discovered in the 20th century, they were often collected in ground surveys and mixed with artifacts from other cultures (Du 2014). No comprehensive study of this culture was undertaken until the excavation of the Haminmangha from 2010 to 2012, a large settlement site containing abundant features and artifacts (Figure 2). This new culture was also named after the Haminmangha site (ICRAIM and RCCFA 2012, 2015).

The Haminmangha culture has been found distributed across northeastern Horqin Sandy Land. The major Haminmangha Culture sites are Haminmangha, Nanbaoligaotu, Haerqin in

Inner Mongolia, and Shuangta and Houtaomuga in Jilin. It is characterized by dot-marked and non-decorative pottery. The gritty clay wares tend to be mostly tan-brown, but include some gray and red pottery.

The discovery of the Haminmangha site shed light on the settlement structure and social development of Haminmangha culture. The overall site pattern at the Haminmangha site is formed by similarly structured house features arranged in parallel rows across the settlement landscape (ICRAIM and RCCFA 2012, 2015). Two circular ditches outside the occupation zone probably constitute the boundary of the whole village. House structure has been well preserved, perhaps because of sudden abandonment because of some catastrophe. Most house features are of the same shape, consisting of a square or rectangle as the central part of the house, plus a long doorway. All doorways face in a southeastern direction (ICRAIM and RCCFA 2012, 2015). The consistency in structure and orientation reflects a planned layout conceived before the construction of the whole site.

The grid-shape decoration on ceramics was another unique characteristic that can be distinguished from other cultures. Some Z-striped ceramics similar to ceramics of the Hongshan culture on the western Liao River region were also found at the Haminmangha site (Du 2014). While the ceramics have been described and studied in great depth, the faunal remains were only analyzed in a preliminary way (Chen 2014). Bovid bones larger than domesticated cattle were found and identified as bison (*Bos priscus*) at the Haminmangha site. However, I suspect that these larger bovid bones are probably from aurochs since bison were already extinct in Late Pleistocene China (Tong et al. 2013). Their proportion was small, however, relative to all faunal remains from the site (Chen 2014).

The origin of Haminmangha culture is difficult to pinpoint due to the limited archaeological discoveries; however, there are still some clues that point to the possible direction. The “Z” -markings, which are characteristic of the Hongshan decoration, are also found on the pottery from Haminmangha, indicating possible interaction with the West Liao River region (Wang 2018; Zheng et al. 2013). Some scholars, therefore, have inferred that the Haminmangha culture occupied this site when the Hongshan culture became weak, collapsed and retreated to the south in its late period (Zheng et al. 2013).

Additionally, the dominant cord-marked pottery from the 4th phase of Houtaomuga seems to more closely resemble corded ware from Hulunbuir in east Inner Mongolia and Transbaikal of Siberia to the north (Kuzmin and Vetrov 2007; Wang 2018). Because of this, Wang (2018) reasons that the Haminmangha culture and people must have originated in the north and migrated to this region in the Late Neolithic.

2.2.5 Summary

Archaeologists have studied for decades and established a relatively complete cultural sequence in this region. Before the discovery of Haminmangha culture, the South Songnen Plain was long considered a subsidiary area of the Xinglongwa-Hongshan cultural system. The discovery of Haminmangha is significant not only for identifying a new culture, but also for inspiring scholars to reconsider cultural interaction and migration in northeast China.

Although Haminmangha is considered an independent development, it shares fundamental similarities in pottery (“Z” motif), architecture (roundhouse), and site plan (circular village) with other prehistoric complexes of the West Liao drainage (Xinglongwa, Zhaobaogou, and Hongshan). The cord-marked pottery also indicates the possible relationship with archaeological cultures in the further north.

2.3 Climate and environment change around the Houtaomuga site

The Holocene was a warmer period compared to the Pleistocene, and its favourable climate provided the conditions for the prosperity of many prehistoric cultures in China (Renssen et al. 2012). Holocene climatic oscillations, however, may be implicated in the collapse of some highly developed societies.

There are various types of evidence, such as peat sediment, ice cores, stalagmites, and even historical documents that we can use to reconstruct past climatic and environmental conditions (Dykoski et al. 2005; Li et al. 2011; Li et al. 2017; Liu et al. 2015; Liu et al. 2017; Xia et al. 2014). An ice core is a sensitive indicator of climate change. A single ice core, Dunde from Mount Qilian (38°06′N, 96°24′E), probably provides the best rough image of climate change in the Holocene across China by measuring the variation of $\delta^{18}O$ value (Shi et al. 1992). The Holocene Climate Optimum in China took place during 8500 to 3000 cal BP based on the data from the Dunde Ice Cap, although a series of climatic fluctuations also occurred in this period (Figure 2.6).

Four climatic phases have been identified from the fluctuations observed in this sequence. The first phase, which dates to between 8500 to 7200 cal BP, was characterized by unstable temperature fluctuations. The climate was quite warm and wet in the entire episode, except the two low-temperature events occurring at about 7800 and 7300 cal BP. During 7200 to 6000 cal BP, the climate was stable. This phase is also called the climax of the Holocene optimum period, during which the temperature in northeast China was 3-4 °C higher than that at present. The third phase, from 6000 – 5000 cal BP, is marked by strong climatic fluctuations. The warm and wet climate continued at the beginning of this period; however, three cooling events took place at 5900 cal BP, 5400 cal BP, and 4900 cal BP. The weather in the last phase, which dates from 5000 – 3000 cal BP, was warm and humid during the first millennium, but turned cold and dry around 4000 cal BP (Shi et al. 1992).

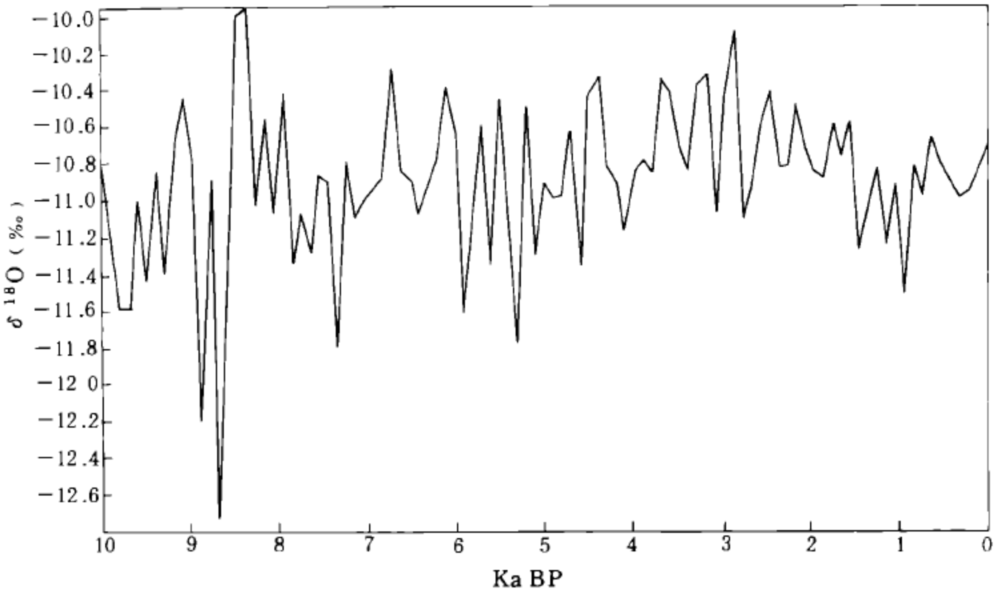


Figure 2.6 The variation of $\delta^{18}O$ values in ice core from Dunde Ice Cap, Mount Qilian, since 10,000 BP (after Shi et al. 1992).

The record from Dunde ice core represents an overview of the climate dynamics during the Holocene in China, but China's climate is more complicated because of its wide span in both latitude and longitude. Northeast China extends from 37° to 59°N and 110° to 135°E. The major topographical features of the area are the extensive Northeast Plain surrounded by a series of mountains and hills, including Changbai Mountain, Daxing'an Mountain and Xiaoxing'an Mountain. Our research target, the Houtaomuga site, is also located in this area.

The study of herbaceous phytolith indices from the Changbai Mountains indicates that climate became cooler and dryer between 4060-3456 cal BP (Li et al. 2017). This is consistent with the results from pollen studies. Pollen assemblage data from a sediment core from Hulun Lake in northeastern Inner Mongolia indicated that the climate became drier between 6400 and 4400 cal BP (Wen et al. 2010). Compared to the previous stage (8000 to 6400 cal BP), which is viewed as the Holocene climatic optimum in this region, arid-tolerate plants, *Chenopodiaceae* and *Asteraceae,* gradually predominated in the lake basin (Wen et al. 2010). After 4400 cal BP, this region experienced an arid climate, characterized by the development of steppe desert around the lake basin. The grassland vegetation recovered, and conditions became moister until 3350 cal BP (Wen et al. 2010). Based on the study of pollen and oxygen isotopes on a peat core from Taishizhuang, Jin and Liu (2002) also observed that coniferous forest developed during 4800-4200 cal BP, suggesting a cold climate in this period. The cold-arid interval was reconstructed using data from Sihailongwan Maar Lake (Stebich et al. 2015). Stebich and his colleagues proposed that the summer temperature was consistantly high between 10,700 and 3,500 cal. BP. Later, the spread of birch forests and Artemisia steppes and the increase of conifer taxa probably reflected much drier and colder conditions (Stebich et al. 2015). Goldsmith et al. (2017) also found an abrupt termination of the Holocene humid period at 5000-5000 cal BP from the study of the level records of Dali Lake, although the starting time differs from the results from pollen analysis results.

Some scholars, however, believed that climatic fluctuation was not the only reason for the change of vegetation during the late-Holocene in northeast China. For example, Ren and Zhang (1998) considered that the decrease in tree abundance which started around 5000 cal BP was the result of human activity. They studied the pollen records from the territory which remained unsettled before 1950, and claimed that the summer climate in northeast China became colder and wetter since 5000 cal BP (Ren and Zhan 1998).

As summarized above, it is evident that the climate turned colder around 5000 to 4000 cal BP, although the results derived from different schemes do not always match well with each other. The vegetation around the Houtaomuga site probably transitioned from abundant deciduous forest to conifer forest or even sparsely-forested steppe because of the deteriorating climatic conditions, and these climate and vegetation conditions were likely to have prevailed during the time frame for the G2 trench.

The social strategies for coping with climate change varied from region to region in China. For instance, in the Central Plain, Longshan (around 4500 years ago) cultures appeared and started a period of rapid agricultural development in the Loess Plateau. The frequency of foxtail and broomcorn millet increased, and numerous settlements and cities of various size were built and occupied (Mo et al. 2010). In northeast China, however, a broad-spectrum food strategy was undertaken only in some sites. For example, the Haminmangha site, which dated back to 5500 to 5000 years ago, depended on small game hunting and diverse food resources. Hare accounted for 75% of the number of identified mammal specimens, which differs from the concentration on *Cervidae* noted as a pattern in the Early Neolithic (Chen 2014). The high frequency and density of aurochs remains in Houtaomuga, therefore, might also relate to the cultural response to the change in climate.

Chapter 3: Cattle Domestication and Exploitation

Aurochs have generally been considered ancestors of modern domestic cattle. It is broadly accepted that cattle were first domesticated in the Near East around 10000 years ago. Domestic cattle first appeared in Middle Neolithic China. Therefore, it is necessary to understand the process of cattle domestication and the role that cattle played in the subsistence economy in China and in neighbouring regions (the Near East and Central Asia).

3.1 Near East

The Near East is an important region for the study of early domestication in both plants and animals. Archaeological discoveries and studies there have provided more evidence of early cattle domestication than those of many other regions. I divided the Near East into four zones (according to the variation in climate-topography and cultural chronology within the region): Northern Levant, Southern Levant, Central Anatolia, and East Fertile Crescent (EFC) (Figure 3.1).

Figure 3.1 Map showing the location of sites mentioned in the text and the timing of the appearance of domesticated cattle within the four regions of the Near East.

1) Northern Levant: 11950-10950 cal BP; 2) Southern Levant: 10950 cal BP; 3) Central Anatolia: 9450-8450 cal BP; 4) East Fertile Crescent: 7950 cal BP.

3.1.1 Northern Levant

Northern Levant, a region including the Syrian and Turkish parts of the Upper Euphrates basin, has been considered the earliest region for the initial domestication of taurine cattle. Helmer et al. (2005) found evidence of a reduction in cattle size and degree of sexual dimorphism at several Early and Middle Pre-Pottery Neolithic B (PPNB) sites (especially at Halula and Dja'da) in the upper and Middle Euphrates valley. Body size reduction and kill-off pattern are also used in identifying the domestication process of cattle in Çayönü Tepesi. Hongo et al. (2009) observed a gradual diminution in body size and a subtle change in the slaughter schedule of cattle between Early and Middle PPNB, changes which are characteristic of autochthonous domestication.

Today, genetic technology provides more evidence about the initial process of domestication by analyzing modern and ancient samples of cattle with DNA markers of maternal, paternal, or autosomal inheritance. The mtDNA sequence falls into two very distinct geographic lineages based on the genetic examination of the taurine and zebu cattle (*Bos taurus* and *Bos indicus*). This divergence between taurine and zebu was interpreted as evidence of two separate domestication centres, the Near East for taurine and India for zebu cattle (Loftus et al. 1994). Moreover, *Bos taurus* had the highest diversity in the Near East, with four different mtDNA haplogroups (T, T1, T2, and T3). This indicated that cattle were first domesticated in this region, then spread to the rest of world, as evidenced by a sample from an Early PPNB site Dja'de, yielding a T3 haplotype (Ajmone-Marsan et al. 2010; Bollongino et al 2006; Götherström et al. 2005; Scheu et al. 2015; Troy et al. 2001). It is the earliest dated DNA evidence for the occurrence of T haplogroup in the Near East, which also suggests the Near East is the center of cattle domestication at the very beginning of Neolithic (Edwards et al. 2007). MtDNA sequences from 15 Neolithic to Iron Age Iranian domestic cattle along with 26 modern cattle sequences from Anatolia and Iraq, showed that only around 80 female aurochs were initially domesticated. The low number of progenitors revealed that successful cattle domestication took place in a restricted area and this process was assisted by the development of sedentism, which could provide for sustained managing and breeding of the wild ancestors of domestic cattle (Bollongino et al. 2012).

3.1.2 Central Anatolia

Çatalhöyük was once considered as the earliest site presenting domesticated cattle in Central Anatolia. Size reduction in the humerus through time and the high frequency of cattle bones were observed by Perkins (1969). Therefore, he argued that cattle had already been domesticated in Çatalhöyük. However, the analysis of a large sample of remains from the renewed excavations at the site does not support this conclusion. The reduction in body size which Perkins observed in Çatalhöyük was more likely due to the shift to more females in the later phase, and the dominance of cattle bones in the assemblage he mentioned as one of the markers of domestication was actually the result of poor recovery techniques (Russell and Meece 2006).

Significant and abrupt body reduction was noticed in cattle from Erbaba, the upper level of Çatalhöyük, and Höyücek when compared with their measurements from earlier sites (Mureybet, Asikli, and the lower levels of Çatalhöyük) (Arbuckle and Makarewicz 2009). There is no evidence of change in body size for red deer from sites in central Turkey from Pre-Pottery Neolithic A (PPNA) to Pottery Neolithic (PN), so it is reasonable to conclude that the decrease in cattle size in central Anatolia during the seventh millennium BC was the result of human management rather than environmental impact (Arbuckle and Makarewicz 2009).

The kill-off pattern, which was dominated by immature cattle at Erbaba, fits with the survivorship pattern of domestic animals (Arbuckle and Makarewicz 2009). In contrast, red deer, which were never domesticated, were slaughtered as prime-aged adults (Arbuckle and Makarewicz 2009). This significant difference was also observed in the skeletal part distribution in these two taxa. The poor meat-bearing parts in cattle, including foot elements, are abundant, and this indicates that butchering of cattle carcasses probably occurred in or near the site

(Arbuckle and Makarewicz 2009). The over-representation of forelimbs and hindlimbs for red deer suggests that red deer were hunted and butchered outside the settlement (Arbuckle and Makarewicz 2009).

The abrupt appearance of small-sized cattle in Central Anatolia sites, along with the continued presence of aurochs and the absence of the process of gradual diminution in body size showed that domestic cattle in central Anatolia were introduced from adjacent regions (Arbuckle and Makarewicz 2009).

Central Anatolia is one of the nearest regions adjacent to the upper Euphrates region, which is the center of cattle domestication. But there, the appearance of domesticated cattle was delayed by nearly two millennia compared to the presence of the first domesticated cattle in the ninth millennium (Arbuckle 2013). Both environmental conditions and cultural factors would contribute to this phenomenon.

On the one hand, cattle have a significantly higher water requirement than either sheep or goats; thus, the semi-arid environment in Central Anatolia may not have provided enough water for the husbandry of cattle (King 1983; Redding 1981). However, this line of thought is problematic because environmental reconstructions indicate that there was more abundant surface water in the early Holocene. Additionally, the long history of aurochs exploitation from the Early Neolithic suggests that Central Anatolia can offer habitats conducive to *Bos* (Arbuckle 2013). On the other hand, cultural and social factors provide a more reasonable explanation for the late adoption of cattle husbandry. Cattle, unlike small livestock such as sheep or goats, require higher investment, and therefore bring higher risk. The high risk and uncertainty of return became an obstacle on the road to breeding domestic cattle and developing cattle husbandry (Arbuckle 2013). Moreover, wall paintings depicting hunting and baiting scenes at Çatalhöyük indicated the unique position of wild cattle in communal hunting and feasting events (Russell and Meece 2006; Russell et al. 2009). The symbolic importance of cattle, therefore, could provide another explanation for the resistance to incorporate domesticated cattle into their subsistence economy.

3.1.3 Southern Levant

This area encompasses Syria south of the Damascus Basin, Lebanon, Jordan, Israel and the Sinai Peninsula (Horwitz and Ducos 2006). Although the mid-Pre-Pottery Neolithic (MPPNB), which is characterized by a marked and significant increase in caprine frequencies, is generally considered as the onset of caprine domestication in the Southern Levant, data for the domestication of cattle are less clear (Horwitz et al. 1999; Makarewicz et al. 2016; Martin 1999).

Horwitz and Ducos (2006) identified a diachronic trend in cattle remains in the Southern Levant based on the analysis of three main ungulate taxa – gazelle, caprine, and bovine. They divided this region into five sub-areas: the Western Israel-Coastal zone, the Mediterranean zone, the Baqa'a-Jordan Valley (which falls into the Mediterranean phytogeographic region), and the East and South arid zones encompassing the desert margins (Horwitz and Ducos 2006). All PPNA sites were dominated by hunted taxa, gazelle in the Mediterranean region and wild goat in the arid zone. A rise in the proportion of cattle was noticed in most sites in MPPNB, especially in the Mediterranean region, although the frequency of cattle was still low. It is not until PPNC that a significant increase in the incidence of cattle remains was documented for all zones in Southern Levant. A high degree of inter-site variation was observed in each zone; for example, no cattle remain was found in Gresher and Netiv Hagdud — two PPNA sites in the Baqa'a-Jordan Valley — while another two sites have yielded 10% and 20% cattle remains respectively (Horwitz and

Ducos 2006). This variation probably reflects the mosaic of contrasting physical environments in the Southern Levant.

It is evident that the earliest appearance of domesticated cattle occurred in the Southern Levant in the MPPNB, which also coincided with a marked and significant reduction in species richness between the PPNA and MPPNB (Horwitz 1996). But it is only by the time of PPNC that there is substantial evidence for the widespread occurrence of domestic cattle throughout the Southern Levant.

3.1.4 East Fertile Crescent

The East Fertile Crescent (EFC) encompasses portions of the Tigris drainage, the Zagros Mountains of western Iran and the adjacent Piedmont zone of northern Iraq. Although recent studies have identified the Zagros Mountains as the likely heartland of domesticated caprines, the pattern for cattle remains poorly understood in this region (Zeder 2006, 2008, 2011).

Arbuckle and his colleagues (2016) provided greater clarity on the timing and process of cattle domestication for the EFC based on the analysis of 86 faunal assemblages from published and unpublished zooarchaeological studies on the hunting of aurochs and management of taurine cattle. Although the frequency of bovids was low from the Pleistocene to early Holocene, a dramatic increase was observed around the sixth millennium BC. The biometric data also show that an abrupt reduction in the size of bovids occurred in the sixth millennium BC (Arbuckle et al. 2016). Therefore, they proposed that domesticated cattle were imported into the region in the sixth millennium BC, as the appearance of small-sized, domestic cattle in the EFC occurred suddenly and with no evidence of gradual shifts in body size over time, which is considered the vital signature of autochthonous domestication (Arbuckle et al. 2016).

The appearance of domestic cattle in the EFC lagged behind that in the neighbouring upper Euphrates basin for nearly two millennia. Except for the unsuitable semi-arid climate in the region that is unable to support a large population of bovids, the highly conservative strategy serves as another reason for the resistance to domestic cattle. In other words, a strong regional preference for specific taxa among the people of South-western Asia made them reluctant to accept new species (Arbuckle 2005; Arbuckle and Atici 2013; Arbuckle et al 2016).

3.2 Central Asia

Central Asia is the core region of the Asian continent, and it encompasses the five countries of Kazakhstan, Uzbekistan, Turkmenistan, Kyrgyzstan, and Tajikistan. It is a vast area of interior drainage formed by the streams draining the Kopet Dagh and the northern Hindu Kush mountains and by the Atrek, Tedien, Murghab, Amu Darya, Zeravshan, and Syr Darya rivers and their tributaries (Zarins 1992). Soviet archaeologists provided the cultural chronology in this area, but reports and studies about faunal assemblages were quite rare at that time (Benecke 2017; Zarins 1992). Fortunately, this situation has improved slightly in the last two decades due to the international cooperation of archaeologists in this region. However, the publications are still limited and only offer a restricted glimpse of cattle domestication and exploitation (Benecke 2017).

The Jeitun Culture is the earliest evidence of settled village life in western Central Asia, and spanned some 1400 years, from 8050 to 6450 cal BP. The discovery of extensive numbers of domesticated goats and sheep indicated a robust development of caprine pastoralism. Compared to the widespread presence of caprines, no remains of domestic or wild bovids have been found at Jeitun, or at other Jeitun Culture sites (Harris 2011). Recent excavation at the Neolithic site of Ayakagytma in the Kyzylkum has identified bovids in both earlier and later phases of occupation

(7950-7450 years ago and 5950-4950 years ago) (Lasota-Moskalewska et al. 2006). Those researchers argued that the cattle were nearly or fully domesticated in the site. However, some other specialists have doubted the accuracy of identification (Harris 2011).

In the Chalcolithic, horse bones dominate the faunal assemblages, and most researchers focused on whether the horses of these sites represent still-wild or already-domesticated animals. Signs of cattle domestication remain absent in this period (Benecke 2017). In the Bronze Age, although cattle were found in a low number of animal assemblages at Gonur, the cattle figurines that were excavated from the site showed clear humps indicating the presence of domestic cattle (Moore et al. 1994). The faunal data from Begash also suggested that cattle played an essential role in Eurasian pastoralism (Frachetti and Benecke 2009).

The process of cattle domestication remains unclear due to the limited evidence of domestic cattle in the Neolithic and Chalcolithic, although the importance of cattle increased dramatically in the Bronze Age. However, genetic analyses of modern breeds in Eurasia and Africa have revealed that cattle were independently domesticated in Southwestern Asia (Ajmone-Marsan et al. 2010). Based on the archaeological and genetic evidence, therefore, it is reasonable to infer those domestic cattle were introduced to Central Asia from the Fertile Crescent probably through northern Iran between the Chalcolithic and the Bronze Age.

3.3 Bovine exploitation in Neolithic China

Both wild and domesticated cattle have been important to human beings since the early Neolithic period in China, not merely as a significant part of their diet, but also for agricultural labour, as raw materials for craftsmanship, and as a critical sacrifice for ancient rituals.

However, the position of cattle in subsistence strategies in prehistoric China remains unclear in the previous studies. In this dissertation, an analysis of the changes in large-game acquisition and utilization patterns during the Neolithic is undertaken to provide the context for explaining the phenomenon of the intensive consumption of aurochs in the Houtaomuga.

Based on the available published literature, more than 60 Chinese Neolithic sites (Figure 3.2) contain the remains of bovids (Lv 2007; Yu 2015). Most of the studies merely listed the animal species discovered in the site, while other necessary information, such as quantity calculations and bone measurements, were not mentioned. Furthermore, sometimes the identification is not reliable. Take the Baiyinchanghan site as an example, Tang et al. (2004) claimed that there was great similarity in size between the bovids remains from Baiyinchanghan and the Dabusu aurochs fossils. In the final report, however, they identified the *Bos* individuals in Baiyinchanghan as *Bos gaurus*, which is contradicted by the earlier comparison.

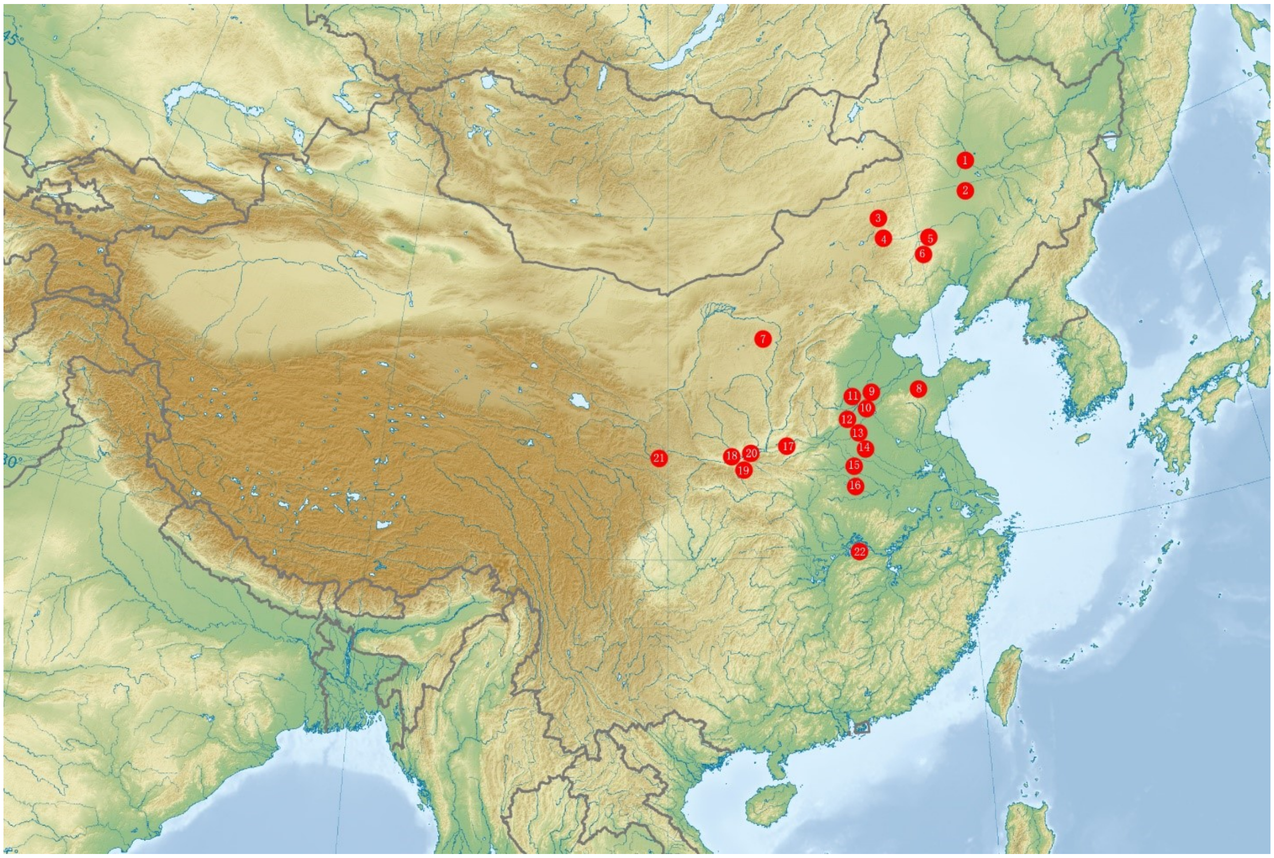


Figure 3.2 Locations of the sites mentioned in this section.

1.Houtaomuga, 2. Haminmangha, 3. Xiliang, 4. Baiyinchanghan, 5. Weijiawopu, 6. Zhaobaogou, 7. Zhukaigou, 8. Lujiakou, 9. Xihe, 10. Zhangjiatun, 11. Yuezhuang, 12. Xiwusi, 13. Liulijing, 14. Zhuanglixi, 15. Shishanzi, 16. Yuchisi, 17. Yuanqu, 18. Yangguanzhai, 19. Jiangzhai, 20. Kangjia, 21. Xishan, 22. Luosishan

3.3.1 Bovid Exploitation

In this analysis, I selected 21 Chinese Neolithic sites and divided them into the Early Neolithic (7000-5000 BC), the Middle Neolithic (5000-3000 BC), and the Late Neolithic (3000-2000 BC) (based on Liu and Chen 2012). The sources used included comparatively detailed reports on faunal remains, and therefore, could provide the primary data for identification and description.

Table 3.1 List of sites discussed in this section, the abbreviation of their name, and the NISP of the *Bos*, *Sus*, and *Cervidae* bones found in them.

Phase	Site	Abbreviation	Bos	Sus	Cervidae	Total
The Early Neolithic	Xiliang	XL	2	6	74	82
	Xihe	XH	10	26	60	96
	Yuezhuang	YZ	136	169	271	576
	Zhangmatun	ZMT	3	21	92	116
	Baiyinchanghan (Early)	BYCH_E	24	15	328	367
The Middle Neolithic	Liulijing	LLJ	2	29	7	38
	Yuanqu	YQ	1	25	16	42
	Shishanzi	SSZ	32	196	353	581
	Luosishan	LSS	1	20	1	22
	Lujiakou	LJK	30	201	0	231
	Yuchisi (Mid)	YCS_M	15	658	799	1472
	Xishan	XS	49	90	87	226
	Jiangzhai (Mid)	JZ_M	86	674	1800	2560
	Baiyinchanghan (Mid)	BYCH_M	3	18	95	116
	Zhaobaogou	ZBG	2	138	347	487
	Weijiawopu	WJWP	2	62	114	178
	Haminmangha	HMMH	50	980	221	1251
	Houtaomuga (G2)	HTMG	8123	247	82	8452
The Late Neolithic	Xiwusi	XWS	1	30	23	54
	Zhukaigou	ZKG	46	32	0	78
	Yuchisi (Late)	YCS_L	18	258	238	514
	Kangjia	KJ	102	87	238	427
	Zhuanglixi	ZLX	3	110	42	155
	Yangguanzhai	YGZ	6	290	15	311

The absolute frequencies of ungulates from each site are presented in Table 3.1. Numbers of identified specimens (NISP) counts were used as a necessary measure of taxonomic abundance (Grayson 2014; Lyman 2008). Equids, goats, and sheep were excluded from the analysis, as their occasional appearance across the sample did little to change the results. The distinction between wild and domestic *Bos* and *Sus* was not considered, since it is difficult to make a reliable conclusion from the rough reports. All the deer, including red deer (*Cervus elaphus*), elk (*Cervus canadensis*), sika deer (*Cervus nippon*), and roe deer (*Capreolus*

capreolus), were counted in one category (*Cervidae*) to represent a clearer pattern. Changes in the composition of the various faunal assemblages and the importance of *Bos* in the human diet were explored using correspondence analysis through PAST 2.17 (e.g., Marom and Bar-Oz 2009).

The correspondence analysis biplot shows the observed similarities between the assemblages in terms of three main species frequencies in the Neolithic archaeological sites (Figure 3.3). Most of the sites fall near the *Sus* and *Cervidae*, indicating the higher dependency on these two species. Some variations also exist through the Neolithic period. The proximity of the row points (sites) to the column points (taxa) associated with the Early and Middle Neolithic clusters shows that the difference between the assemblages is due to the isolated high frequency of *Cervidae* in the Early Neolithic group and the high rate of both *Sus* and *Cervidae* in the Middle Neolithic cluster. The dependency on *Cervidae* continues to decrease in the Late Neolithic.

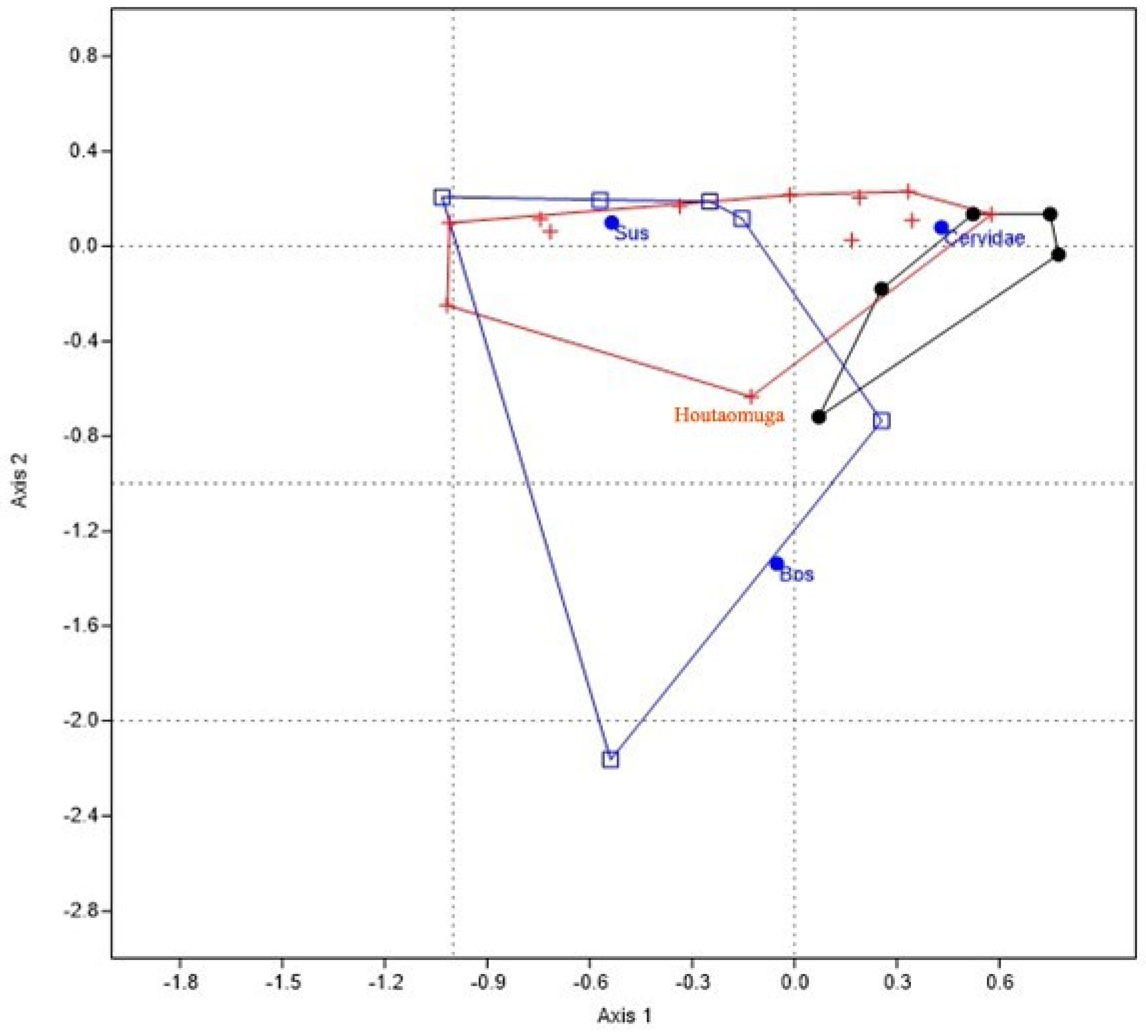


Figure 3.3 Correspondence analysis results of three main animal species in Neolithic sites.

Blue dot = column points (taxa), black dot = the Early Neolithic sites, red crosses = the Middle Neolithic sites, blue rectangle = the Late Neolithic sites.

If we narrow our focus to the seven sites in northeast China where the ecological setting is similar, and compare those with the Houtaomuga site, the pattern becomes more apparent (Figure 3.4). Most of the sites are strongly associated with *Cervidae*, while the three faunal assemblages of Haminmangha, Houtaomuga, and Zhukaigou show the highest disparity from the mean first axis scores of the Neolithic collections, due to their high percentages of *Sus* and *Bos* specimens.

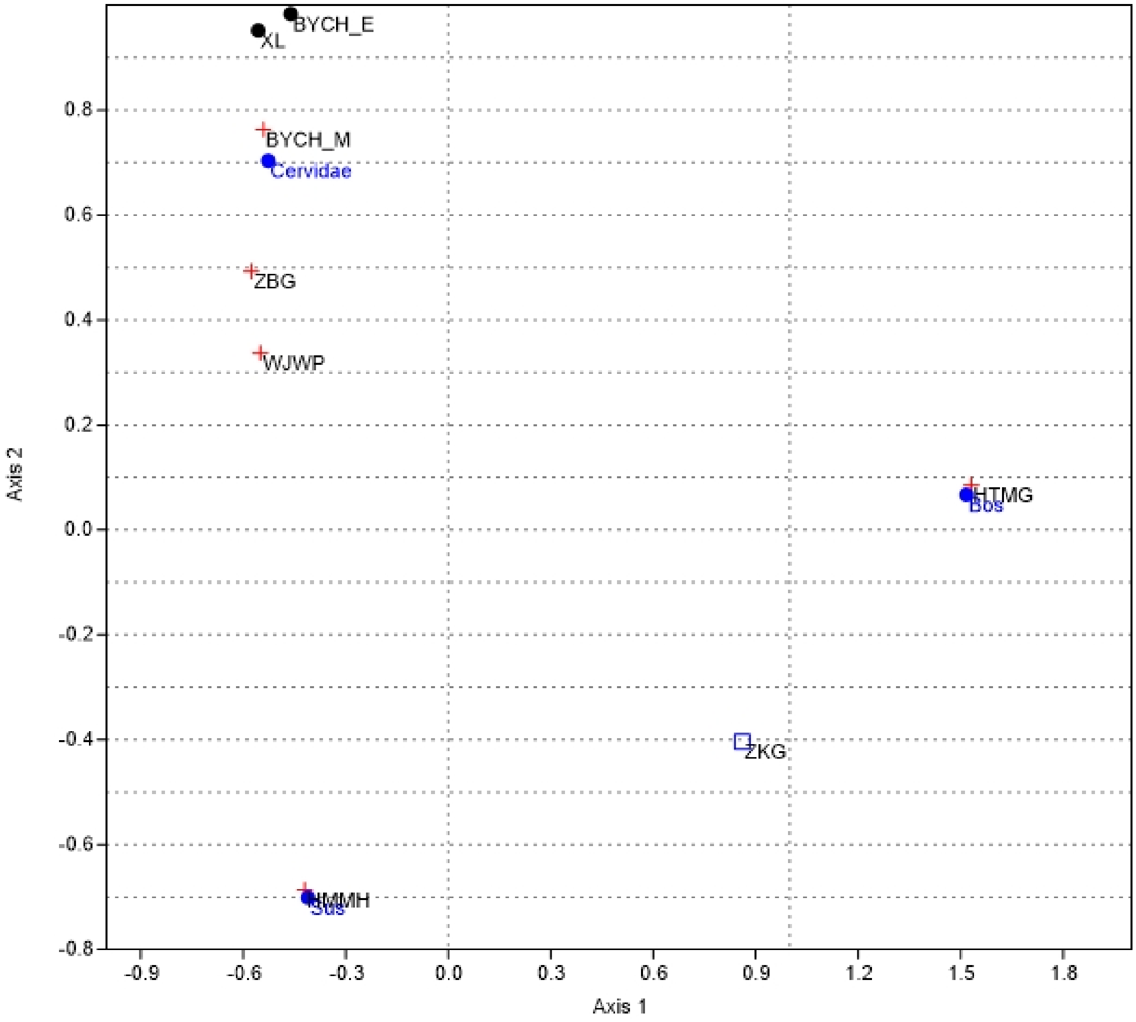


Figure 3.4 Correspondence analysis for sites in northeast China.

Blue dot = column points (taxa), black dot = the Early Neolithic sites, red crosses = the Middle Neolithic sites, blue rectangle = the Late Neolithic sites (the abbreviations of each site can be seen in table 3.1).

The analyses undertaken in this study point to an overall trend of higher frequencies in hunting and utilizing *Sus* and *Cervidae* compared to *Bos* in Neolithic China. The Neolithic faunal sequence from China is essential for illustrating the fact that *Bos* was not the dominant food or at least the primary meat source during the Neolithic. Some scholars have also proposed that *Bos*, especially domestic cattle, were more likely used for traction in prehistoric China based on pathology and age reconstruction analysis (Fargo 2014; Liu et al. 2001).

The high frequency of aurochs remains found in Houtaomuga, therefore, is uncommon in China. The interpretation of this pattern is also crucial for understanding the function of trench G2 and what happened at this site.

3.4 Aurochs ecology and genetic analysis

Aurochs are regarded as the extinct ancestors of modern domesticated cattle; the last individual died in Poland in 1964 (Vuure 2002). They were once widely spread across the Old World, including nearly all of Europe and large parts of Asia and North Africa (Vuure 2002). A larger amount of more accurate data has been documented in Europe than elsewhere because many aurochs bones have been found in archaeological excavations, from the Pleistocene to Holocene (Figure 3.5). Unlike the numerous findings from Europe, the study of aurochs distribution and history is limited in China. Based on this limited research, all Chinese aurochs remains had been found in North and Central China, in the area between 105° east longitude and 33° north latitude (Vuure 2002).

In previous research, aurochs had been regarded as extinct during the Pleistocene period since no aurochs bones had been found from the Holocene period in China (Tong et al. 2013; Vuure 2002). Even though Jiu and Wei (1980) claimed to have found unique remains of "*Bos* *primigenius,*" their assessment was considered unreliable because the faunal assemblage included animals from both the Pleistocene and the Holocene and was likely disturbed and dislodged by the river. More recent research concerning oracle bones DNA analysis from late Neolithic sites in Central Plain of China, however, challenged this common view (Brunson et al. 2016). Three specimens (all carved oracle bones), dated to 2300-1750 cal BC, belonged to the unique haplogroup C that was first identified in an East Asian Bos mandible dating to over 10000 cal BP (Zhang et al. 2013). This suggested that aurochs did not go extinct in Central China until at least the Late Neolithic Period. Later, aurochs bones found in the Houtaomuga site also provided strong evidence that aurochs still lived in the Northeast Plain in the Neolithic Period (Cai et al. 2018).

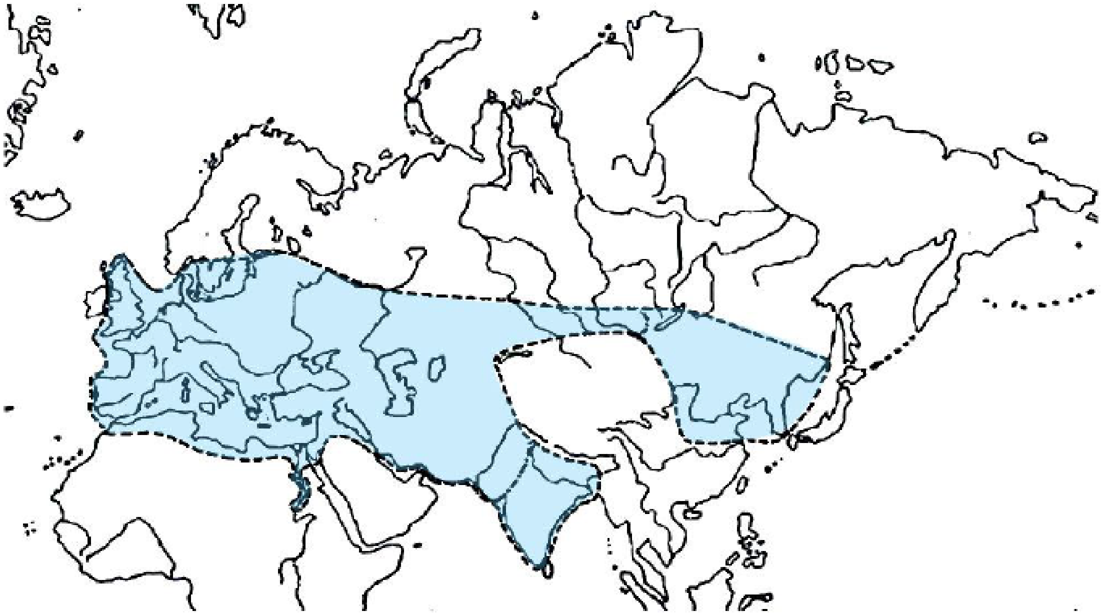


Figure 3.5 Pleistocene and Holocene distribution for aurochs (after Vuure 2002).

3.4.1 Ecology of aurochs

Studies about the ecology of aurochs are rare because of the difficulty in exploring the diet and habitat of an extinct animal species. Compared to biological methods, zooarchaeology, paleontology and historical ecology are more useful in the reconstruction of the lives of aurochs (Stephen 2008; Vuure 2002, 2005). Isotope analysis is a new technology that has also been utilized in recent research (Drucker and Bochererns 2009; Noe-Nygaard et al. 2005).

Vuure (2002, 2005) proposed that, unlike their close relative the steppe bison, aurochs preferred a warmer and wetter environment based on the distribution derived from archaeological discoveries in Europe and the biological observation of cattle, which were considered their domestic counterpart. Ecological partitioning occurred between European bison and aurochs to avoid resource competition as a result of coexisting in the forests. The European bison inhabited the drier forest types in the lowlands and the higher mountain areas, while the aurochs took advantage of the wetter forest types in the lowlands and the lower mountain areas (Vuure 2005). Aurochs also seemed to favour estuarine areas or flat land near rivers, probably because of their preference for marshes, especially sedge marshes (*Magnocaricion elatae*) which existed along many rivers and in river deltas (Wright 2013; Vuure 2005). Stephen (2008) came to a similar conclusion that aurochs were floodplain animals by analyzing the present-day topographical characteristics of the sites in Britain where their bone remains were discovered. Habitat and resource competition also existed between aurochs and domestic cattle. Although they have broadly similar dietary preferences, they occupy different ecological niches and habitats as a result of human interference (Lynch et al. 2008). Lower $\delta^{13}C$ values in aurochs bone collagen and its increase in domestic cattle revealed the influence of human behaviour. Wild aurochs tended to live in the deep, dense forest but forests were being cleared for agricultural and domestication purposes (Drucker and Bocherens 2009). North Slovakian aurochs were even forced to take refuge in mountain forest environments due to human pressures in the Bronze Age (Chrószcz et al. 2011).

Although aurochs were relatively versatile and highly adaptive animals as evidenced by their wide distribution, the number of aurochs remains decreased dramatically after the Neolithic period in Europe, and they finally died out in 1926 (Vuure 2005). Researchers ascribed their extinction to the destruction of their habitats and their over-hunting by humans.

Based on the studies above, the aurochs preferred to live in the wetter type of forest, and in the plains or riverside marshes which were also favourable habitats. The Houtaomuga site is located on the gently sloping foothills along the southeast shore of Lake Xinhuangpao; therefore, it is reasonable to infer the environment around the site provided suitable conditions for the aurochs to survive. It also offered the fundamental preconditions for the aurochs hunting and utilization in the Houtaomuga site.

3.4.2 Genetic analysis at Houtaomuga

Aurochs, as I discussed in the former chapters, were considered to have become extinct after the late Pleistocene. Therefore, because of the large size of the bovid bone assemblage from Houtaomuga, zooarchaeologists identified them as *Bison exiguous*, which was once widespread in the Pleistocene and supposedly continued thriving in the late Neolithic (as many bovid remains from various Neolithic sites have been identified as *Bison exiguous*).

A recent genetic study of bovid remains from 24 specimens at Houtaomuga, however, identified 23 samples as aurochs (*Bos primigenius*) and one sample as cattle (*Bos taurus*). No *Bison exiguous* instances were identified in the samples tested for DNA (Cai et al. 2018). Although the absence of *Bison exiguous* in the Houtaomuga samples would not indicate the absolute absence of *Bison exiguous* in northeast China, it is necessary to rethink the former identification of bovid remains from Houtaomuga. In this paper, based on the genetic analysis, I believe that most of these bovid bones were from wild aurochs.

The one identified *Bos taurus* sample is the earliest known taurine specimen in China, and it could point to the existence of the northeast China Route (via the Mongolian Steppe) for domesticated cattle entering China. This discovery also reminds us of the possibility of incipient conditions for aurochs management in northeast China. Nevertheless, the aDNA analysis indicated that none of the identified aurochs from Houtaomuga made a direct contribution to later domesticated cattle in China.

Chapter 4: Methods

4.1 Zooarchaeology Methods

4.1.1 Identification

All the faunal material was analysed using the modern comparative skeletal collection housed at Jilin University. Owing to the extinction of aurochs, the size data of aurochs from Denmark Neolithic sites (Degerbøl and Fredskild 1970), was also used as a guide. The general analytical approach used in this study is that provided by Driver (2011) and summarised in Appendix 4. Specimens were identified to the most specific taxonomic category and skeletal element. Bone measurements were taken following the standards of von den Driesch (1976).

Most bovid bones were larger than modern cattle specimens. The genetic result indicated that both aurochs and cattle were present at Houtaomuga. Of all the 24 bovid samples selected for ancient DNA analysis from Houtaomuga, only one sample was identified as cattle (Cai et al. 2018). Therefore, I assumed that all or nearly all large bovid remains in the site are from aurochs as opposed to cattle or any other large bovid.

Sus remains were identified as wild boar because the size of post-cranial elements was smaller than the pig remains from archaeological sites in the Wei River Valley, China (Wang et al. 2013). Dog remains were identified based on size. All the dog remains were smaller than Chinese wolves.

4.1.2 NISP and MNI

The most fundamental unit used to quantify animal remains at archaeological sites is the number of identified specimens, or NISP. It is the number of skeletal elements or fragments that can be identified as to the taxon they represent (Lyman 2008). This quantification method provides the insight of taxonomic abundances at an archaeological site. At Houtaomuga, the several freshly broken fragments (that is, from excavation and lab processes) from one individual were recorded as single specimens; old breaks, however, would be recorded in separate entries. The summing of these records for different taxa will be represented in NISP.

The minimum number of individuals (MNI) is applied in this study in order to estimate the minimum number of aurochs present. As a large number of long bones were broken in the middle and separated into large proximal and distal ends, one individual could be represented by two or more specimens; consequently, the estimation of MNI based on the abundance of right or left long bones will cause inflation of taxa abundance. Where an MNI for one taxon was best decided by long bones, the MNI value chosen will be based on the greatest number of either proximal or distal parts. For example, 12 right proximal tibiae and seven right distal tibiae will result in an MNI of 12.

4.1.3 MNE, MAU and %MAU

Different body parts have various values for humans and, therefore, the relative abundance of anatomical units can reflect human decision making in regard to carcass use. MNE (Minimum Number of Individual Elements), MAU (Minimum Animal Units) and %MAU are applied in this dissertation to illustrate the relative frequency of aurochs elements.

MNE is the minimum number of elements that can account for an assemblage of specimens of a particular skeletal element or portion (Lyman 2008). It was first proposed by Binford (1981) and was defined as the "minimal number of elements in each anatomical category." Although many scholars have pointed out that unrecognized anatomical overlap in archaeological specimens can result in underestimation of the real number of anatomical units, calculation of MNE remains an important approach to estimate frequencies of skeletal portions of individual taxa, and is an essential step in the calculation of MNI (Bunn and Kroll 1986; Klein and Cruz-Uribe 1984; Lyman 1994; Morlan 1994).

The question of how MNE is to be determined has been debated during the last few decades. The overlap approach is one of the most recently proposed ways to calculate MNE values. There are several ways to count the overlaps. The use of shaft portions was first illustrated by Todd and Rapson (1988); then, Morlan (1994) defined a series of named portions for most major elements of the bison skeleton. Portions mentioned here refer to specific, readily identifiable anatomical features. Stiner (2002, 2004) developed a coding system for skeletal elements and portions of elements based on the bone density parameters obtained by photon densitometry (PD) and computed tomography (CT). The portion with the greatest frequency for any given element represents the MNE for that element. Marean et al. (2001) and Abe et al. (2002) introduced GIS in calculating overlaps. Each bone fragment is drawn individually onto ArcView as a shape file and MNE is calculated based on the maximum number of overlaps.

The two methods mentioned above are applied in this research in order to determine which one is better at representing skeletal completeness. For the overlap method, although specimens were identified and recorded mainly using Stiner's coding system, several anatomical features (such as the teres tuberosity of the humerus), which are not involved in her system but appear frequently in aurochs' bones from Houtaomuga, were added into the analysis. Stavrova et al. (2019) developed a more effective GIS protocol to standardize the documentation process for fragments, and I have followed their approach to simplify the manipulation process. Due to the large sample size and the limitations of time, only limb bones (humerus, radius, metacarpal, femur, tibia, and metatarsal) were drawn into shapefiles. The detailed description of the GIS method will be discussed in a later section.

Similar to MNE, minimum animal units (MAU) are analytical units of quantification that assess the abundance of skeletal part representation. MAU (Minimum Animal Unit) is calculated through dividing MNE by the number of times that each element appears in a complete skeleton. Lyman (1994) defined it as the "minimum number of animal units necessary to account for the specimens in a collection." MAU was originally used by Binford (1981) but was initially labelled as MNI, and later changed into MAU to reduce the ambiguity of language. He decided to discard the side information of elements because he found that some ungulate elements are difficult to side. Therefore, he calculated MAU by dividing the specimen count for each element by the number of such elements present in a skeleton. For example, if an aurochs humerus is represented by an MNE of 9, this value would be divided by 2 and the MAU for this humerus would be 4.5.

The standard value of (%MAU) was derived from MAU (Binford 1981). %MAU is the standardized value obtained by dividing all MAU values by the greatest observed MAU value in a certain assemblage and multiplying each value by 100. For example, if the highest MAU value for aurochs was 12 mandibles, and the MAU of metacarpals was 6, the %MAU of metacarpals would be 50. Standardization makes it possible to directly compare the relative abundance of different elements in the same scale within the same taxon.

In the case of the circular trench in Houtaomuga, NISP and MNI were calculated for all the taxonomical groups, while MNE, MAU and %MAU were only employed for aurochs.

4.1.4 Animal utility indices

When hunting large animals far from their settlements, hunters may always be confronted with the challenge whether or not to carry the entire animal carcass back. If not, hunters must choose which parts of the animal to transport and leave the rest at the kill site. This would contribute to various representations of the frequency of skeletal parts at separate sites. Therefore, it is crucial to understand which factors might affect the hunters’ transport choices.

Binford (1978) designed utility indices to interpret different procurement objectives for various anatomical units of caribou and sheep. He created meat utility index (MUI), modified general utility index (MGUI), marrow utility index, grease utility index, and drying utility index (DUI) based on the weights of meat, bones marrow, and bone grease. Since they were first developed, Binford’s utility indices have been extensively utilized and modified in archaeology.

Metcalfe and Jones (1988) simplified the derivation of MGUI and generated a new index: food utility index (FUI). This model requires ranking of the weights of the usable soft tissue and thus has the potential to lead to the creation of economic utility indices for animals other than caribou and domestic sheep. The corrected food utility index (CFUI), developed by Morin and Ready (2013), is based on the simplified MUI but is altered for “riding.”

For the marrow utility index, Binford (1978) emphasized the proportion of oleic acid in the total fatty acids of bone marrow, with the marrow’s cavity volume and processing time being considered as the less critical factors. Jones and Metcalfe (1988) argued that a better predictor for determining which bones the Nunamiut will select for marrow processing is the volume of the marrow cavity alone. Morin (2007) discovered the quantity of unsaturated fatty acids had a stronger correlation with the skeletal parts which would be selected for marrow procurement. He therefore introduced a new measure of marrow utility as unsaturated marrow index (UMI).

Binford constructed a complex deviation in the DUI since the amount of edible parts would not be the only consideration in determining the drying value. This procedure was simplified by Friesen (2001), who created the meat drying index (MDI), which is more transparent and easier to calculate.

Based on the average weights of the anatomical parts of four bison using Emerson's (1990) raw data, Morin and Ready (2013) computed the bison indices. In this study, FUI, CFUI, UMI, and MDI for bison are all applied for aurochs bones from G2 and house features to identify which are the most significant factors influencing the frequency of bone elements at Houtaomuga.

Before leaving the topic of indices, I should note that Speth (2022) recently acknowledged the importance of Binford's contributions regarding utility indices, but nonetheless made the critical observation that Binford did not actually heed the element rankings his Nunamiut informants provided to him with regard to the caribou hunting he documented. He instead assigned high values to the meaty elements of the caribou skeleton, the femur, tibia, humerus and scapula—primarily because they were meaty—when these were *not* highly ranked by Nunamiut hunters.

Speth (2022) provided other examples of Indigenous element rankings at variance with Binford's influential ranking, perhaps the most compelling for a bovid being that of Buffalo Bird Woman's (Hidatsa) account (see also Brink 2004):

"After the hunters had placed the hides and the greater part of the meat from the five cows on the stage, they returned to the camp, packing some of the choicer cuts on their backs. Usually, these were the tongues and kidneys and the meat on the breastplate bone. They brought in only the choicest pieces because we already had a good supply on hand (Wilson 1924:247)."

"When they returned, each hunter packed a load of meat on his back… Only the choice cuts were brought back in this fashion: the tongues, the kidneys, and the ham bones for the marrow; the rest of the meat was left behind on the meat pile. Some of the ribs with the meat clinging to them were also brought in (Wilson 1924: 249-250)."

In fact, the actual Nunamiut rankings Binford received were consistent with a great deal of fur trade and northern hunter-gatherer literature indicating that flesh from these elements was often readily discarded by hunters or relegated to dog food. Wild animals have very little (or essentially no) intramuscular fat in the meat associated with Binford's highly ranked elements. Given the energy dynamics of protein digestion, and the ever-present possibility of "rabbit starvation" in northern environments, there are important limits to the amount of pure protein human beings can consume. For northern environments in which carbohydrates are not readily available, fats and greases are the irreplaceable sources of sources energy required for a successful human diet. Speth (2022) argued that where elements like the femur and humerus are highly ranked and defleshed, this would actually have been for accessing their marrow content.

Speth's findings from accounts like that of Buffalo Bird Woman have important implications to which I will return when interpreting the enormous mass of meat products that the aurochs in the G2 trench provided for Houtaomuga's Neolithic residents.

4.1.5 Gnawing, burning and weathering

Gnawing marks include punch marks, pitting and striations generated by the canines and parallel grooves produced by the incisors of rodents (Fisher 1995).

The tooth marks made by carnivores generally leave impressions as pits in the bone surface when an animal bites down hard. Impressions may become furrows, scratches, or incisions when the animal moves its teeth on the bone (Haynes 1983). Different features result when bites occur in different bone materials. On epiphyses, cancellous or thin compact tissue may be ground or sheared off by teeth; cheek teeth may form grooves in which the cusps pressed deeply. In compact bone, these marks are characterized by uneven edges and incomplete slicing through bone lamellae (Blumenschine 1995; Haynes 1983; Parkinson et al. 2015).

Rodents are the other important factors in bone modification or even destruction because of their need to grind continuously growing upper incisors (Haglund 1992). They prefer more dense and compact bones to provide attrition; incisor gnawing leaves a series of short, broad parallel grooves on bone surfaces.

Burned bone provides important information for reconstructing food preparation technologies and disposal behaviors at archaeological sites. Researchers agree that heat-induced alteration should be represented in a sequential spectrum of chromatic change, from yellowish to white, although different researchers suggest varying temperatures at which these stages are achieved (Carroll and Smith 2018; Ellingham et al. 2015; Stiner et al. 1995).

Burning was recorded for all bones and teeth in three stages—light, medium, and heavy—based on the colour sequence that was caused by heat. Light burning was described by a yellowish or dark brown colour. Medium burning showed as black burning on bone or as black or grey on carbonized bone. Heavy burning was shown as calcined white bone, which is caused by the complete combustion of the bone's organic material and minerals. Based on preliminary observations, a large number of long bones displayed scorched marks on the shaft. Therefore, the location of burning—proximal end (P), the distal end (D), and shaft (S)—was recorded to determine whether there was a specific pattern from burning.

Weathering was challenging to record objectively. The observation of bone weathering followed Behrensmeyer's (1978) criteria. Behrensmeyer presented weathering stages, ranging from zero to five, to indicate the degree to which elements such as moisture and temperature have affected the specimen.

4.1.6 Butchery marks

Zooarchaeologists have long been interested in analyzing the traces of human butchering activities visible on animal bones. Lyman (1987) defined the butchering process as "a set or series of sets of activities that are directed towards the extraction of consumable resources from an animal carcass." Activities, such as skinning, disarticulation, filleting, and marrow extraction, leave diagnostic marks on bone surfaces. The identification of these marks provides important information for analysing whether people consumed or utilized the animal carcass, and how these carcasses were butchered into different parts (Lyman 1987). Therefore, it is possible to infer the human behaviors involved in processing and consumption based on the butchering pattern and the butchering marks on bones.

Binford (1978, 1981) suggested a coding system for cutmarks based on his ethnological observations of butchering activities from Nunamiut groups. These codes record the location and orientation of the cutmarks and provide information for identifying skinning, disarticulation and defleshing activities. Nilssen's (2000) work is a great supplement to Binford's system. He videotaped the entire butchering sequence including evisceration, skinning, disarticulation, and filleting. This allowed Nilssen to attribute most cutmarks to specific butchering activities. Soulier and Costamagno (2017) continued to complete and to clarify the coding system by presenting each butchering activity (skinning, disarticulation, defleshing and tendon-removal) separately to provide an overview of all the cutmarks produced during butchering process.

Although this coding system can provide a way to record the rough location of cutmarks on different bone sections as categorized by grouping codes that identify a unique activity, the accurate location of each butchering mark is still unclear. In this study, therefore, marks were first identified to bone portion and element with the aid of 30x-21mm hand lens, and then documented and analysed using GIS to gain a better understanding in human behaviours behind these marks. For the marks on limb bones, I drew their location in a four-view template and transferred them into a shapefile in order to analyse and represent them in ArcGIS. Separate point layers were created to illustrate all the identified butchering marks on the bone surface. I marked them with a point symbol which is also linked to an attribute table with information about the mark: (1) type of butchering mark (cutmark, chopmark, scrape mark, etc.); (2) direction of the mark (transversal or longitudinal).

4.1.7 Fracture pattern

Although bone conchoidal flake scars and corresponding bone flakes can be diagnostic marks of fracturing for marrow extraction, the relatively low frequency of their occurrence in animal bone assemblages and the possible deterioration of cortical surfaces due to sediment attrition make it difficult to represent the level of marrow extraction (Fisher 1995). Therefore, providing additional lines of evidence is an important issue in faunal analysis, in order to distinguish post-depositional fracture from fresh fracture. Scholars have developed a series of criteria to identify fracture patterns (Johnson 1985; Morlan 1984; Outram 2001, 2002; Villa and Mahieu 1991). Most of them focus on separating dry bone breakage from hammerstone breakage of green bone.

This analysis was designed to determine whether bones in the assemblage were broken when they were fresh or dry. Villa and Mahieu (1991) concluded that curved and V-shaped fracture outlines are strongly associated with butchery and marrow extraction, while transverse fracture outlines are most often associated with factors such as sediment pressure and excavation damage. Outram (1998) developed a more comprehensive system, called fracture freshness index (FFI), to record and evaluate the freshness of bone fractures. The three principal criteria of fracture outline, edge texture and angle were used in the creation of the fracture freshness index. For each criterion, a score of zero, one or two was given to each fragment. A score of zero meant the fragment was entirely consistent with fresh fracture according to that criterion. One was scored if some "unfresh" features were present, and two was scored if "unfresh" features dominated. In this study, I will use this fracture freshness index to record and evaluate the aurochs bone fractures from the G2 trench.

(1) Fracture outline

The fracture outline is a description of the fracture's basic shape. Fresh bones are generally expected to fracture with a helical (spiral) fracture (Figure 4.1 a). Other outlines tend to be straight breaks, whether they are diagonal, transverse or longitudinal (Figure 4.1 b, c and d). A combination of outline types may co-exist in a single fracture. In this analysis, the outline types found on both the proximal and distal ends of the fractured specimen are described and recorded.

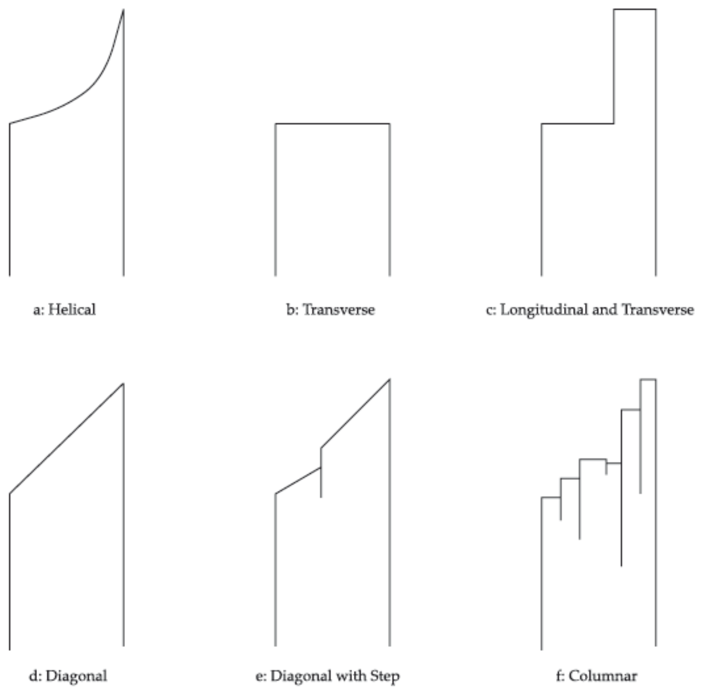


Figure 4.1 The shape of some possible bone fracture outlines.

a) helical; b) transverse; c) longitudinal and transverse; d) diagonal; e) diagonal with step; f) columnar (after Outram 1998).

(2) Fracture edge texture

The broken surface of a fresh fracture is usually smooth, while on less fresh specimens, it may appear rough. Roughness resulting from lack of freshness is relatively easily discerned. The fracture surface appears granular (Figure 4.2), while the edge of freshly fractured bone looks more like broken plastic (Figure 4.3).

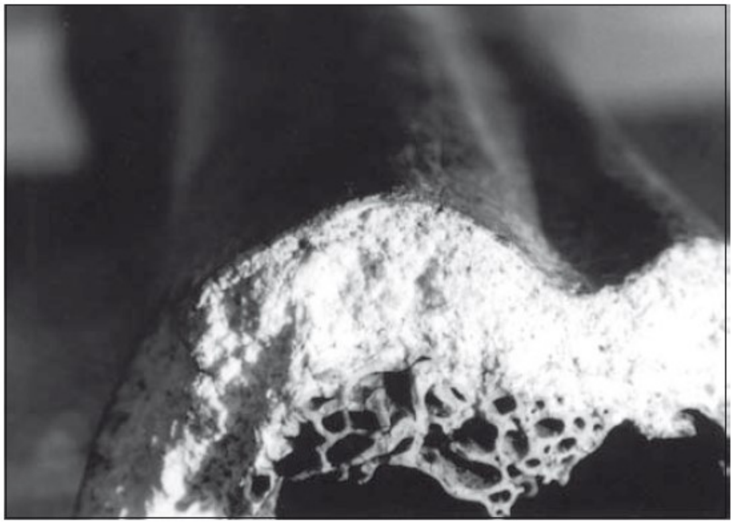


Figure 4.2 A very granular and rough fracture surface on a metapodial, broken after most of its organic content had been lost (after Outram 1998).

Figure 4.3 The very smooth fracture surface on a humerus broken when the bone was still fresh (after Outram 1988).

(3) Fracture angle

On a fresh fracture, the angle of the fracture surface to the bone's cortical surface is usually either acute or obtuse (Figure 4.4). A right-angle more commonly appears on unfresh specimens. For this study, an estimate of the approximate percentage of fracture surface that was at an angle was made for both the proximal and distal ends of the bones.

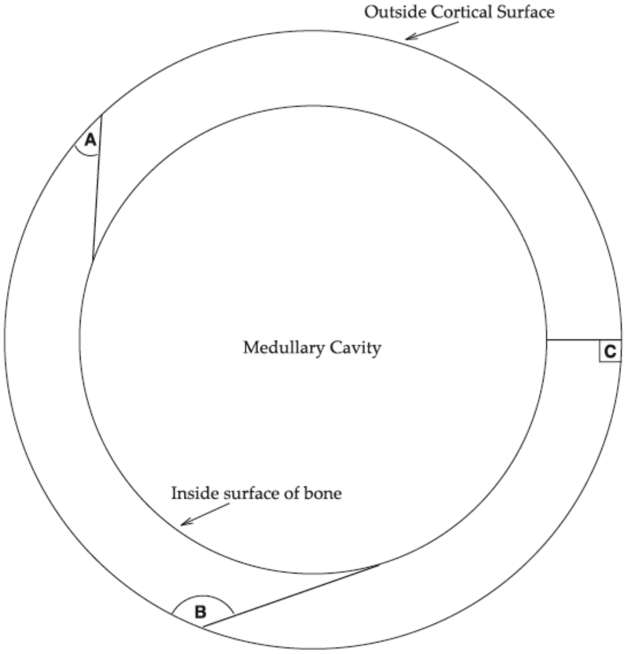


Figure 4.4 Three possible angles of fracture to the bone's cortical surface

A) acute; B) obtuse; C) at right angles (after Outram 1998).

4.1.8 Estimating meat weight

Meat weight or meat yield has frequently been calculated by archaeologists to assess the dietary contribution of different taxa to human subsistence. Several methods have been used to calculate the weight of meat per taxon represented by the bones in a faunal assemblage (Barrett 1993; Casteel 1978; Jackson 1989; Lyman 1979; Reitz et al. 1987; Smith 1975; Uerpmann 1973; White 1953). The most common approaches fall into two categories, differentiated by manners of deriving meat weight based on 1) the weight of bones per taxon, and 2) the minimum number of individuals (MNI) in the skeletal population.

The former weight method utilized the dry bone weight, which was calculated for the faunal aggregate, and then multiplied by a specific factor to obtain meat weight. This approach was based on the assumption that bone weight has a fixed percentage proportional to meat weight (Barrett 1993; Casteel 1978; Cook and Treganza 1950; Jackson 1989; Reitz et al. 1987; Uerpmann 1973). There are several advantages in this method, including avoiding the influence of bone fragmentation and identification biases among different analysts. However, determining the correct factor to use in converting bone weight to meat weight is a serious difficulty in applying the weight method. The conversion value that was used in early research varied from author to author. Cook and Treganza (1950) proposed that the ratio of dry bone to the original live weight of a mammal or a bird would be six percent. Fishbone weight was assumed to represent five percent of total weight. Kubasiewicz (1956), however, estimated that bone constituted seven percent of the total weight in cattle, sheep, and pig. Yet, as the earliest advocates of this method, neither researcher described how the ratios had been derived. Later, Chaplin (1971) pointed out that the relationship of bone weight and body weight cannot be described by a constant factor, and the ratio between the weight of meat around a bone and the weight of the bone would be varied. He suggested establishing the ratio of bone and total weight for each bone at different ages of the animal and for each sex. Casteel (1978) demonstrated that the ratio of bone weight to body weight varied with size as well as species based on McMeekan's data for pigs. Casteel showed that "estimates made by the weight method are in error by between 28 and 1156 percent" (Casteel 1978). Some proponents still insisted that this was a potentially useful method. Barrett (1993), for example, proposed estimating "a range of meat yield estimates for groups of excavated bone" to solve the intra-taxon variation. While he was the strongest advocate of perfecting and using the weight method, it has rarely been applied in recent research.

The second method of calculating the weight of usable meat provided by animals, involving MNI was first proposed by White (1953). He suggested that the meat yield estimate be calculated from the number of individuals of each species multiplied by the number of pounds of meat that one individual of the species could provide based on modern butchering and meatpacking data. This method has been modified by many other scholars. Smith (1975) argued that the bias could be significant if the species of animal showed variation in live weight among individuals of the same population. Taking white-tailed deer as an example, he proposed the live weight of a white-tailed deer would be influenced by the variation in geographical location, age, sex, seasonality of harvest, population density and quality of forage. In the analysis of the meat yield of white-tailed deer from the Banks site, he estimated the age and sex distribution and the seasonality of exploitation of the white-tailed deer by the size of the pelvis and the tooth eruption patterns in mandibles. He then calculated the meat weight multiplied by the deer weight data obtained from a modern deer population with different age and sex categories. Thus, by combining available age, sex and seasonality information about the prehistoric deer harvest with more specific modern deer weight data, a much lower and more accurate deer meat yield estimate was represented. Lyman (1979) pointed out another problem with an assumption of the MNI method. It assumed the complete consumption of the carcass so that the result of MNI multiplied by the average meat weight would represent the amount of meat yield from all the animals. Lyman (1979), however, argued that one or two bones did not necessarily represent the meat of a whole carcass. He suggested determining the minimum number of butchering units or skeletal portions to multiply those units by the meat amount of each quantitative unit.

Age and sex are two important factors which could influence the liveweight and available meat weight of aurochs. Sex variation of live weight is significant in cattle and bison, and similar characteristics can also be expected for aurochs. Bone size in male adults is generally larger than in females. The influence of age is more complicated, since there are different patterns of long-term growth between males and females. The growth in females slows between two and three years of age, maintaining a slow rate until it reaches a peak at around five years (Figure 4.5). Female weights stabilize after that. In males, growth occurs at a relatively high rate before three years of age and continues at a lower rate until reaching a plateau at six years of age (Figure 4.6). For both males and females, however, the variation of liveweight in different age groups is significant before both sexes reach their peak weight. Therefore, in this paper, I will ignore the effect of age on live weight to estimate the range of meat weight based on the equation I mentioned in the last chapter. The average liveweight for male (815 kg, n=157) and female (474 kg, n=486) bison, which is considered the reference in this paper, is derived from records of bison live weight at Theodore Roosevelt National Park, the National Bison Range, Wind Cave National Park, and the Fort Niobrara National Wildlife Refuge (Emerson 1990).

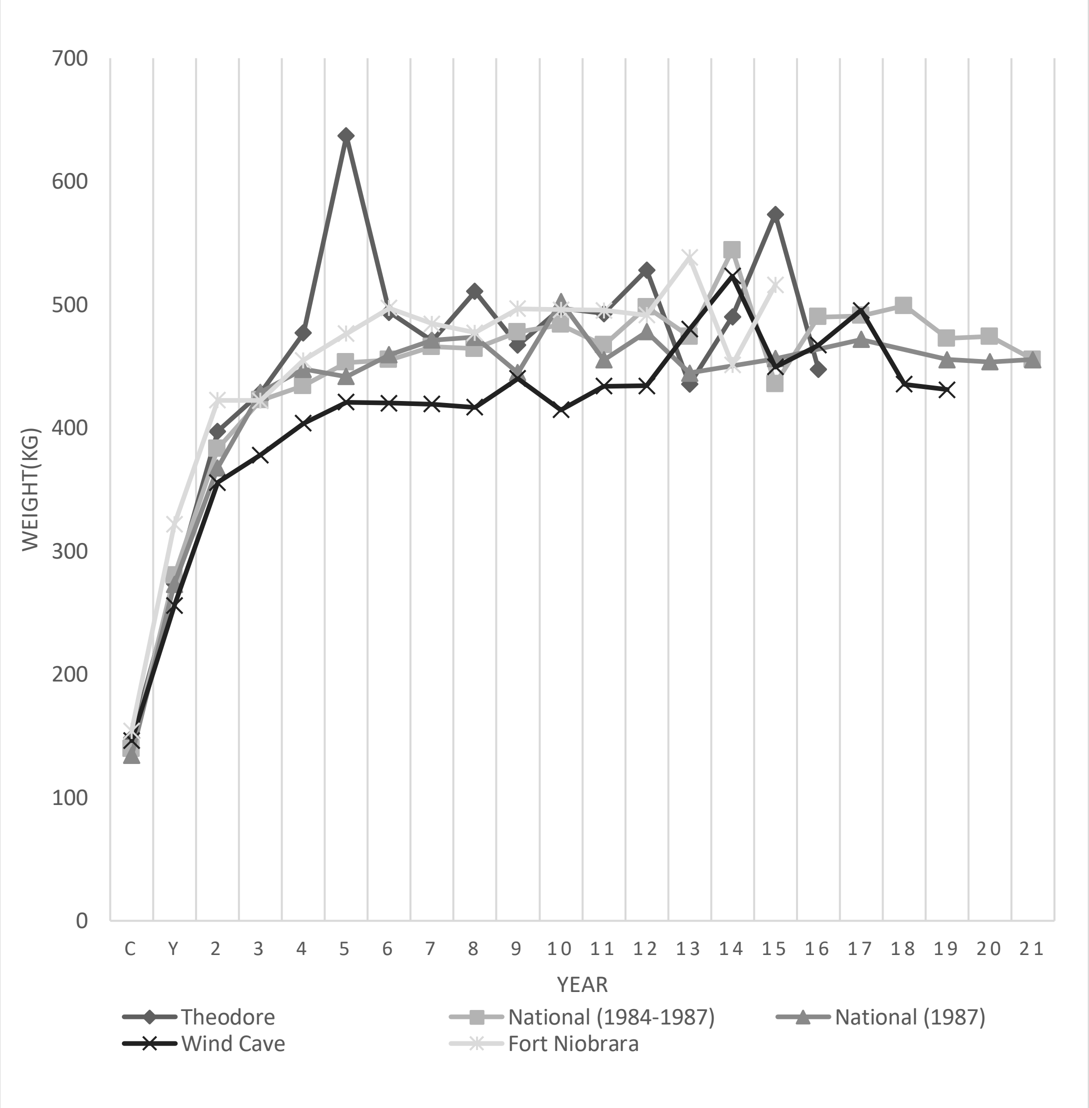


Figure 4.5 Average female bison liveweight by age class for Theodore Roosevelt National Park, National Bison Range (1984-1987, 1987), Wind Cave National Park, and Fort Niobrara National Wildlife Refuge (Modified from Emerson 1990).

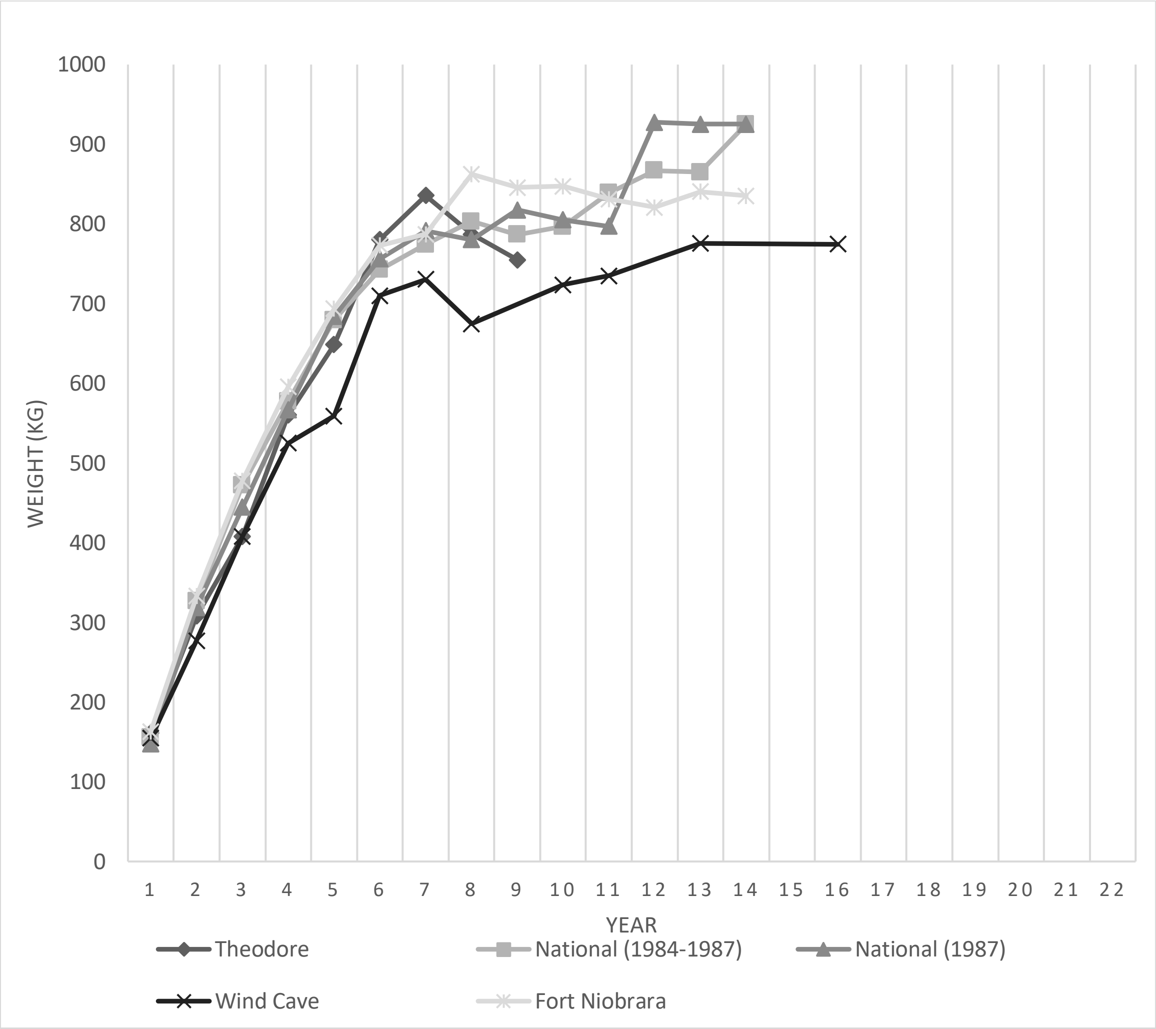


Figure 4.6 Average male bison liveweight by age class for Theodore Roosevelt National Park, National Bison Range (1984-1987, 1987), Wind Cave National Park, and Fort Niobrara National Wildlife Refuge (Modified from Emerson 1990).

In this study, I estimate the meat weight of aurochs based on the bones that were found in trench G2 in Houtaomuga. Generally, information regarding live weight or meat weight of aurochs of known age and sex is necessary no matter which method is applied in this analysis. However, even in European literature, where there has been a relatively large number of studies of aurochs, no comprehensive survey of live weight or meat weight exists. The most detailed biometric research on aurochs came from Degerbøl and Fredskild (1970), in which they described the size of all the aurochs' bones that were found in Denmark.

The reference data for meat weight is the first problem I need to address in this study. Fortunately, there are many studies related to meat weight in bison and domesticated cattle, both close relatives of the aurochs. Although the live weights of both cattle and bison are different with aurochs, compared to cattle, bison are bigger, and the live weight is closer to that of aurochs. Therefore, if I can verify that the meat distribution of different bison skeletal portions is similar to that of cattle, it is reasonable to believe these Neolithic aurochs will have shared similar characteristics with bison, so that the data from bison can be applied as a reference in this analysis to calculate an estimated value of aurochs meat from Houtaomuga.

Emerson (1990) recorded meat weight for each carcass unit from four bison individuals that were of different ages and sexes. She noted that the previous studies, which focused on the meat weight distribution in animal carcasses, always used the combined weight of all non-dry bone products to calculate the relative importance of each carcass unit. Thus, the importance of body fat in wild ungulates was often underestimated. In her study, therefore, meat production included all the muscles and a small amount of intramuscular fat that was difficult to separate from the muscle. My data for cattle were gathered from Butterfield and May (1966), which described the origins and insertions of each muscle on cattle. They also calculated the approximate weight of the muscle in a 227 kg would be 136 kg. I divided the attached muscles for each carcass unit so that they could be compared with bison.

Table 4.1 shows the percentage values of the weight of muscle on long bones relative to the carcass dressed weight, with more specific sex information included for bison, following Emerson (1990: 432). These data suggest that although there is a variation of muscle weight by key skeletal elements between cattle and bison, the proportional meat distribution for different carcass units is quite similar with the exception of the tibia.

Table 4.1 Comparison of meat distribution between cattle and bison.

	Cattle		Bison			
			Adult (♂)		Adult (♀)	
	Muscle weight (kg)	% Total meat weight	Muscle weight (kg)	% Total meat weight	Muscle weight (kg)	% Total meat weight
Femur	16.73	24.6	28.0	23.0	22.6	26.3
Tibia	4.32	6.4	3.5	2.9	2.3	2.7
Humerus	4.06	6.0	7.9	6.5	6.0	7.0
Radius-ulna	1.85	2.7	2.6	2.1	1.7	2.0

I applied the method developed by Lyman (1979) in this dissertation. The most important point of this method is that one or two bones cannot be used to infer that a complete animal carcass was consumed at the site. The equation for calculation of meat amounts in his study was written as:

X% butchering unit weight = consumed meat weight of a butchering unit.

However, the meat weights for bone and bone groups of the carcass were influenced by age, sex, and other conditions in both bison and cattle. Therefore, instead of attempting to calculate a single meat weight for the G2 aurochs' skeletal elements, I estimated a range of meat weights to reflect the diet contribution of aurochs in Houtaomuga. If we assume all the aurochs in G2 trench are adult females, then we can calculate the minimum value for meat weight of the whole group using Lyman's equation; if, however, the G2 trench consisted only of male adults, we can calculate the maximal value of the meat weight. Consequently, no matter what the proportion of each sex in the slaughtered G2 aurochs, the meat weight would occur somewhere in this range. Male and female adult mentioned here are assumed to be older than five years, which would reach the maximum liveweight in both genders. The live weight variation for the individual younger than five years old, which is in the fast growth period, is significant and difficult to estimate. Therefore, they are not involved in this equation.

The equations for calculating meat weight at Houtaomuga are represented as:

X% carcass weight (in female adult) = minimal consumed meat weight of a butchering unit.

Y% carcass weight (in male adult) = maximal consumed meat weight of a butchering unit.

The percentage figures utilized in the equations are from Emerson (1990), who provided the detailed percentage for each butchering unit. Different scholars use varying definitions of "butchering unit." In order to use the references from Emerson, this paper will follow her definitions (Emerson 1990).

While many of the bone elements from Houtaomuga are visible to us, there would be significant aspects of aurochs butchered at the site that are not directly visible in the archaeological record. Apart from the connection between the hyoid and the tongue, organ meats and the digestive tract leave few or no traces. This would be equally true of the hides that would be recovered, which could be used for footwear and other clothing as well as other applications. As noted earlier, fleshy meat products are not necessarily the critical components of a carcass from a northern hunter-gatherer perspective, and it is important to bear in mind these other aurochs products.

According to Speth (2022a and 2022b), northern foraging bands maybe compelled to focus on organ meat, marrow or grease, the fatty part of the animal carcass, and discard the excess lean meat for daily subsistence. Because organ meat, bodily fat stores, and an animal's digestive tract are often highly ranked by hunting populations, they must also be included in our total calculations. To do this, I use the MNI of aurochs from the G2 trench while assuming that each individual that was represented in the MNI was killed and consumed completely at Houtaomuga. Then, the total organ meat weight would be the value of the MNI multiplied by the individual organ meat weight.

Emerson (1990) reported the weights of the heart, liver, kidney, and tongue from four bison of different ages and sex (Table 4.2 and 4.3). The smallest size of all organs came from the FYM bison since it is the only immature individual. In the other three adult specimens, there remains considerable variability of organ weights because different sexes were involved. As a compromise, I have taken the average organ weight of just the three bison adult individuals (SAM, SAF, and FAF) to calculate the total organ meat weight of the G2 trench.

Table 4.2 Acronym, age, and sex for bison study specimens collected from Theodore Roosevelt National Park, 1985 (from Emerson 1990).

Acronym	Age Group	Known Age	Sex
SAM	3.6-3.9 yr		Male
SAF	5.6-5.9 yr or 6.6-6.9 yr		Female
FAF	10.5-13.5 yr	16.5 yr	Female
FYM	1.5 yr	1.5 yr	Male

Table 4.3 Organ weights in four adult bison (in gram).

Organ	FYM (♂)	SAM (♂)	SAF (♀)	FAF (♂)	Average
Heart	1502.6	2842.1	2537.3	2863.3	2747.6
Liver	4309.2	5896.8	4762.8	7626.2	6095.3
Kidneys	340.2	574.1	407.6	556.4	512.7
Tongue	850.5	1771.9	1396.2	1679.7	1615.9
Total					10971.5

4.1.9 Construction of age profiles

Age profiles were constructed for aurochs in order to determine the season of occupation for G2. There are a variety of techniques to approach this problem: epiphyseal fusion (Duffield 1973), tooth eruption, and tooth wear (Frison and Reher 1970; Reher and Frison 1980). The age sequence is often built on the observation and comparison of a modern sample of known age animals to an archaeological example of unknown age. Applications of each of these methods have their own strengths and weaknesses. However, the fact that aurochs became extinct by 1964 (Vuure 2005) is a problem that must be noted. It is, therefore, impossible to form the age frame based on a modern aurochs' sample. Fortunately, numerous sources for age at death both in cattle and bison provide us with an opportunity to evaluate the mandible eruption and wear stages in aurochs. The premise of this approach is that tooth eruption and wear proceeds in a regular and observable pattern, which can be linked to the biological age of a species. Since the three species, bison, cattle and aurochs, are all under the subfamily of Bovinae, I assume that they share a similar sequence and schedule in tooth eruption. Based on the published sources for age estimation using cattle and bison dentition, if their tooth eruption falls into the same age range, it is reasonable to infer that aurochs were similar, and the modern data for age estimation in cattle and bison could be used as a proxy for aurochs.

Detailed studies relating tooth eruption to age in cattle began in the mid to late 19th century AD. These came about at first because of the demand for applications in the livestock trading market. Many researchers have made a large number of observations on cattle dentition since then. Published data on tooth eruption were presented in diverse ways, such as description, drawing and by means of various methods for categorizing stages of eruption and wear. The latest synthesized research was done by Jones and Sadler (2012). They proposed a new method of categorizing stages of eruption and wear based on the observation of 94 cattle of known age at death and compared this method with several established methods for cattle ageing. This research indicates that for cattle up to four years old, which teeth were still in eruption or replacement, age at death can be estimated with greater precision. For cattle of four to 20 plus years old, the variability is much greater since the estimation is reliant on the tooth wear.

The first observations on the relationship between eruption patterns and changes in the wear of the teeth with advancing age in the bison were made by Fuller (1959). However, the description was quite sketchy and more concentrated on the eruption and wear in incisors. Although the incisor is an accurate indicator in determining the age of ungulates, in archaeological sites, incisors are not commonly preserved in large numbers. It was not until a pioneering study by Frison and Reher in 1970 that the basic assumptions and techniques for estimating age based on the eruption and wear of lower molars was developed. This approach then plays a vital role in the investigation, especially with respect to seasonality reflected in North American Great Plains bison assemblages.

Table 4.4 shows that in cattle and bison the tooth eruption sequence and age are similar. Thus, it is reasonable to believe aurochs, the ancestor of domestic cattle, would share similar attributes with cattle and bison in tooth eruption. In this study, age data for cattle will be mainly used as the reference to estimate the aurochs age since they have a closer relationship. In contrast, bison age will act as complimentary information about tooth eruption.

Table 4.4 Age estimates for Jones/Sadler, Fuller and Frison.

	Jones and Sadler (cattle)		Fuller (bison)		Frison (bison)	
	Definition	Age (month)	Definition	Age (month)	Definition	Age (month)
dP	dp4 4H to a	a few days	dp all present	absent	absent	absent
M1	M1 4H to a	4-6 m	M1 3E to 5U	3-12 m	M1 3E to a	6 m
M2	M2 4H to a	13-18 m	M2 3E to 5U	12 m	M2 3E to a	18 m
M3	M3 4H to a	23-28 m	M3 3E to ? m	24-? m	M3 3E to?, 3rd cusp unerupt	30 m
M3 third cusp in wear	M3 3rd cusp in wear, <g	34-43m	M3 3rd cusp in wear	36-48 m?	3rd cusp erupted but unworn	42 m

Eruption and Tooth Wear Stages as given by Ewbank et al. (1964), Grant (1982) and Jones and Sadler (2012); 3E - erupting; 4H - halfway between bone and full height; 5U - up but unworn; dp – deciduous premolar.

4.2 GIS and Zooarchaeology

Geographic Information Systems (GIS) are a relatively new technology, but despite their recent appearance, they are now widely used in archaeological research. GIS use computer systems that can store, manipulate, analyze and present information about geographic or other forms of space, making it a formidable practical tool for archaeology.

For zooarchaeology, it is also a powerful tool, and the application of GIS can be divided into two dimensions depending on the different purposes. First, some researchers have applied GIS to the study of the spatial distribution of zooarchaeological remains within individual sites or deposits. Another application of GIS in zooarchaeology is treating each bone as a "map." Marean and his colleagues (2001) are pioneers in introducing GIS to calculate the minimum number of skeletal elements (MNE) based on anatomically overlapping specimens. Each bone fragment was drawn as a polygon feature over the template for that element and then converted into grid themes. The maximum number of pixel overlaps represents MNE. Although some researchers criticized that MNE could be potentially inflated because of the lack of precision in hand-drawing, others found it more valid and expanded its application in other fields. Abe et al. (2002) argued that GIS is a useful tool in calculating cutmark frequencies from assemblages with differing levels of fragmentation. Parkinson and her colleagues (2014, 2015, 2018), through a series of experiments about tooth marks and other bone damage that were made by large canids and felids, observed that large felids produce less bone damage than large canids or spotted hyenas. She accomplished this by documenting and analyzing bone preservation and surface modification in GIS. More recently, Stavrova et al. (2019) improved Marean and Parkinson's method by applying GIS software to analyze the distribution of percussion marks to test whether intuitiveness could affect the appearance of percussion mark patterns. The result showed bone morphology played an essential role in bone breakage by beginners, and more importantly, this study exhibited the potential of GIS to deal with large amounts of information by facilitating visual observation of spatial distribution patterns.

In this study, GIS will be used in counting MNE, bone survivorship, bone breakage patterns and cluster patterns for burning marks to provide more information on butchery and cooking practices.

4.2.1 Template Preparation

In order to analyze breakage and burning patterns, the first step is to create templates for each element. Only limb bones, such as the humerus, radius, metacarpal, femur, tibia, and metatarsal, are included in this analysis. In previous studies, most researchers created templates based on the photographic images of modern specimens. In this case, as aurochs are extinct, I selected bison bone images, since bison are close relatives and share a high degree of morphological similarities (Figure 4.5a). Each element is drawn from four perspectives: anterior, posterior, medial, and lateral. Georeferencing is an important attribute for GIS (Figure 4.5b). Although bones do not constitute a geographic space, I assigned an arbitrary reference coordinate (WGS_1984_UTM_Zone_1N) so that the data can be shared and made compatible with other GIS systems if needed.

4.2.2 Drawing the Bone Fragments and Burning Marks

All identifiable specimens were drawn digitally in ArcGIS over graphic templates (Figure 4.5c). An intensive level of training in bone anatomy is required because recognizing well-known anatomical landmarks allows for a more accurate drawing of fragments (Lyman 2008; Parkinson et al. 2014). Each fragment is drawn in vector mode as a polygon feature in a separate layer.

Burning marks were mostly identified based on colour, and separate point layers were created to illustrate them on the bone surface because it is difficult to confirm their explicit boundaries. Besides, the position, rather than the shape of burning marks, was more significant in observing the cluster pattern.

4.2.3 MNE Counting and Bone Survivorship

For counting MNE, I followed the method adjusted by Stavrova and her colleagues (2019), which calculated MNE directly with overlaying polygons. The maximum number of fragment overlaps indicates the MNE, and the darker area in the "map" illustrates the higher frequency of bone overlaps (Figure 4.5d).

ArcGIS can calculate the area defined by the outline of polygon automatically, therefore making it possible to calculate the area of each fragment. To calculate the frequency of bone survivorship for each element, I applied the equation developed by Abe et al. (2002) and Stavrova et al. (2019).

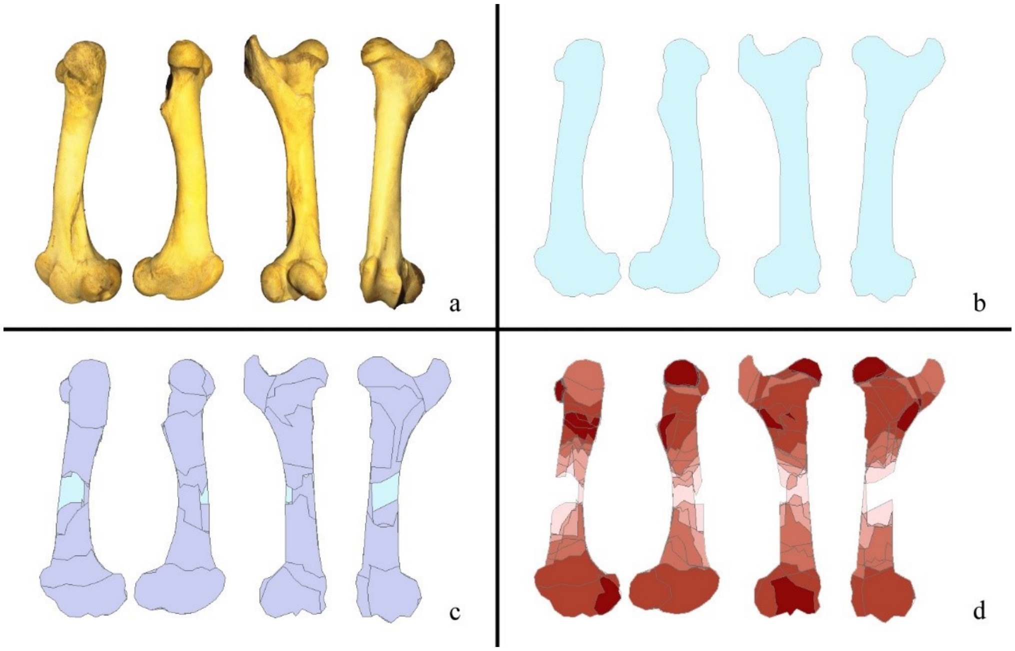


Figure 4.7 Different GIS layers.

(a) Georeferenced photographic template for a bison femur; (b) GIS outline template; (c) GIS fragment layer; (d) Bone survivorship map.

4.2.4 Spatial Analysis of Butchery and Burning Marks

The GIS method is also very useful in recording the spatial distribution of bone surface modification marks. In previous studies, researchers used this approach to document cut marks, carnivore tooth marks and percussion marks. It should be equally helpful in analyzing burning marks. The kernel density tool was applied to represent clusters visually in order to reveal the possible patterns or techniques during butchering and cooking.

4.3 Biometrical Methods

Although there have been some debates about the importance of biometry in zooarchaeology over the last decades, its essential role in certain fields, such as the detection of early domestication, estimating the sex/age composition for one taxon, and distinguishing between morphologically similar taxa, cannot be ignored.

Small sample size is one of the problems that zooarchaeologists need to deal with. Even in an extensive excavation that can produce a large number of measurable bones, the sample size will become smaller when dividing them into chronological or spatial subsets. Researchers developed various size index scaling techniques based on comparing metric data from archaeological sites with a standard animal to overcome this problem. Logarithm size index (LSI), which was first described by Meadow (1981), is the most influential method in the comparison of body sizes, especially in research discussing the spread of domesticated animals in southwest Asia.

Although it was not a new method in zooarchaeology, its application with Chinese materials was rare. The first and almost the only extensive research was conducted by Yu (2015). She revisited and collected biometry data on *Bos* from 13 archaeological sites that date from the Middle Neolithic to Early Bronze Age period. A clear size diminution in *Bos* was observed from the Middle Neolithic onward, suggesting that early domestic cattle may first have appeared in the upper and middle Yellow River Valley no later than 5,500 years ago.

In this research, LSI is used to examine metric distinctions when comparing European aurochs and modern cattle. By using this method, all the measurements from an archaeological assemblage are converted into logarithmic values from which are subtracted from the standard animal/individual (d=log $_x$ – log $_{standard}$). Although natural log better approximates proportional changes in typical body size ranges, log $_{10}$ is the base I used here for easier calculation. A negative LSI value indicates that a specimen is smaller than the standard animal; in contrast, specimens larger than the standard animal will produce a positive value.

4.3.1 Standard Animal, Dabusu Aurochs, and Modern Cattle

Most aurochs bones were found and identified in Europe. However, the preservation of the complete skeleton is rare. In this study, I use a female adult aurochs from the Mesolithic Ullerslev site in Denmark as the standard animal (Degerbøl and Fredskild 1970). This is the most complete aurochs skeleton. It has been widely used as the standard animal in previous research (Grigson 1989).

In China, most aurochs remains were in Pleistocene contexts in north China. The only complete aurochs skeleton is from Dabusu, Jilin province (a possible female based on the biometry). Although Tang et al. (2003) published its measurements for both sides of the skeleton, not all the elements were measured. Therefore, the Dabusu aurochs was only selected as a reference to demonstrate the similarity in size between aurochs in Europe and China.

Another reference sample used here is a modern adult domestic cow from the zooarchaeology laboratory at Jilin University. For details of the measurements see Appendix 1.

4.3.2 Measurement Selection

Although the LSI technique is generally described as a way to deal with the small size of many animal bone assemblages, the technique has the advantage of allowing researchers to plot different measurements on the same scale rather than making comparisons separately.

In general, there is large size difference between mature and immature individuals. The adult animal also has a more stable live-weight compared to a juvenile one during its growth. In previous LSI studies, researchers collected the measurements from elements where epiphyses had fused or were fusing in order to exclude the immature specimens. However, there is a variation in the time of epiphysis fusion in different post-cranial bones, and some bones, like the scapula, will grow a great deal even after fusion (Rowley-Conwy 1995).

Although there is a different growth pattern in males and females, 4.5-5.5 years has generally been considered as the age that cattle reach their maximum mature weight (Beltran et al. 1992). However, the growth rate does not have a uniform distribution, with rapid growth occurring on and around the onset of puberty, and a lower rate of growth characterizing the period following maturity. Gbangboche et al. (2011) proposed that most Lagune cattle are fully developed (≥ 90%) at 720 days of age. In straightbred and crossbred Kedah-Kelantan cattle, different traits express rapid growth before 36 months (Ariff et al. 1993). A similar pattern is also observed in bison. Female bison gain their weight between two and three years, while males maintain a relatively high rate of growth before three years of age.

Based on the information from cattle and bison, two years of age is a reasonable cut-off point as the period having the strongest incremental growth rate and expression of sexual dimorphism in size. For post-cranial elements, age can be calculated from the epiphyseal closure. Since there are no specific data for the age of aurochs epiphyseal fusion, domestic cattle (Silver 1963) and European bison (Duffield 1973) are selected as the reference. Although these both belong to *Bovidae*, the processes of epiphysis fusion are quite different (Table 4.5). For example, the proximal radius epiphysis fuses at an early stage in cattle, while for bison, the proximal end of the radius begins to fuse at the beginning of the 4th year. From the observation for aurochs in

Houtaomuga, some radii remained small and had low levels of compactness even when the proximal end had fused. This suggests that for aurochs the proximal epiphysis of the radius fused at a young age. Thus, in this study, the ageing data for cattle will be used as the standard for aurochs.

Table 4.5 Epiphysis fusion age of cattle and bison.

Element	Portion	Age of fusion	
		Cattle	Bison
Scapula	Bicipital tuberosity	7-10 mo.	
Humerus	Proximal epiphysis	42-48 mo.	36-40 mo.
	Distal epiphysis	12-18 mo.	36-40 mo.
Radius	Proximal epiphysis	12-18 mo.	48 mo.
	Distal epiphysis	42-48 mo.	60-64 mo.
Ulna	Olecranon	42-48 mo.	48-52 mo.
	Distal end	42-48 mo.	60-72 mo.
Metacarpal	Proximal epiphysis	Before birth	
	Distal epiphysis	24-30 mo.	48 mo.
1st phalanx	Proximal epiphysis	Before birth	42 mo.
	Distal epiphysis	18 mo.	
2nd phalanx	Proximal epiphysis	Before birth	24-36 mo.
	Distal epiphysis	18 mo.	
3rd phalanx			

Pelvis	Fusion of main bones	7-10 mo.	8-12 mo.
Femur	Proximal end (2 epiphyses)	42 mo.	54 mo.
	Distal end (1 epiphysis)	42-48 mo.	60 mo.
Tibia	Proximal epiphysis	42-48 mo.	60 mo.
	Distal epiphysis	24-30 mo.	42 mo.
Calcaneus	Tuber calcis	36-42 mo.	48 mo.
Metatarsal	Proximal epiphysis	Before birth	
	Distal epiphysis	27-36 mo.	48 mo.

Because body growth rates slow down after three years in both male and female bison, all the individuals that are younger than three years were excluded from further study in aurochs size change at Houtaomuga. In this case, the distal end of the radius, metacarpal and metatarsal, the proximal and distal end of femur and tibia, and the calcaneus were used. Only specimens with fully fused epiphyses were selected.

4.4 Background to stable isotope analysis and the laboratory methods

Scientific advances in the 1960s and 1970s allowed archaeologists to expand research methods to include new techniques. Stable isotope analysis was introduced in archaeological research at that time. At first, the application of stable isotope analysis was mainly concentrated on human bones and aimed to provide direct evidence of an individual’s diet (Bender et al. 1981; Krueger 1965; Krueger and Sullivan 1984; Lee-Thorp and Van Der Merwe 1991; Lynott et al. 1986; Richards and Hedges 1999; Richards et al. 2006; Schwarcz et al. 1985; Van Der Merwe

1982; Van Der Merwe and Vogel 1978; Vogel and Van Der Merwe 1977). The earliest applications of the stable isotope analysis in human bone collagen were from sites in North America by Vogel and Van Der Merwe (1977). The field has since diversified to include analysis of carbon and nitrogen isotopes in collagen and apatite to reconstruct diet (Ambrose and Krigbaum 2003; DeNiro 1987; Krueger 1991; Sillen et al. 1995), oxygen isotopes to determine the geographic origin and paleoenvironment (Benson et al. 2006; Chamberlain et al. 1996; Chisholm et al. 1986; Hobson 1999), and strontium and lead isotopes to understand population movements (Carlson 1996). In 1988, Noe-Nygaard proposed that the isotopic analysis of dog bones provided important data supplementary to prehistoric human diet.

The recovery of information about animal diets need not only reflect the paleoenvironment; changes in diet and feeding strategies can shed light on human influence on animals. Therefore, stable isotope analysis became an essential approach to illustrating animal domestication. Carbon and nitrogen isotopes of animal bones were most commonly used in solving this issue (e.g., Barton et al. 2009, Kamjan et al. 2020, Stewart et al. 2003, Zangrando et al. 2014).

Stable carbon isotope ratios ($\delta^{13}C$) vary between plants depending on the mechanism used when plants fix atmospheric carbon during photosynthesis. In terrestrial ecosystems, plants that use the most common C_3 pathway are typically found in temperate environments and discriminate against the heavier isotope $\delta^{13}C$ when fixing the CO_2 into the tissue during the process, which results in C_3 plants have an average of approximately -26‰. In contrast, C_4 (the less common pathway) plants are typically found in arid conditions, which have a less of a fractionation between the atmospheric CO_2 and the plant tissues compared to C_3 plants. As a result, C_4 plants have an average $\delta^{13}C$ value of -13‰. Besides these two pathways, the least common photosynthetic pathway is CAM (Crassulean acid metabolism). The plants that utilize this pathway are able to significantly vary their uptake of CO_2 and discrimination against atmospheric $\delta^{13}C$, causing their $\delta^{13}C$ values to lie between the C_3 and the C_4 plant values (Richards 2020).

Similar processes to those in terrestrial ecosystems occur in ocean food webs as well. However, marine ocean carbon values are approximately 7 ‰ more positive than atmospheric carbon, resulting in marine plants having greater $\delta^{13}C$ values than atmospheric C_3 plants, with an average of approximately -19 ‰ (Richards 2020).

Animals require the carbon they consume from either marine or terrestrial plants to develop their body tissues like muscle tissue and bone collagen. Therefore, the carbon isotope values in animal body tissues can reflect what they eat. The $\delta^{13}C$ values in animals, however, are not identical with the food they consumed because there are numerous processes involved in the formation of bodily tissues. For instance, the average plant tissue's $\delta^{13}C$ values are about 5 ‰ heavier than those of herbivore bone collagen (e.g., Katzenberg 2008, Fu et al. 2010). Therefore, the average $\delta^{13}C$ values of C_3 and C_4 types of food reflected in herbivore bone collagen would be -21‰ and -8‰ (Fu et al. 2010, Wang et al. 2014).

Nitrogen enters the food chain through plants and then passes along to the consumer's tissues. The $\delta^{15}N$ values of plants are close to the values of atmospheric or soil N since they obtain nitrogen from either the atmosphere directly (legumes) or from nitrogen in the soil. Meanwhile, nitrogen also varies depending on temperature, salinity, and soil pH. In comparison to more temperate areas, warmer environments have greater $\delta^{15}N$ values (Richards 2020). The nitrogen isotope ratios ($\delta^{15}N$) can be used to assess the trophic level position of human and other animals within the local food chain. For example, experimental and field studies on animals have revealed that $\delta^{15}N$ values show a "trophic" enrichment of 2 ‰ to 4 ‰ in $\delta^{15}N$ values between an animal's tissues and its food (DeNiro and Epstein 1981; Schoeninger and DeNiro 1984; Sealy et al. 1987; Bocherens and Drucker 2003). Variability in nitrogen isotope ratios may therefore impact their potential for dietary reconstruction.

In this analysis, aurochs, deer, and dog bones from G2 will be used in carbon and nitrogen isotope analysis to investigate the animal forage and human diets at Houtaomuga. Because human and animal diet are reflected in stable isotope concentrations in bone collagen and carbonate (Ambrose and Norr 1993), long bone fragments were sampled in this analysis. Diaphyseal bone density is higher than other element portions, potentially increasing the chance of collagen occurrence. The selection of bone fragments will also minimize the destruction of skeletal information by preserving the most critical features of the remains.

Dog sample preparation was done in the laboratory facilities of the Department of Anthropology under the direction of Dr. Garvie-Lok. About five grams of bone sample were taken from the animal bones after removing all the discolored surfaces with a fine dental drill. Then the samples were washed in double distilled water with an ultrasonic cleaner machine for ten minutes. After the samples were dried and weighed, they were soaked in a 1% HCl solution. This process was aimed at dissolving away bone mineral to leave the collagen. The solution was refreshed every two days until the samples were fully demineralized. At this stage, the collagen yielded the shape and size of the original bone, but was translucent and flexible owing to the loss of the mineral component. After they were rinsed and kept in double distilled water for 24 hours, demineralized samples were treated with 0.125 NaOH for 20 hours to remove base-soluble contaminants such as humic acids and some lipids. Samples were then rinsed in double distilled water for another 24 hours before heating in pH3 acidified water for 48 hours to allow the collagen fibrils to denature. Samples were centrifuged prior to freezing and freeze-drying. The final product of this process was purified collagen, which was then measured for $\delta^{15}N$ and $\delta^{13}C$ using the Vario Pyrocube coupled with the Isoprime Isotope Ratio Mass Spectrometer housed in University of Alberta, Biogeochemical Analytical Service Laboratory.

Six aurochs samples were processed in the Keck Carbon Cycle Accelerator Mass Spectrometer (AMS) Facility at the Department of Earth System Science in University of California-Irvine. For each sample, 1 to 1.5 g of bone were decalcified in 6cc of 0.5N HCl at room temperature for 24 to 36 hours until the bone fragments stopped bubbling and looked translucent. The bones were then neutralized with MQ (Milli-Q) water. Five cc of 0.01N HCL solution were added to gelatinize for 8 to 10 hours. After ultrafiltration, the solution was freeze-dried for at least 10 hours to get the fluffy cotton like collagen samples. They were analyzed using a Fisons NA 1500NC elemental analyzer and Finnigan Delta Plus isotope ratio mass spectrometer at the Keck Carbon Cycle Accelerator Mass Spectrometer (AMS) Facility.

The stable isotope ratios of all the deer samples and two aurochs samples were analysed at the Environmental Stable Isotope Lab, Institute of Environment and Sustainable Development, Chinese Academy of Agricultural Science. For each sample, 1.5 g bones were sonicated, cleaned and demineralized in 0.5 mol/L HCl at 5 °C. The solution was replaced every three or four days until the bone samples were fully decalcified and no bubbles emerged. Afterwards, the remains were washed into neutrality with deionized H_2O and immersed in 0.0125 mol/L NaOH at room temperature for 20 hours. The remains were washed again into neutrality, and 0.001mol/L of HCL solution was added to gelatinized for 48 hours at 70 °C. After filtration, the solution was freeze-dried to get the collagen. The purified collagen was measured using an IsoPrime 100

Isotope Ratio Mass Spectrometer coupled with a Vario Elementar at the Environmental Stable Isotope Lab.

Chapter 5: Radiocarbon Dates from the G2 Trench

Kunikita et al. (2017) dated two samples from the 4th phase of Houtaomuga to 4420 ± 45 BP (Table 5.1) (approximately 5000 cal BP). They tested charred residues on both the inner and outer rim from the same pot and obtained dates that were consistent. The ceramic vessel in their study is from pit 84 rather than the G2 trench; therefore, it is necessary to develop a finer chronology for the G2 trench in order to better understand the formation processes involved.

All the bone samples for radiocarbon dating came from a segment of G2 quadrant IV. This quadrant has then been arbitrarily divided in seven sections, marked by A, B, C, D, E, F, G, and H. Only animal bones from section A, B, C, and D were collected separately. Therefore, I selected two samples from excavation area A, two from area B, and one each from C and D, dispersing the samples for those segments of the trench (as in Figure 5.1).

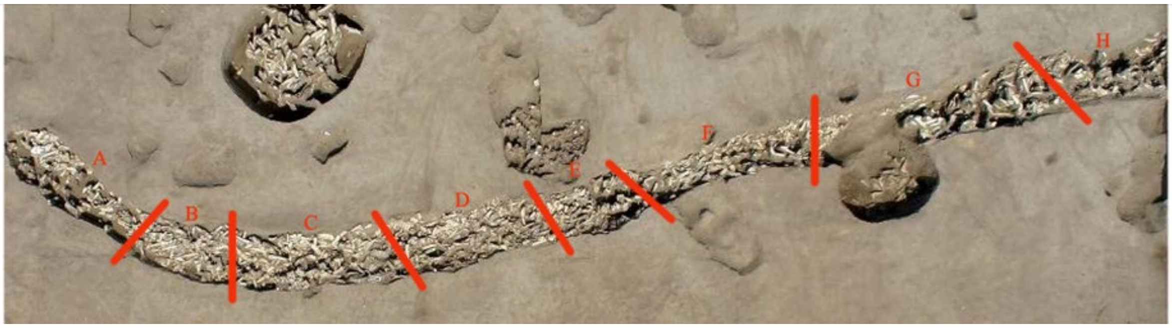


Figure 5.1 The G2 segment in IV quadrant. The red marks show the division of seven sections.

The total of six samples from trench G2 were submitted to the University of California-Irvine Keck Carbon Cycle Accelerator Mass Spectrometry (AMS) Laboratory, where they were demineralized, ultrafiltered, combusted, and counted. The radiocarbon results were calibrated using OxCal v4.3.2 (Bronk Ramsey 2013; Bronk Ramsey and Lee 2013; Reimer et al. 2020) and are represented in Table 5.1 and Figure 5.2.

Table 5.1 Radiocarbon dates from the 4th phase of the Houtaomuga site.

Lab ID	Feature	Sample Type	^{14}C Date (BP)	δ^{13}C	δ^{15}N	C/N (atomic)
MTC-17593	11DHAIIIH85	charred residues (inner rim)	4420±45	-27.5	8.2	16.5
MTC-17592	11DHAIIIH85	charred residues (outer rim)	4420±35	-27.9	8.0	12.0
UCIAMS-205798	12DHAIVG2A91	bone (aurochs)	4705±20	-15.7	7.7	3.18
UCIAMS-205799	12DHAIVG2B1078	bone (aurochs)	4745±20	-14.5	7.5	3.18
UCIAMS-205800	12DHAIVG2D176	bone (aurochs)	4680±20	-15.5	7.5	3.22
UCIAMS-205801	12DHAIVG2B564	bone (aurochs)	4695±20	-16.4	8.2	3.19
UCIAMS-205802	12DHAIVG2A8	bone (aurochs)	4705±20	-15.9	6.9	3.18
UCIAMS-205803	12DHAIVG2C284	bone (aurochs)	4700±20	-15.3	7.4	3.20

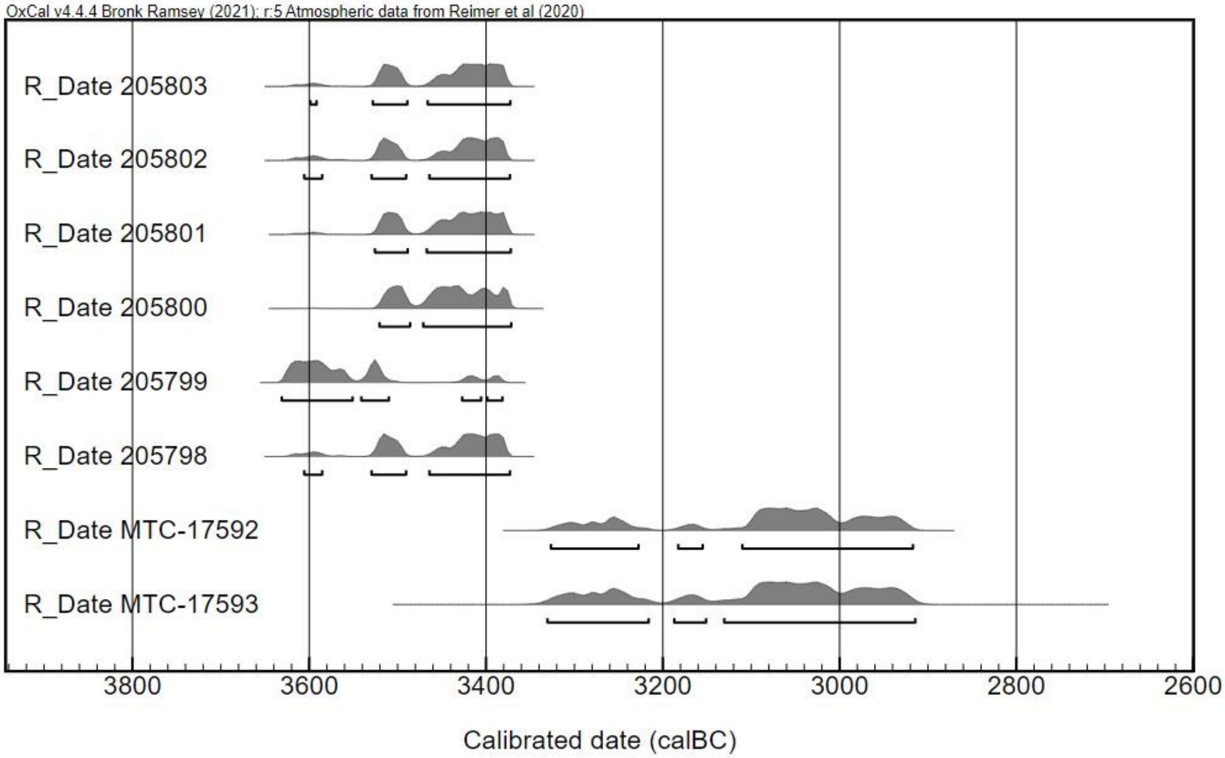


Figure 5.2 Unmodelled calibrated dates from Houtaomuga. The gray shading represents the distribution of simple radiocarbon calibration ages.

Table 5.2 Unmodeled and modelled G2 trench dates from Houtaomuga.

Name	Unmodelled (BC/AD)						Modelled (BC/AD)						Indices:Amodel=84.6; Aoverall=86.8		
	from	to	%	from	to	%	from	to	%	from	to	%	Acomb	A	C
Sequence															
Boundary Start							-3526	-3392	68.3	-3567	-3382	95.4			97.7
Phase															
R_Date 205798	-3522	-3380	68.3	-3606	-3374	95.4	-3428	-3385	68.3	-3525	-3377	95.4		118.4	99.1
R_Date 205799	-3626	-3519	68.3	-3632	-3382	95.4	-3427	-3384	68.3	-3535	-3378	95.4		40.3	99
R_Date 205800	-3513	-3376	68.3	-3521	-3372	95.4	-3432	-3382	68.3	-3522	-3375	95.4		96.7	99
R_Date 205801	-3518	-3379	68.3	-3526	-3373	95.4	-3431	-3383	68.3	-3524	-3376	95.4		112.1	99.1
R_Date 205802	-3522	-3380	68.3	-3606	-3374	95.4	-3428	-3385	68.3	-3525	-3377	95.4		118.3	99.1
R_Date 205803	-3519	-3380	68.3	-3599	-3373	95.4	-3429	-3384	68.3	-3525	-3377	95.4		115.5	99
Span							0	33	68.3	0	141	95.4			97.6
Boundary End							-3418	-3370	68.3	-3520	-3336	95.4			97.4

The six dates from the trench predate the charred residue samples from pit 85 (Figure 5.2). AMS dates on pottery residues are less reliable than purified bone collagen because residues are “open systems” susceptible to old or new carbon contamination from sediment and groundwater sources (e.g., Roper 2013). Note that the residue dates have far larger standard errors. In addition, the charred residue samples were from a pit, not the G2 trench. Therefore, for the G2 trench, I believe the radiocarbon dates that were obtained from the aurochs bones were both more accurate and precise than dates from pottery residues.

To improve the interpretation of the occupation date for the G2 trench, I conducted a Bayesian analysis using the OxCal program (Ramsey 1995, 2001). In this investigation, six dates were chosen from aurochs bones found in the G2 trench. I grouped all dates as part of a single phase using the boundary function for the start and end. The phase is bracketed by two boundaries that generated age estimates for the beginning of the trench (Boundary Start) and the end of occupation (Boundary End). The span function is inserted to calculate the total span of the sequence.

For the Bayesian analysis of our dates, although UCIAMS-205799 has a poor agreement, the whole model shows good agreement between the radiocarbon dates and the phase modeling of the occupation of the site (Amodel = 84.6; Aoverall = 86.8) (Table 5.2). The model provides both start and end probability distributions for this feature at cal 3526-3392 BC and cal 3418-3370 BC at 68.3% probability, cal 3567-3382 BC and cal 3520-3338 BC at 95.4% probability (Figure 5.3). The estimated length of the occupation is 141 years, with a probability of 95.4%. The trench is predicted to have been used for 33 years if the probability is 68.3%, a figure that would be reasonable given that the dates obtained from the samples from the G2 trench fall within a wiggle on the radiocarbon calibration curve, which translates into highly bimodal probability distributions. This affects the estimation of duration (Figure 5.4). Given the results of our Bayesian modeling, we can say with some degree of confidence that the probabilities indicate the actual age range would reflect a relatively narrow time frame.

Although the results of radiocarbon dating suggest a narrow time span for the G2 trench, other sources of information, such as whether the bone assemblage was rapidly buried or subject to longer surface periods where attrition and scavenging could take place also need to be considered to develop a more comprehensive picture of bone deposition in the G2 trench.

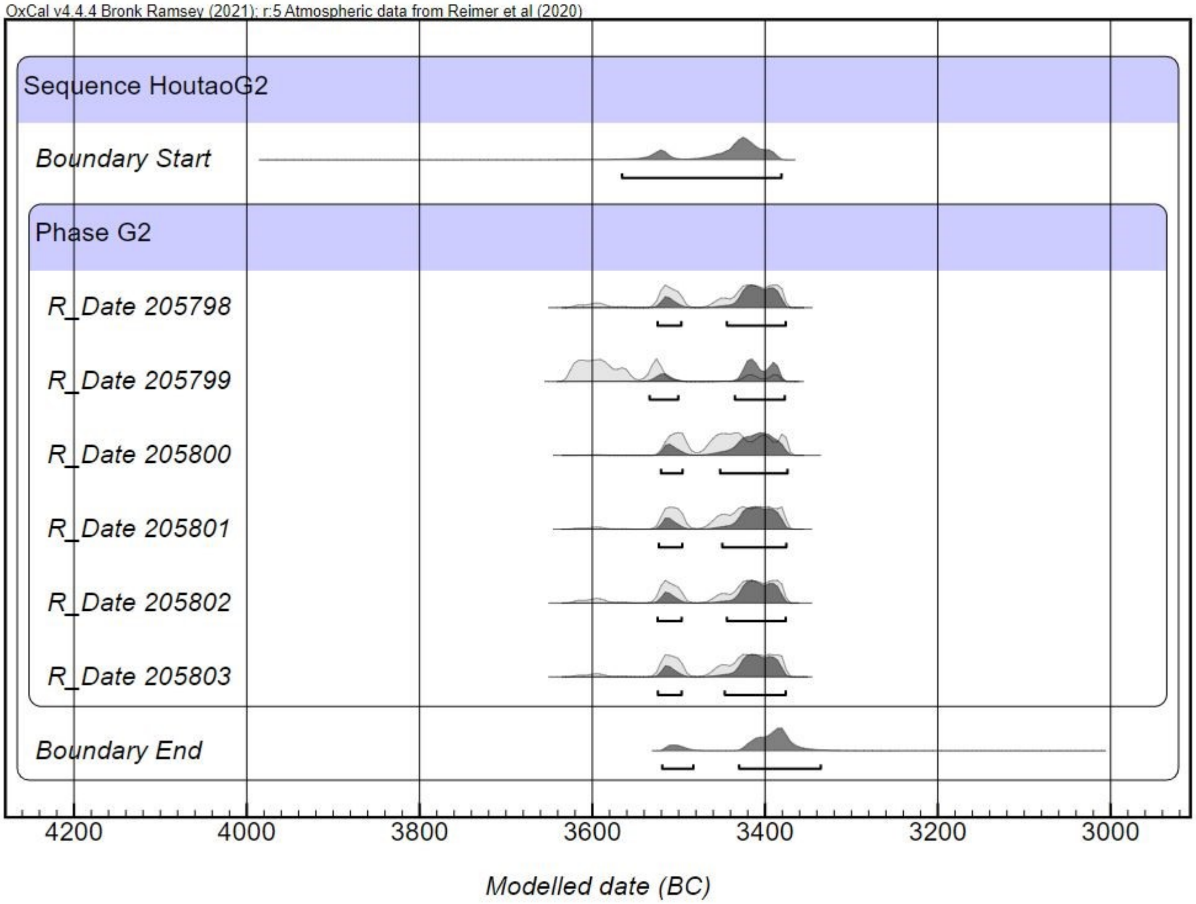


Figure 5.3 Results of the Bayesian model for G2 trench. Two distributions are plotted for each radiocarbon date: one in white with a black outline reflects the distribution based on simple radiocarbon calibration, and the other in gray reflects the posterior distribution on the basis of the chronological model used.

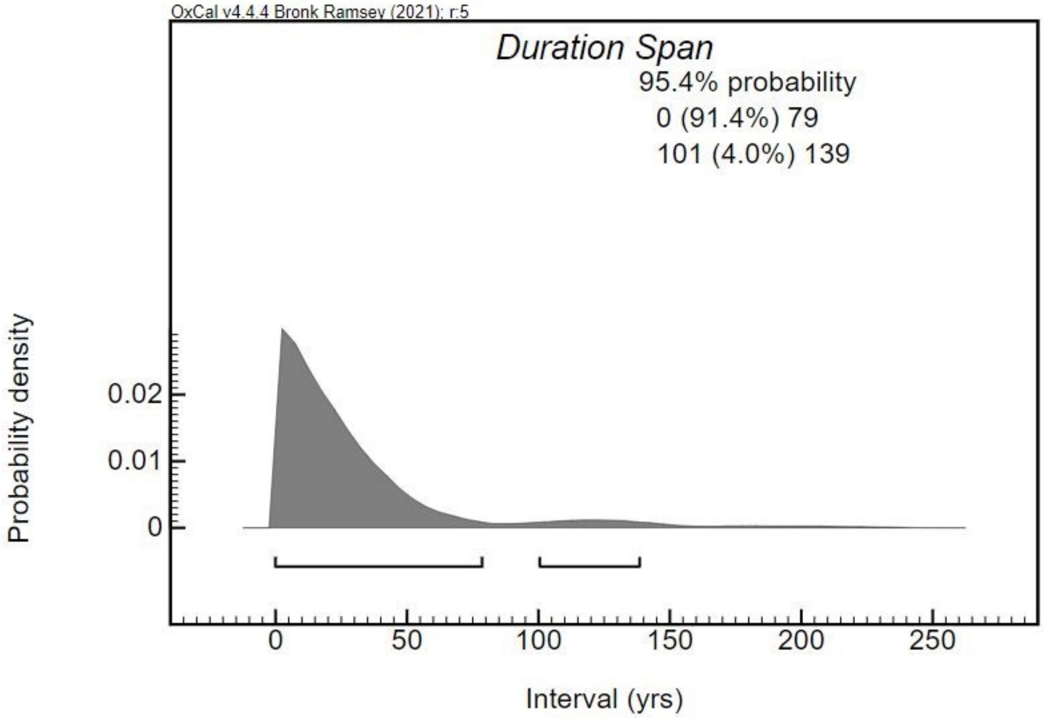


Figure 5.4 The estimation of occupation duration for the G2 trench.

The absence of vertical layering within the G2 trench suggests that for at least this segment of the entire trench, bone deposition took place all at once. That conclusion is reinforced by the absence of evidence for significant ravaging or weathering of the bone assemblage, also suggesting rapid and immediate burial. Consequently, it would be my suspicion that the actual time frame for deposition of these bones would be closer to the briefer end of the time range— that is, several years or conceivably, a single episode. As further excavation and analysis proceed for this Neolithic occupation of the Houtaomuga village, it will be important to see if the spatially separate segments of the G2 trench yield contemporaneous or detectably different ages for aurochs bones deposited there (as in Figure 1.2), and to see how G2 trench dates align with house pits both inside and outside the trenches.

Chapter 6: Zooarchaeological Study of Houtaomuga Aurochs

Aurochs (*Bos primigenius*) had been long considered an extinct species in the Holocene in China. Recently, the aurochs findings from several Neolithic sites in northern China have challenged this traditional opinion, bringing aurochs back to the front stage of archaeological research (Tang 2020). Although many aurochs remains have been uncovered in the latest excavations or re-identified from previous excavations, Houtaomuga is the first and only site in which researchers found a large number of aurochs bones in a single trench feature. According to an aDNA study (Cai et al. 2018), the Houtaomuga samples clustered within haplogroup C, which has been previously identified in other *Bos primigenius* remains from China (Brunson et al. 2016; Zhang et al 2013). However, in a recent study, Hou and his colleagues (2022) discovered that the bison haplogroup C from northeastern China is a profoundly divergent maternal bison lineage that is different from their counterparts from other regions; the basal mitochondrial lineage C is similar to the aurochs from northeastern China. This deep divergence also characterized extinct cave hyenas which were excavated from this region. These findings suggest that during Holocene, northeastern China may have served as a refugium for both species. This may explain the huge amount of aurochs bones discovered in Houtaomuga.

Based on the size and the morphology of bovid bones from Houtaomuga, they were originally identified as bison (*Bison exiguous*). Later, the genetic data indicated that (except for one specimen that is similar to the *Bos taurus* reference sequence) 23 of the 24 bovid remains from Houtaomuga were *Bos primigenius* (Cai et al. 2018). The Houtaomuga finding suggested aurochs were present in northeast China until at least 5000 cal BP, contradicting the notion that *Bos primigenius* had gradually become extinct in the Pleistocene. Here I reconsider the distribution of aurochs within the site, the role it played in human life, and assess the possibility of early domestication of aurochs in Houtaomuga.

6.1 Results of Applying the Log Size Index (LSI) Technique to Houtaomuga Aurochs

In total, a set of 429 values could be measured for aurochs remains from trench G2 at Houtaomuga. The size of aurochs long bones was compared against the measurements of a standard animal, a Danish female aurochs from Ullerslev. The Dabusu aurochs and a modern female cow were also plotted in the same scale to provide a broader comparison.

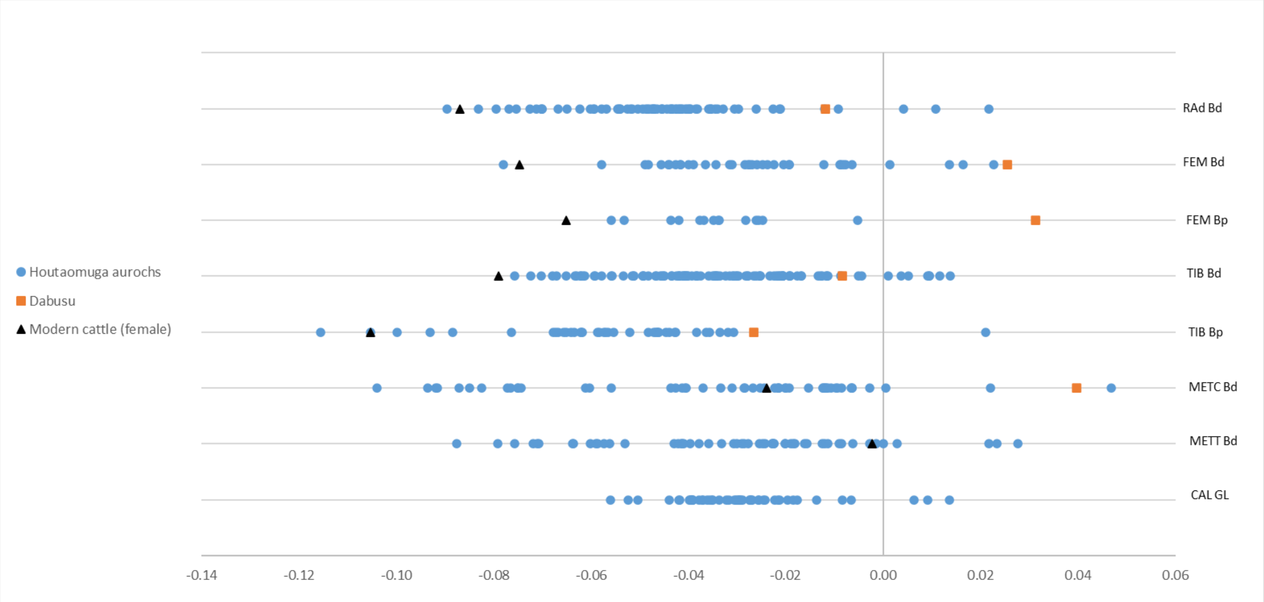


Figure 6.1 LSI values of Houtaomuga aurochs, Dabusu aurochs, and modern female cattle postcranial measurements using the Ullerslev aurochs as the standard animal.

Most of the values from Houtaomuga aurochs fall between the standard values and the modern female cow, suggesting that the Houtaomuga aurochs were smaller than both the European aurochs and Pleistocene aurochs in China. They were still bigger than the modern female cow, however (Figure 6.1). Whether these small-sized specimens represent the appearance of domesticated cattle at the site or reflect other factors impacting local wild aurochs variation — e.g., temperature change or sexual dimorphism — are the main issues discussed here.

6.2 Differentiating Cattle and Aurochs based on Sex Dimorphism

As there is distinct sexual dimorphism in bovid body size, sex is one of the factors that complicates archaeozoological determinations concerning remains from wild and domestic aurochs (Figure 6.2). The ratio of males to females of a certain species found in an archaeological site can influence our understanding of size diminution.

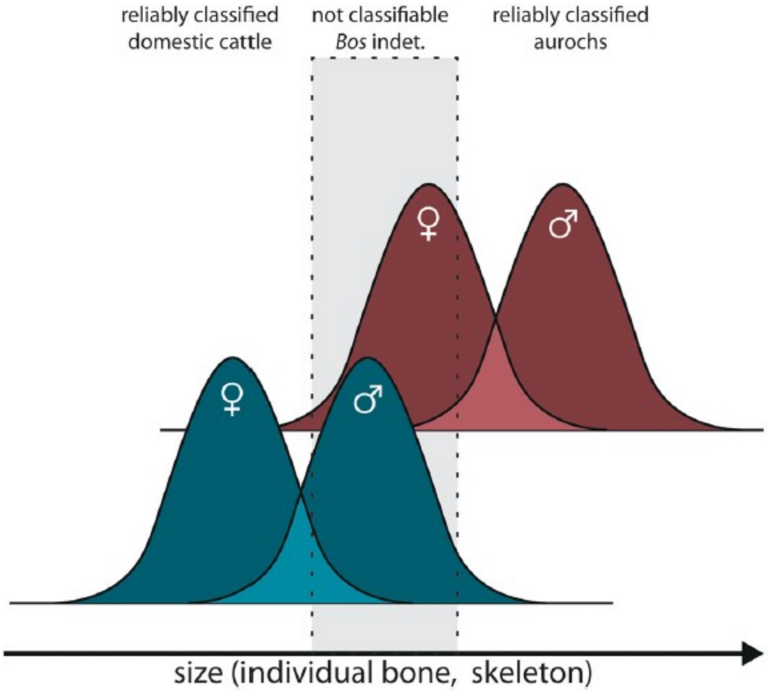


Figure 6.2 A schematic illustration of the general cattle identification problem in the Central European Neolithic (from Schmölcke and Groß 2020).

The measurements employed in the identification of male and female mammal bones have their basis in the sexual dimorphism inherent in some species. For example, male bison are typically 30-40% bigger than females (Brink 2008). Male caprines are similarly larger and heavier than females, and these differences are reflected in bone length, breadth, and depth dimensions (Fernández and Monchot 2007). Zooarchaeological evidence has shown that sexual dimorphism also existed in aurochs (Figure 6.3). Some researchers even initially described the two size groups as two different forms of *Bos primigenius* because of the tremendous sexual dimorphism (Grigson and Smith 1985; Pigott 1954). However, it became clear that the size differences represented the males and females of one form (Chazan and Horwitz 2007; Degerbøl and Fredskild 1970; Grigson 2017; Jewell 1962; Wright 2013).

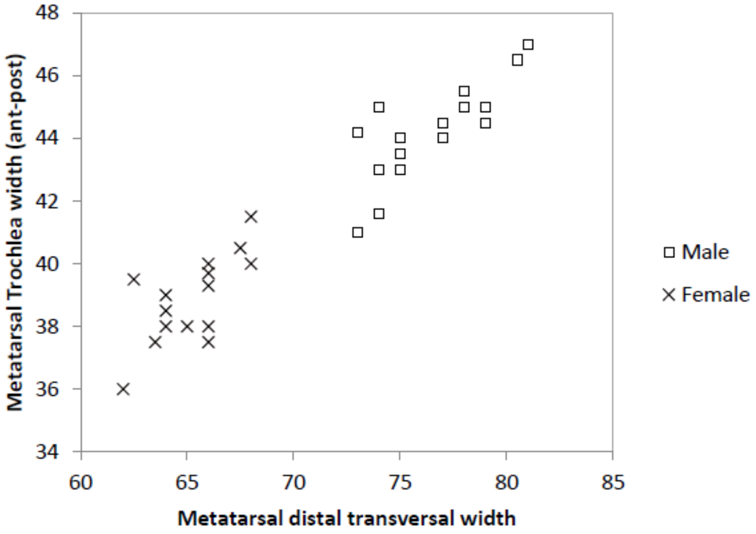


Figure 6.3 Measurements of the distal end of Danish aurochs metatarsals clearly showing two different clusters, interpreted as belonging to males and females (Degerbøl and Fredskild 1970; Wright 2013).

Since the early 1970s, researchers have developed a series of methods and measurements to use in sex distinction for bison bones (Bedford 1974; Duffield 1973; Peterson and Hughes 1980; Lewis et al. 2005; Morlan 1991; Reher 1973; Speth 1983; Walde 2004). Frison (1973) discovered a bimodal distribution of mature mandibles through the frequencies of jaw widths under the third molar. Volume measurements of the astragali were obtained by water displacement for sex identification in a study conducted by Zeimens and Zeimens (1974). Morlan (1991) demonstrated bimodality in many measurements of carpals and tarsals, suggesting that carpals and tarsals could also separate sex in large bison assemblages, although his findings have generally been ignored in analyses of sex composition.

Measurements used to identify long bones to sex have been applied by some researchers (Speth 1983). Metapodials were more likely to be useful in sex identification because of their better preservation, a situation resulting from their relatively low food value and comparatively high bone density (Bedford 1974; Duffield 1973; Lewis et al. 2005). Duffield (1973) proposed a method for sexing modern bison metapodials that relied on bivariate plots. He measured and calculated the distal width and the ratio of maximum element length and mid-shaft width in an effort to obtain two clusters in the bivariate plot that represented males and females. The results showed that some elements are better for sex identification than others, such as patellas, metapodials, and phalanges, although not all post-cranial elements were examined in his study. Speth (1983) also defined a method for separating males and females by plotting various long bone measurements against each other in a discriminant function analysis (DFA).

Neither the method proposed by Duffield (1973) nor the one from Speth (1983) can address the identification of more ambiguous individuals, like smaller males and larger females. To overcome the problem of the bivariate and ratio-based sexing methods, Lewis et al. (2005) introduced principal component analysis (PCA) for sexing bison metapodials and demonstrated that the best measurements to separate the sexes are distal width, mid-shaft width, and proximal width and breadth. This method requires that those partially preserved specimens be intact to at least the mid-shaft. This limitation made it inappropriate for bone collections with poor preservation. Walde (2004), on the other hand, developed a series of discriminant function equations applicable to the articular ends of long bones based on variables and measurements described by Speth (1983) to solve ambiguous identification. Phalanges were also employed in sex identification. Duffield (1973) demonstrated clustering by sex for the rear second phalanges with a graph of an index (width of proximal end divided by length) plotted against the width of the distal end, while Roberts (1982) developed a new equation she used to determine sexual designation through discriminant function analysis for phalanges.

Research on sex distinctions of aurochs bones is scarce because there are no modern specimens (Wright 2013). Recently, Schmölcke and Groß (2020) applied the LSI method as a tool for discrimination between aurochs and domestic cattle. Their analysis demonstrated the LSI width values are suited both for differentiating domesticated versus wild animals and sexes within the single groups. However, as they mainly focused on distinguishing cattle from aurochs, the process of identifying sex was not illustrated clearly.

In this study, following Schmölcke and Groß (2020), the LSI method is applied to obtain statistical data to identify any significant size difference between Houtaomuga aurochs and cattle. Kernel density estimates are another approach to identify underlying normal distributions, and the density plots based on that will represent a more visualized distinction within the single animal group.

A density plot represents the distribution of a numeric variable and the peaks of a density plot display where values are concentrated over the interval. Therefore, natural populations with extensive sexual dimorphism should provide bimodal distributions. For example, if *Bos* remains consisted purely of either aurochs or cattle, we could expect a bimodal distribution in the kernel density plot; otherwise, a mixture of cattle and aurochs would be expected to produce a pattern of three or multiple peaks.

To test this assumption, I used the published data from Degerbøl (1970) to obtain size and sex values for cattle and aurochs. For the length of bones, I use only the GL (Greatest length) measurements of humerus, radius, femur, tibia, calcaneus, metacarpal and metatarsal, as well as GLl (Greatest length of the lateral part) of the astragalus. For width, I include either Bp (Greatest breadth of the proximal end) or Bd (Greatest breadth of the distal end) of the humerus, radius, femur, tibia, calcaneus, astragalus, metacarpal and metatarsal. I collected 158 and 50 LSI values for the width of aurochs and cattle, while for the length, the number of LSI values reached 219 in aurochs and 42 in cattle.

The density plots of aurochs show that both width and length values represent a bimodal distribution (Figure 6.4-6.7). The width values only provide light shoulders primarily because data for female aurochs were too small. When the plot combines cattle and aurochs, the width values show a pattern of multiple peaks, whereas length appears to be quite a reliable measurement for differentiating male and female, exhibiting three peaks.

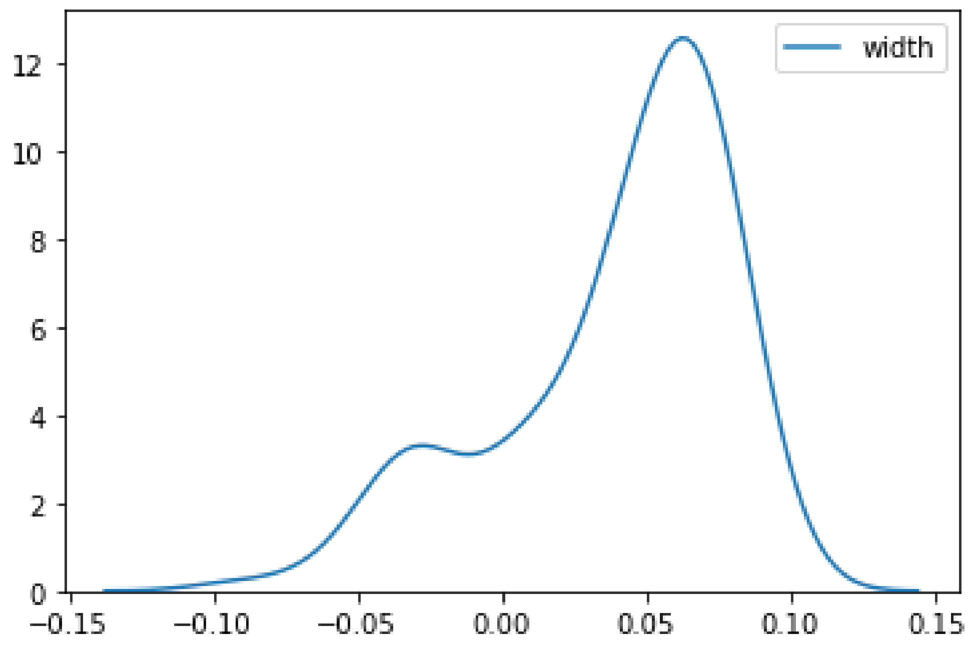


Figure 6.4 Density plot of LSI values for the width indices of Degerbøl aurochs (118 males, 40 females).

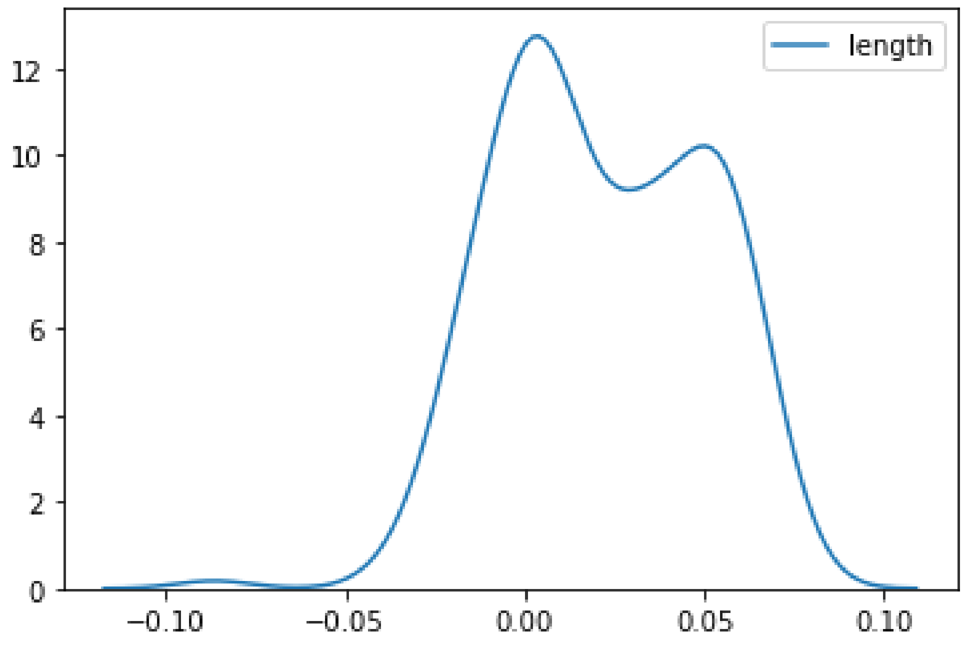


Figure 6.5 Density plot of LSI values for the length indices of Degerbøl aurochs (136 male, 83 females).

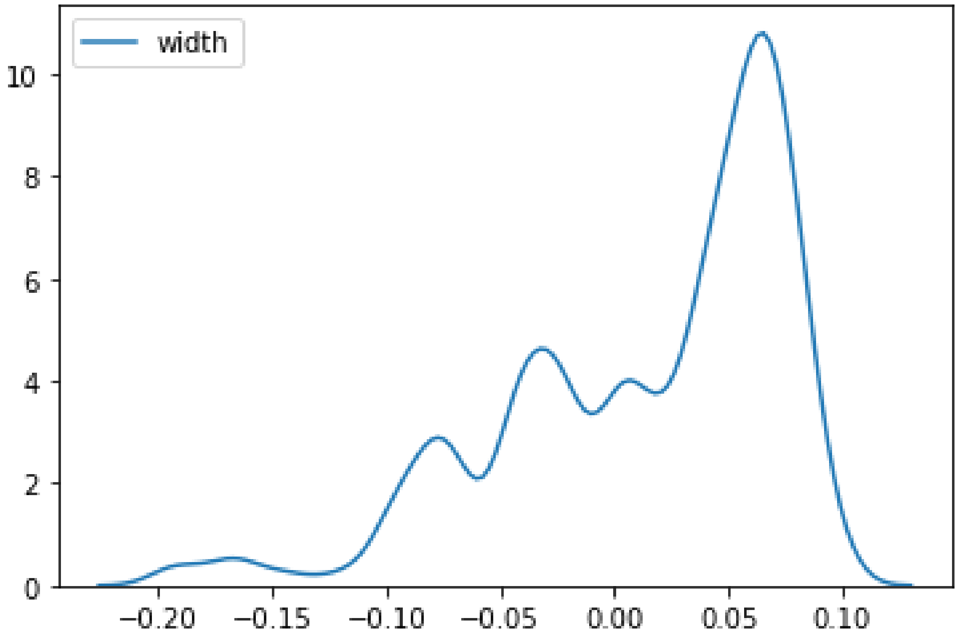


Figure 6.6 Density plot of LSI values for the width indices of Degerbøl aurochs and cattle (118 males and 40 females for aurochs, 34 males and 16 females for cattle).

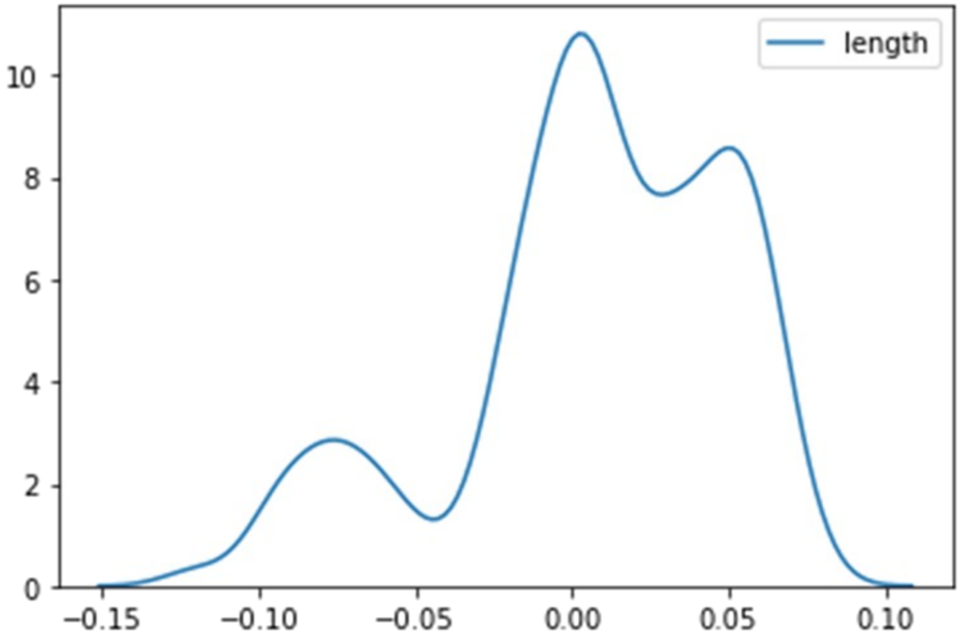


Figure 6.7 Density plot of LSI values for the length indices of Degerbøl aurochs and cattle (136 males and 83 females for aurochs, 28 males and 14 females for cattle).

In the case of bones from aurochs and cattle, the LSI method and kernel density plot seem to be an appropriate approach to provide good indications for sex discriminations. However, it should be noted that this method can only present the ratio of males to females within the single animal group; the degree of overlap means that the precise proportion of the sexes will still be unknown.

For the sex analysis of aurochs from Houtaomuga, I used the measurements of Bp of the femur and tibia, Bd of the femur, tibia, metacarpal and metatarsal as the width values. For the length values, only GL values of the calcaneus are included because almost no complete limb bones were discovered in Houtaomuga (except for two metacarpals and one metatarsal). Both width and length values show a tendency to be unimodal with light shoulders, suggesting an unbalanced sex ratio for aurochs at Houtaomuga (Figure 6.8-6.9). The concentration on negative values may indicate a greater proportion of female individuals in the Houtaomuga aurochs population.

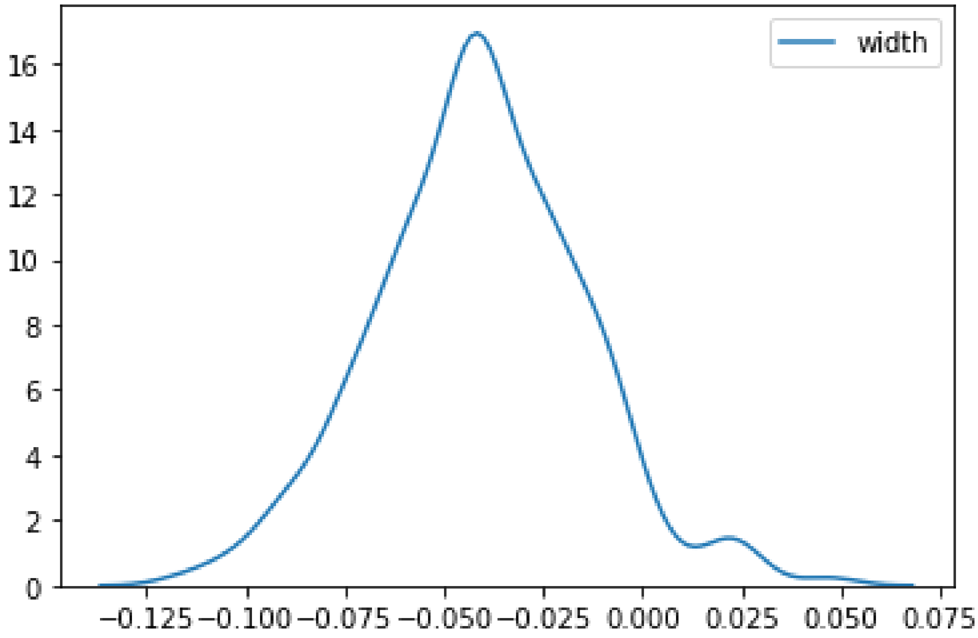


Figure 6.8 Density plot of LSI values for width indices of Houtaomuga aurochs.

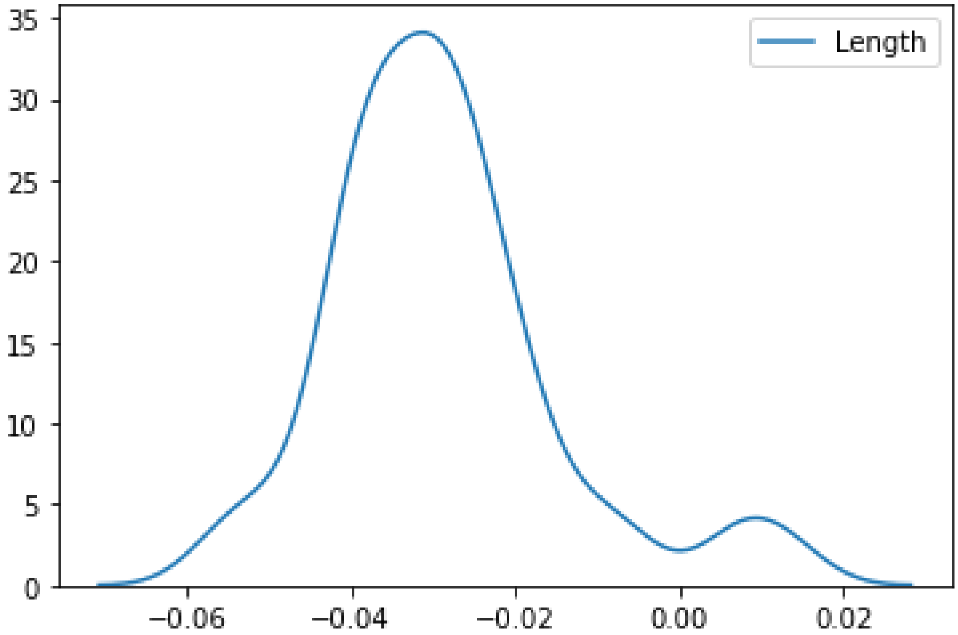


Figure 6.9 Density plot of LSI values for length indices of Houtaomuga aurochs.

6.3 The Evidence for the Possible Aurochs Domestication in Houtaomuga

6.3.1 Climate

Temperature shift could cause a size change of mammals as well. This pattern was first described by Bergmann when he proposed that within a broadly distributed taxonomic clade, populations and species of larger size are found in colder environments, while populations and species of smaller size are found in warmer regions. Most bird and mammal species follow this rule, although there are some debates about the validity of it (Ashton et al. 2011; Meiri and Dayan 2003).

Many mammal species underwent a size decline during the Pleistocene-Holocene transition. In Israel, abundant fossil gazelle and fox data indicate that their size diminution coincided with the temperature elevation at the end of the Pleistocene (Davis 1981). African aurochs, like their European cousin, experienced a size reduction during the Pleistocene-Holocene transition (Linseele 2004). There is a strong possibility, however, that some other factor such as food availability – itself resulting from a change of temperature – had an additional effect, so that temperature change should be considered as a strong factor in body size change in the mammal species.

The high lake level of Chaka Salt Lake resulting from the increased moisture during the late glacial indicates a warmer temperature in Northwest China at the Pleistocene-Holocene transition (Liu et al. 2008). Mineral-magnetism measurements of lake sediments recovered from Haoluku and Liuzhouwan also reveal that the environment began to ameliorate gradually after 13500 yr BP on the southeastern Inner Mongolia Plateau (Wang et al. 2001). It is reasonable to assume that size diminution that was influenced by temperature change also affected aurochs and this resulted in the appearance of smaller sized aurochs at Houtaomuga.

6.3.2 Kill-off Pattern

Animal domestication is defined as multi-generational control of animal breeding that results in detectable changes in genetics, morphology, and behaviour (Zeder 2006, 2012, 2015). Although the reduction in body size in domestic animals has been attributed to a variety of causal mechanisms, change in body size is the most widely used marker of animal domestication (Bökönyi 1974; Meadow 1986; Uerpmann 1978; Tchernov and Horwitz 1991; Zohary et al. 1998). Changes in body size during the domestication process have been confirmed in most mammals (Hongo et al. 2009; Manning et al. 2015) and have therefore become one of several potential markers of domestication. Changes observed in size and morphology, however, are in many cases subtle and often allow multiple interpretations. Diminishing body size also requires a temporal series in the data, to reveal a trend connected with domestication. In recent studies, shape and genetic changes become more reliable markers. Therefore, it is necessary to examine the faunal remains with a different approach to provide multiple lines of evidence, in order to see whether the size difference is the consequence of human intervention or a natural process.

One approach to determine whether domesticated animals were present in a human subsistence system is through the examination of the slaughter pattern. Different kinds of exploitation strategies will generate different age-of-slaughter distributions for domestic animals in zooarchaeological assemblages (Greenfield 2005).

Payne (1973) provided three hypothetical harvest profiles for ovicaprids. He proposed that meat production is characterized by larger slaughter numbers for young adults when they reach the optimum weight, while milk production requires a massive killing of very young lambs; if wool production is the aim, the mortality profile will be characterised by frequent slaughtering of both males and females.

Although Payne's theoretical models are commonly used in zooarchaeological analysis, other types of management strategies can be taken into consideration to improve and refine the models. Vigne and Helmer (2007) proposed a late slaughtering for meat model that has animals predominantly of aged 12-24 months. Another model for milk exploitation without slaughtering of the very young lambs was also added based on the observation from Kurdish semi-nomads of northern Khorassan.

Both epiphysial fusion and tooth eruption/wear are useful in constructing mortality profiles. However, tooth-based age construction provides a better dimension for mortality profiles since bone fusion is complete by the age of four. Thirty Houtaomuga mandibles are available to establish an age profile from tooth eruption sequence and wear stages.

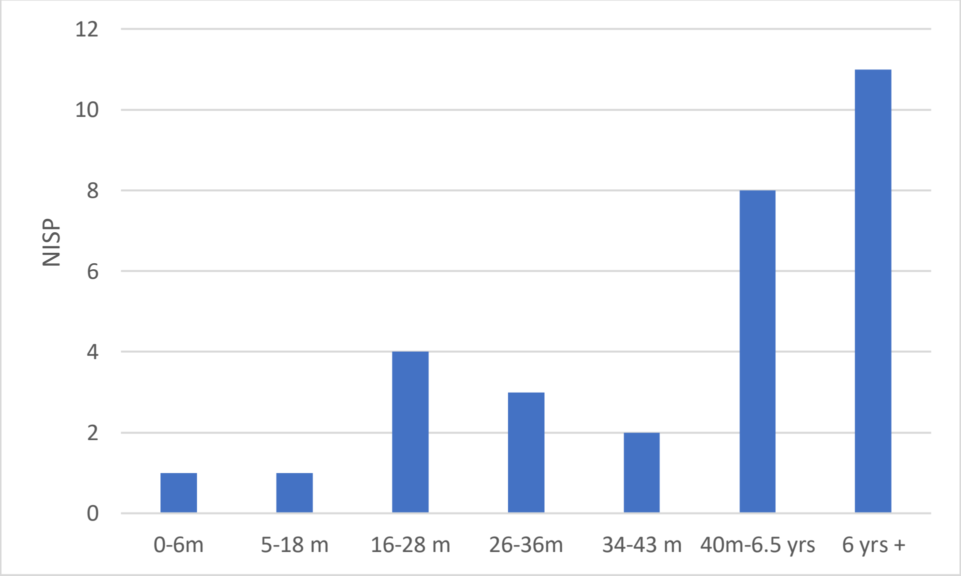


Figure 6.10 Mortality pattern of Houtaomuga aurochs.

According to the tooth eruption and wear data, more than 60% of the aurochs from Houtaomuga survived into late adulthood, which would not be expected if the dominant herding strategy was efficient meat production (Figure 6.10). If the primary goal was for cattle dairy production, the slaughtering profiles should represent a peak for 4 to 8 years old cows on the one hand, and a post-lactation slaughtering peak (5-9 months) on the other hand (Vigne and Helmer 2007). Although the mortality profile in Houtaomuga showed a slaughtering peak after 4 years, the kill-off rate for young calves (less than 18 months) is low. Therefore, the slaughtering pattern of Hougaomuga aurochs is not consistent with these two production forms, suggesting no intentional human selection for meat or dairy production.

6.3.3 Stable Isotope Results

The stable isotope analysis of archaeological skeletal tissues has developed quickly since the first published study in 1977 (Vogel and van der Merwe 1977). Multiple elements, such as C, N, H, O, and Sr, have been applied in different forms of archaeological research to resolve specific issues. Carbon and nitrogen isotope ratios, because of their advantage in reconstructing diets, became important evidence in interpreting the process of animal domestication.

Table 6.1 shows the isotopic data of the different animal species samples from the G2 trench. The preservation of bone collagen in the Houtaomuga samples was good. The quality of preserved collagen was assessed by comparing the collagen yield, C%, N% and atomic C/N ratio of each sample with standard ranges (DeNiro 1985; van Klinken 1999). Of the bone samples, all produced acceptable C%, N% and C/N ratios measurements according to the standard ranges. Collagen yields were variable. Most samples yielded high collagen (higher than 2%) and four samples are a little lower, between 1-2 %. Only one sample yielded less than 0.5% collagen by weight. As the collagen yield of sample HT 18 is only 0.3%, much lower than the standard range, it was rejected for this research. The four samples yielding between 1% to 2% collagen produced C%, N% and C/N ratio within acceptable ranges and have therefore been included with the others in this study.

Table 6.1 Species and isotopic data for G2 trench samples from Houtaomuga.

Sample #	Species	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	%C (%)	%N (%)	C/N	Yield
JHT01	dog	-18.3	10.2	44.2	16.0	3.2	2.8%
JHT02	dog	-19.2	9.2	44.1	16.0	3.2	6.8%
JHT03	dog	-18.7	8.9	44.1	15.8	3.3	2.3%
JHT04	dog	-17.7	9.1	43.9	15.8	3.2	1.6%
JHT05	dog	-17.7	10	43.4	15.6	3.2	1.2%
JHT06	dog	-17.7	9.8	43.6	15.8	3.2	6.2%
JHT07	dog	-16.3	10	43.1	15.7	3.2	5.5%
JHT08	dog	-17.3	9.2	43.5	15.8	3.2	4.1%
JHT09	dog	-16.7	9.1	43.7	15.8	3.2	1.9%
JHT10	dog	-18.1	10	44.3	16.3	3.2	7.4%
JHT11	dog	-20.4	8.1	42.8	15.3	3.3	3.8%
JHT12	dog	-20.3	9.5	44.8	16.2	3.2	6.4%
HT1	roe deer	-20.4	5.3	47.2	17.0	3.2	2.8%
HT2	roe deer	-20.3	5.0	47.1	17.2	3.2	4.0%
HT3	roe deer	-20.4	5.1	47.3	17.0	3.2	2.5%
HT4	sika deer	-19.6	6.5	47.0	17.1	3.2	1.5%
HT5	roe deer	-20.9	6.4	46.3	16.8	3.2	2.8%
HT6	roe deer	-19.9	5.9	46.6	16.7	3.3	2.2%
HT7	sika deer	-19.0	5.6	47.4	17.3	3.2	3.2%
HT8	roe deer	-20.4	5.4	44.8	15.8	3.3	0.3%
HT9	aurochs	-15.4	7.9	46.6	16.6	3.3	2.2%

HT10	aurochs	-16.3	7.5	48.1	17.5	3.2	6.3%
205798	aurochs	-15.7	7.7	42.2	15.5	3.2	6.2%
205799	aurochs	-14.5	7.5	41.7	15.3	3.2	9.8%
205800	aurochs	-15.5	7.5	42.4	15.4	3.2	3.2%
205801	aurochs	-16.4	8.2	43.1	15.8	3.2	2.7%
205802	aurochs	-15.9	6.9	43.3	15.9	3.2	6.2%
205803	aurochs	-15.3	7.4	42.2	15.4	3.2	3.6%

Aurochs bone, dog bone and cervid bone specimens were selected from Houtaomuga for stable isotope analysis (Figure 6.11). The isotopic levels of carbon and nitrogen do not significantly differ between roe deer and sika deer. Cervids' relatively low $\delta^{13}C$ values (mean = -19.8‰ ± 0.8‰, n=7) suggest that they eat primarily C_3 plants, which implied the dominance of C_3 plants in the vegetation around Houtaomuga. Cervids were wild animals with little interference from humans. As a result, they can serve as somewhat of an indicator species showing Houtaomuga's surrounding vegetation. Furthermore, according to a phytolith study from Honghe Neolithic site, C_3 Poodieae dominated the vegetation in the Nenjiang River Basin (Leng et al. 2019), supporting the notion that Houtaomuga is situated in a region dominated by C_3 plants.

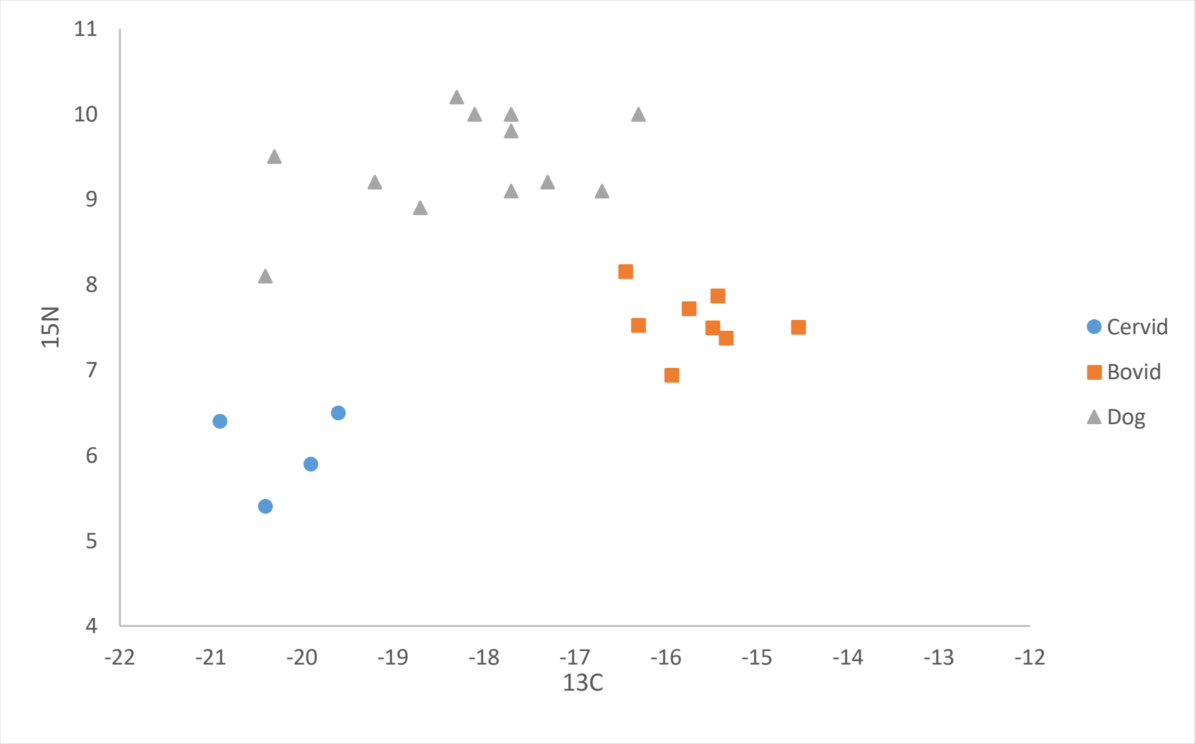


Figure 6.11 δ^{13}C and δ^{15}N values for faunal bone collagen from Houtaomuga site.

Aurochs have the highest carbon isotopic values, ranging between -16.4 and -14.5‰ (mean = -15.7 ± 0.6‰), indicating a mixed C_3/C_4 diet. Aurochs nitrogen isotopic values are between 6.9 and 8.2‰ (mean = 7.6 ± 0.4‰), which is higher than cervids but lower than dogs. Stewart et al. (2003) proposed that δ^{13}C and δ^{15}N differed significantly among species and indicated differences in moisture regimes within habitats and types of forages through the dietary niche examination of mule deer, North American elk, and free-ranging cattle. Therefore, the difference in carbon and nitrogen isotopic values between aurochs and cervids observed from Houtaomuga could be the result of occupying separate habitats.

The stable isotope studies for bovid bones from other Neolithic sites in north and northeast China provide valuable comparative data for interpretating the higher δ^{13}C and δ^{15}N values observed in Houtaomuga (Figure 6.12). Bovids from Baijia, Shengedaliang, Dongying, Kangjia, Buzishan and Honghe showed similar carbon isotopic values to Houtaomuga. The Bajia bovid remains were identified as an extinct water buffalo (*Bubalus mephistopheles*) genetically. Although the possibility of human provisioning cannot be ignored, their preference for specific habitats, such as river floodplains, marshes and swamps, which are ideal areas for wild millet and other C_4 weeds, may account for the elevated bulk $\delta^{13}C$ values. The water buffalo reported from Dongying and Kangjia also showed a similar pattern, suggesting they were likely supplementing their diet with millets and other C_4 weeds. At Shengedaliang site, the $\delta^{13}C$ values of the pigs ranged from -9.5‰ to -7.2 ‰, reflecting a typical C_4 plant-based diet. Contrarily, cattle had lower $\delta^{13}C$ values than pigs with a more varied C_3/C_4 diet. According to Chen et al. (2017), the two distinct methods of raising them – shelter feeding and free foraging – may be indicated by the different diets between them. Ma et al. (2014) reported that certain bovid samples from Buziping had quite high $\delta^{13}C$ values, indicating that these bovids had some C_4 plants mixed into their diets. They may have eaten the leftover stubble in untended fields, made use of wild millet or they may have been provisioned with C_4 plants. According to a recent study, aurochs from the late Neolithic component (ca. 4500-4000 cal BP) of the Honghe site in western Heilongjiang had $\delta^{13}C$ values that were higher than those of other species, indicating that they had a diet richer in C_4 plants than other animals (Liang et al. 2023). Liang et al. (2023:11) nevertheless found that those Honghe occupants relied on the exploitation of freshwater fish and wild terrestrial game without millet horticulture. They inferred that higher $\delta^{13}C$ values for late Neolithic aurochs at Honghe likely resulted from naturally occurring C4 species found in wet land habitats.

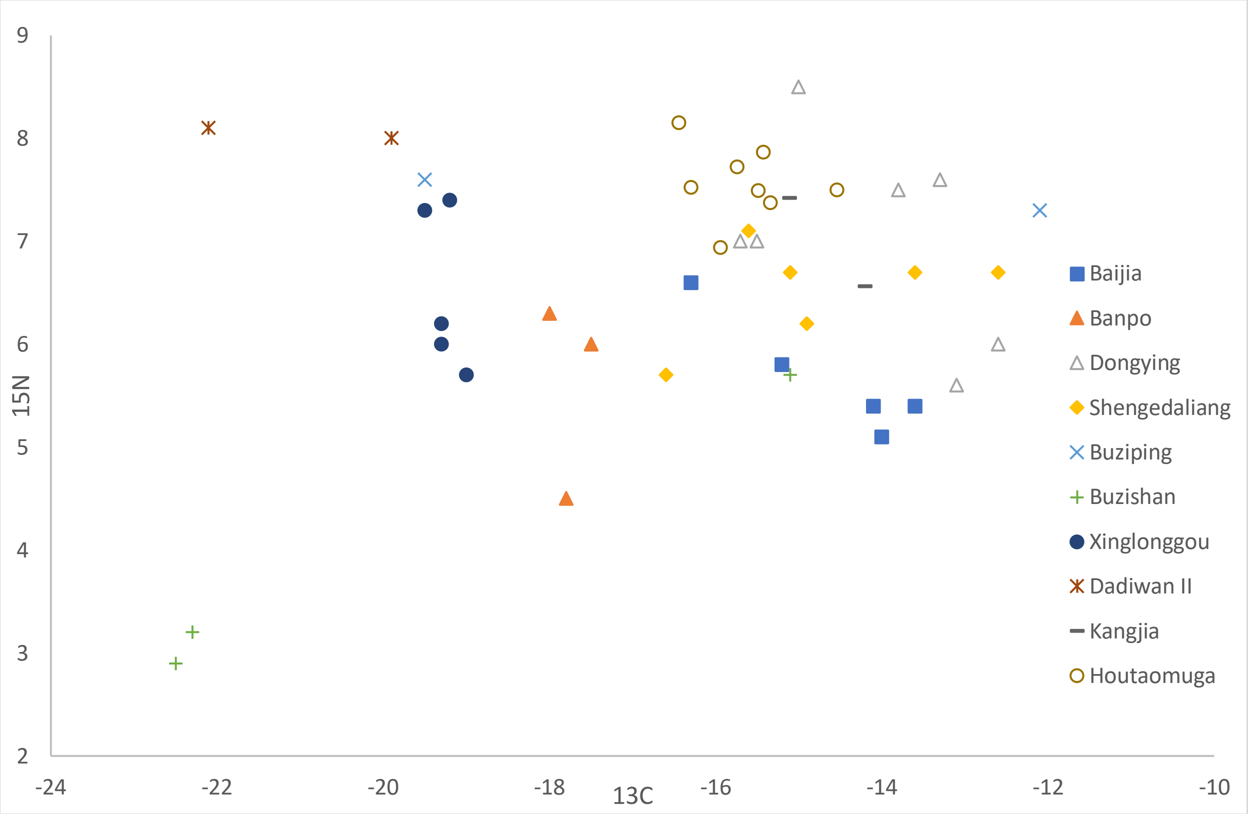


Figure 6.12 δ^{13}C and δ^{15}N values for bovid bone collagen from Neolithic sites in north and northeast China.

The abundance of C_4 plants in the environment may influence the enrichment of carbon and nitrogen isotopic value in herbivores. A change in the frequency of C_3 and C_4 grasses appears as the most likely reason in interpreting rapid shifts in animal size. For example, a dramatic decrease in bison body size during the Late Quaternary in North American was considered to be the result of the spread of the C_4 ecosystem during the early Holocene (Lewis et al. 2010). Studies of the natural occurrence of C_4 species, life forms, and their longitudinal distribution patterns along the Northeast China Transect (NECT) showed that saline meadows, as is the case for the location of Houtaomuga, had the highest number of C_4 species (Figure 6.13). Phytolith analyses and data on the stable carbon isotope composition of sand-palaeosol sediments of northeast China also indicate that the abundance of C_4 species has been increasing in the Songnen grasslands due to the continuous weakening of the East Asia Summer Monsoon (EASM) since the mid-Holocene. Considering the environment and landscape, C_4 plants may have been relatively common near the Houtaomuga site, although C_3 vegetation was still dominant. Therefore, while the Houtaomuga aurochs display features connected with a mixed C_3/C_4 diet, it is most likely the result of consuming (or perhaps being provisioned with) wild C_4 plants (including millet) at Houtaomuga, even though the site's inhabitants relied upon hunting and fishing rather than horticulture for their subsistence.

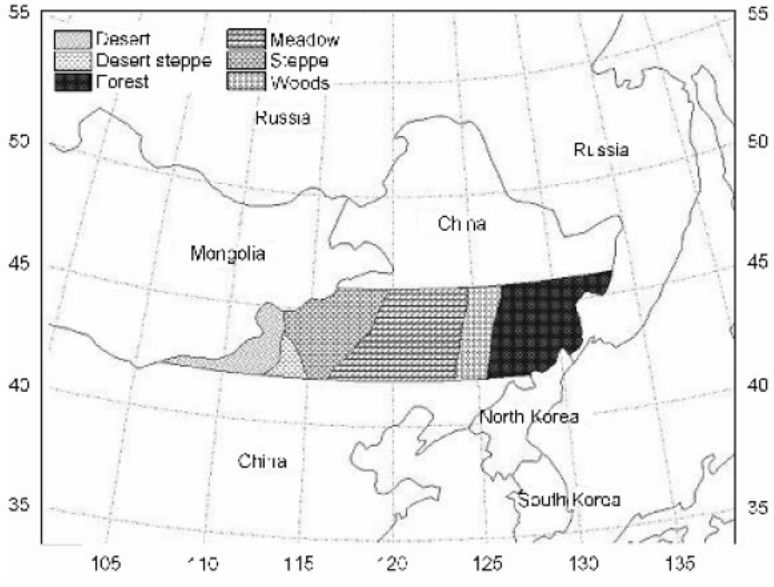


Figure 6.13 Location of the Northeast China Transect (NECT) and vegetation division (Wang 2004).

Most dogs display a similar C_3-based diet (JTL02, JTL11 and JTL12). However, several dogs show a mixed C_3/C_4 diet, indicating that the dogs may in part have been provisioned with millet or, more likely, some consumed animal products that have higher $\delta^{13}C$ and $\delta^{15}N$ values. According to some research (Cannon et al. 1999; Tsutaya et al. 2014), the consumption of marine fish or mammals will increase the isotope value of dog bones since they have higher values of $\delta^{13}C$ and $\delta^{15}N$ than terrestrial mammals. Could the intake of freshwater resources, which are abundant at Houtaomuga owing to its location next to two sizable lakes and the abundance of fish and shellfish bones that have been discovered there, be the cause of some dog bones' elevated $\delta^{13}C$ and $\delta^{15}N$ values? Hesslein et al. (1989) reported that *Salvelinus. namaycus* (lake trout) had a high $\delta^{15}N$ value of 13.9‰ ± 0.5‰, but a relatively low $\delta^{13}C$ value of -27.5‰ ± 1.8‰. According to Cook et al. (2001), significant freshwater fish consumption has been shown to increase human $\delta^{15}N$ values while decreasing collagen $\delta^{13}C$ values at the sites of Lepenski Vir and Schela Cladovei (Iron Gates) along the Danube River. Although Guiry (2019) proposed that freshwater resources could create considerable variation in $\delta^{13}C$ and $\delta^{15}N$ values depending on season and local environmental conditions, a common pattern for archaeological interpretations is that lower $\delta^{13}C$ and higher $\delta^{15}N$ values in human or animal remains are evidence of a reliance on freshwater resources (Bonsall et al. 1997; Cook et al. 2001; Hedges and Reynard 2007). The greater $\delta^{13}C$ and $\delta^{15}N$ values in dog bones may suggest that freshwater resources are not the only factor in the diet of dogs, even though their influence cannot be fully disregarded. On the other hand, aurochs, another important source of meat and protein at Houtaomuga, which had a characteristic of C_3/C_4 diet in $\delta^{13}C$ and $\delta^{15}N$ values, would have the potential to contribute significantly to the pattern of dog's isotopic values. Therefore, it is logical to assume that freshwater resources and aurochs both contributed to the isotopic pattern in dog bones.

6.4 Summary

LSI values showed the size of most of the aurochs bones from Houtaomuga are smaller than the European aurochs and Pleistocene aurochs from northeast China. A large proportion of females in the whole population may contribute to the appearance of smaller aurochs at

Houtaomuga; however, the large number of negative values indicate that most Houtaomuga aurochs are even smaller than the standard animal – a female European aurochs, suggesting that sex is not the only factor in size difference for aurochs from Houtaomuga.

Size change is often considered as a trend accompanying domestication. Despite this, the mortality profile for Houtaomuga aurochs shows no indication of intentional human selection for meat or dairy production. Although the carbon and nitrogen isotopic values indicate a mixed C_3/C_4 diet, the C_4 plants colonizing the expansive distribution of marshes and lake edges near the site may account for the elevated isotopic values of the aurochs.

The mechanism behind the size change was undoubtedly complicated. It is conceivable that the smaller size of the Houtaomuga aurochs resulted from incipient forms of herd management. The data are not definitive in this regard, however, and it was more likely a temperature change during the Pleistocene-Holocene transition, observed in many regions in the world, that was primarily responsible for the size decline in aurochs from Houtaomuga. That being said, further investigation of the smaller aurochs size at Houtaomuga is certainly warranted, and the possibility of early human herd management should not be ignored in future research.

Chapter 7: Faunal Assemblage and Taphonomy at Houtaomuga

This chapter presents the analysis of faunal remains from Houtaomuga, with a focus on the remains from G2 trench and the house features in the 4th stage. There is limited faunal diversity for mammal bones in the G2 trench and the house features. Aurochs is the dominant species in both the G2 trench and house structures (both inside and outside the trench). The distribution of other species was examined separately in the context of G2 trench and the house features. Taphonomic processes, which are important in reconstructing subsistence patterns and paleoecological conditions, are discussed here based on the analysis of bone density mediation, weathering, butchery marks, thermal modifications, bone survivorship, articulated units, skeletal completeness, and meat weight estimation.

7.1 Faunal Species Distribution

A total of 9,765 bones from trench G2 and 4,373 bones from the house features were identified to the lowest taxonomical category possible based on comparative analysis with the modern animal skeleton sample from the Zooarchaeology Laboratory from Jilin University. All soil has been screened for microliths and small animal remains. Aurochs dominate the assemblage in both trench G2 and the house features; however, aurochs represents 90.82% of the sample in trench G2, but only 34.53% of the sample from the assemblage in the house features (Table 7.1 and 7.2).

Table 7.1 The NISP and MNI value of different animal species in the G2 trench.

Common Name	Latin Name	NISP	%NISP	MNI	%MNI
Korean field mouse	*Apodemus peninsulae*	4	0.04	2	1.30
Transbaikal zokor	*Myospalax psilurus*	6	0.07	1	0.65
Unknown rodent	*Rodentia*	2	0.02	1	0.65
Hare	*Lepus*	54	0.60	6	3.90
Siberian weasel	*Mustela sibirica*	1	0.01	1	0.65
Racoon dog	*Nyctereutes procyonoides*	70	0.78	9	5.84
Asian badger	*Meles leucurus*	16	0.18	4	2.60
Eurasian lynx	*Lynx lynx*	0	0.00	0	0.00
Fox	*Vulpes*	5	0.06	3	1.95
Felid	*Felidae*	0	0.00	0	0.00
Dog	*Canis familiaris*	296	3.31	13	8.44
Unknown canid	*Canidae*	34	0.38	1	0.65
Bear	*Ursidae*	0	0.00	0	0.00
Water deer	*Hydropotes inermis*	0	0.00	0	0.00
Siberian roe deer	*Capreolus pygargus*	24	0.27	4	2.60
Sika deer	*Cervus nippon*	18	0.20	1	0.65
Elk	*Cervus canadensis*	24	0.27	1	0.65
Unknown deer	*Cervidae*	16	0.18	1	0.65
Sheep/goat	*Ovis aries/ Capra aegagrus hircus*	1	0.01	1	0.65
Wild boar	*Sus scrofa*	247	2.76	12	7.79
Aurochs	*Bos primigenius*	8123	90.82	92	59.74
Horse	*Equus*	3	0.03	1	0.65
Total		8944		154	

Table 7.2 The NISP and MNI value of different animal species in the house features.

Common Name	Latin Name	NISP	%NISP	MNI	%MNI
Korean field mouse	*Apodemus peninsulae*	56	1.28	11	4.40
Transbaikal zokor	*Myospalax psilurus*	108	2.47	17	6.80
Unknown rodent	*Rodentia*	34	0.78	9	3.60
Hare	*Lepus*	278	6.36	25	10.00
Siberian weasel	*Mustela sibirica*	13	0.30	4	1.60
Racoon dog	*Nyctereutes procyonoides*	567	12.97	55	22.00
Asian badger	*Meles leucurus*	108	2.47	12	4.80
Eurasian lynx	*Lynx lynx*	12	0.27	2	0.80
Fox	*Vulpes*	32	0.73	8	3.20
Felid	*Felidae*	1	0.02	1	0.40
Dog	*Canis familiaris*	784	17.93	26	10.40
Unknown canid	*Canidae*	128	2.93	7	2.80
Bear	*Ursidae*	1	0.02	1	0.40
Water deer	*Hydropotes inermis*	3	0.07	2	0.80
Siberian roe deer	*Capreolus pygargus*	114	2.61	7	2.80
Sika deer	*Cervus nippon*	4	0.09	1	0.40
Elk	*Cervus canadensis*	47	1.07	3	1.20
Unknown deer	*Cervidae*	8	0.18	1	0.40
Sheep/goat	*Ovis aries/ Capra aegagrus hircus*	3	0.07	1	0.40
Wild boar	*Sus scrofa*	480	10.98	24	9.60
Aurochs	*Bos primigenius*	1510	34.53	30	12.00
Horse	*Equus*	82	1.88	3	1.20
Total		4373		250	

7.1.1 Relative Species Abundance (excluding aurochs)

To compare the difference between animal species representation in G2 trench and the house features, all the animal bones were counted in NISP and MNI (Table 7.1 and 7.2). Aurochs bones constitute a great proportion of the faunal assemblage, especially in G2 trench, where more than 90% of animal bones were from aurochs. Therefore, aurochs were not involved in this analysis in order to represent the residual abundance of other animals.

With that proviso, dog was the dominant species in both the G2 trench and the house structures, representing 36.05% and 27.38% of samples respectively (Figure 7.1). Boar is the second most abundantly identified animal in G2, while in the house features, it is racoon dog. Although dog is the dominant species, the high ratio of wild animals in both areas suggested that wild game played a significant role in Houtaomuga subsistence and economy. The percentage of rodent bones in the house features is higher than in G2, and this is probably the result of the attraction of much more food storage and refuse in houses.

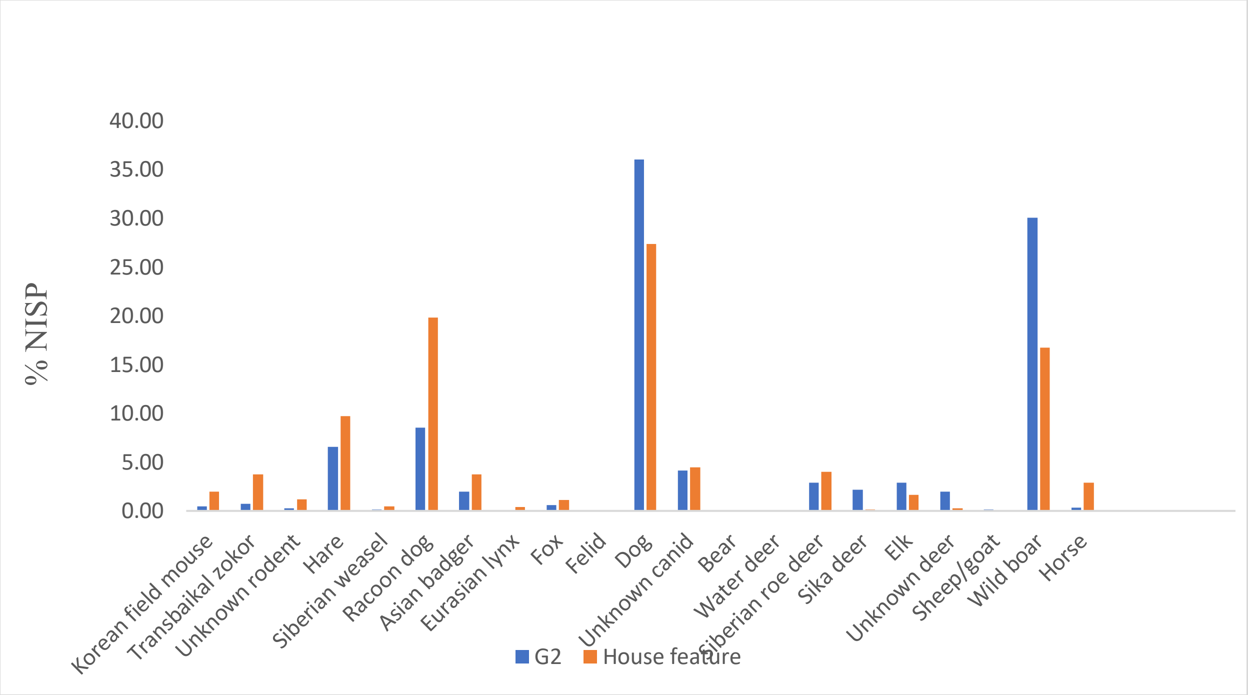


Figure 7.1 NISP distribution in different species (aurochs is not included) from G2 trench and the house features.

7.1.2 Calculating MNE Value with Landmarks and in GIS Overlapping Method

Table 7.3 shows the MNE values of aurochs long bones based on different approaches. Except for tibia, there are no significant differences in the same element between MNE values coming from landmarks and GIS. Calculating MNE through landmarks on bones ignores the side information; this improves the counting of specimens that can be identified in elements but cannot be distinguished by side. For example, it is easy to identify a metapodial based on the distal epiphysis, but the side information is often lost because of the difficulty in distinguishing medial and lateral condyles. In contrast, GIS is a stronger tool for counting fragments that can be recognized by element but present no landmarks. This is especially significant for shaft fragments since most of the identifiable landmarks are concentrated in the two ends, and it is also a possible reason for the larger number of tibia revealed when using the GIS method.

Table 7.3 MNE values derived through different approaches.

	Landmark	GIS
Humerus	180	177
Radius	133	146
Metacarpal	116	102
Femur	111	108
Tibia	120	162
Metatarsal	116	100

MNE values used for revealing element representation in this chapter come from landmark calculations since the GIS method was only applied for the limb bones. Meanwhile, because the GIS method has great advantages in visualization, it is utilized in representing bone preservation and survivorship in limb bones.

7.2 Weathering

Bone weathering is defined as chemical or mechanical decomposition and destruction occurring on bones over time. Behrensmeyer (1978) described six bone weathering stages on the basis of observing bone samples that were placed in six major habitats in the Amboseli Basin of southern Kenya. She proposed that weathering can provide information about the duration bones have been exposed to weathering agents. Lyman and Fox (1989) argued that weathering data cannot directly reveal the formation duration since the weathering process is influenced by various factors, and it is difficult to control all the agents in archaeological studies.

Although it is unreliable to infer exposure time solely on the degree of bone surface weathering, it can still provide important evidence for distinguishing a single episode of bone deposition. For example, a unimodal bone weathering distribution probably indicates the occurrence of one kill event, while a multimodal result would represent attrition from daily consumption (Lubinski 2011; Todd 1993).

Based on Behrensmeyer's description of weathering stages, in this research I divided the aurochs' bones from G2 into three categories: light, medium, and heavy. Lightly weathered bones show either no cracking or a little longitudinal cracking on the bone shaft and mosaic cracking on the articular surfaces; medium weathering shows long thin flakes on the outermost bone; and in the heavy weathering stage, most of the outermost bone is gone, the fibrous texture appears, and some of the bone may even crumble.

The preservation of most of the aurochs bones from the G2 trench at Houtaomuga is good and only shows light weathering (96.8%), while medium and heavy surface weathering is scarce (1.8% and 1.4% respectively). The weathering pattern from house features is similar with that from trench — 89.1% of aurochs bones show light weathering, and only 10.7% and 0.03% show medium and heavy weathering. The unimodal pattern suggests that burial in anthropogenic sediments was rapid in G2. Many bones show heavier weathering in certain areas rather than in the whole bone (Figure 7.2). This inconsistency in the degree of weathering may relate to the specific way aurochs were processed and cooked.

Figure 7.2 Weathering stages for the Houtaomuga bone assemblage:

1. Light; 2. Medium; 3. Heavy.

7.3 Carnivore Marks and Rodent Gnawing

The identification of tooth marks on bones has allowed zooarchaeologists to document the presence of carnivores and rodents in the formation and modification bone assemblages. The distribution and percentages of tooth marks have also been used to evaluate the degree and order of intervention of carnivores and rodents in faunal assemblages.

Both carnivore and rodent tooth marks are rare on the aurochs bones from G2 trench; only 0.3% and 0.2% of bones show evidence of carnivore and rodent modification, respectively. This percentage increases in bones from the house features. Carnivore marks increased to 3.8%, and the rodent marks percentage reached 2.1%, indicating that carnivores and rodents probably had more access to aurochs bones in the houses than in G2 trench. This implies that the treatment of aurochs bones from the trench and those from the houses may differ. The G2 bones were buried quickly, which reduced the chances of gnawing or ravaging.

7.4 Butchery Marks

Four percent of aurochs bones show evidence of butchery (n=351). The percentage of butchery marks in trench G2 is quite low when compared to modern experimental frequencies (Blumenschine 1995; Soulier and Costamagno 2017). Cut marks are present in the highest frequencies, followed by percussion marks (Figure 7.3). The location of most cut marks was concentrated at the articular ends or the process and facet that attaches with muscle and tendons, indicating that the marks were made during disarticulation. Saw marks, which were probably created by rope or leather with an abrasive, only appear on incisors to separate the tooth root and crown for making bone pendants.

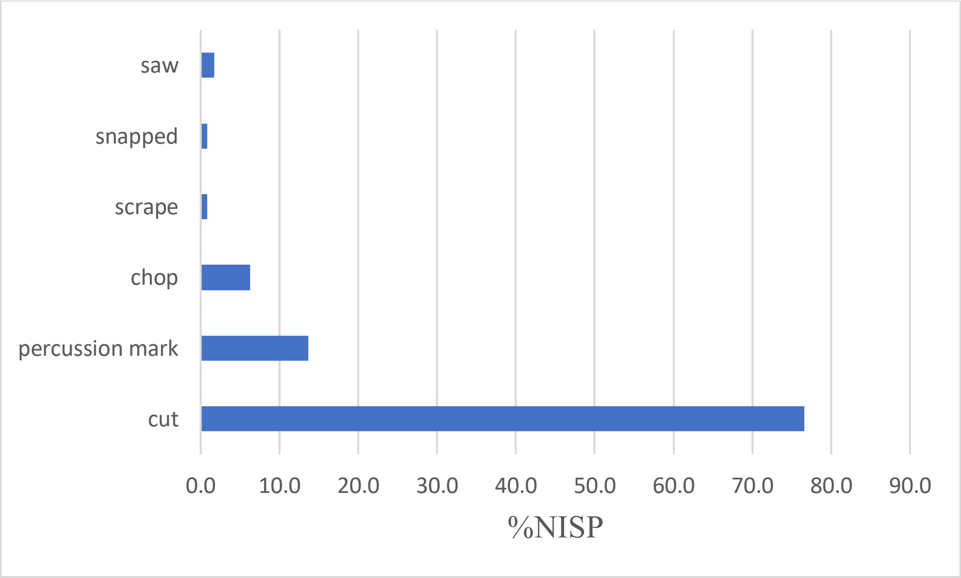


Figure 7.3 Frequency of human surface modifications from G2 trench and house features.

7.5 Thermal Alteration

Approximately 6.2% of the aurochs bones from G2 trench had some degree of burning. Except for one pelvis, which showed a heavy burning intensity, 82.8 % of the affected bones were in the light burning stage, while 17.0% were in the medium stage. Figure 7.4 shows the number of bones in the aurochs' skeleton that had frequent burning marks. Some elements with more meat, such as ribs and vertebrae, have a lower frequency of burning, indicating that meat was probably not a significant factor in selecting which element would be exposed to heat. In contrast, a higher percentage of burning evidence is concentrated in limb bones, especially metapodials, which are relatively rich in marrow but of the least utility for meat consumption. This suggests a preference for marrow.

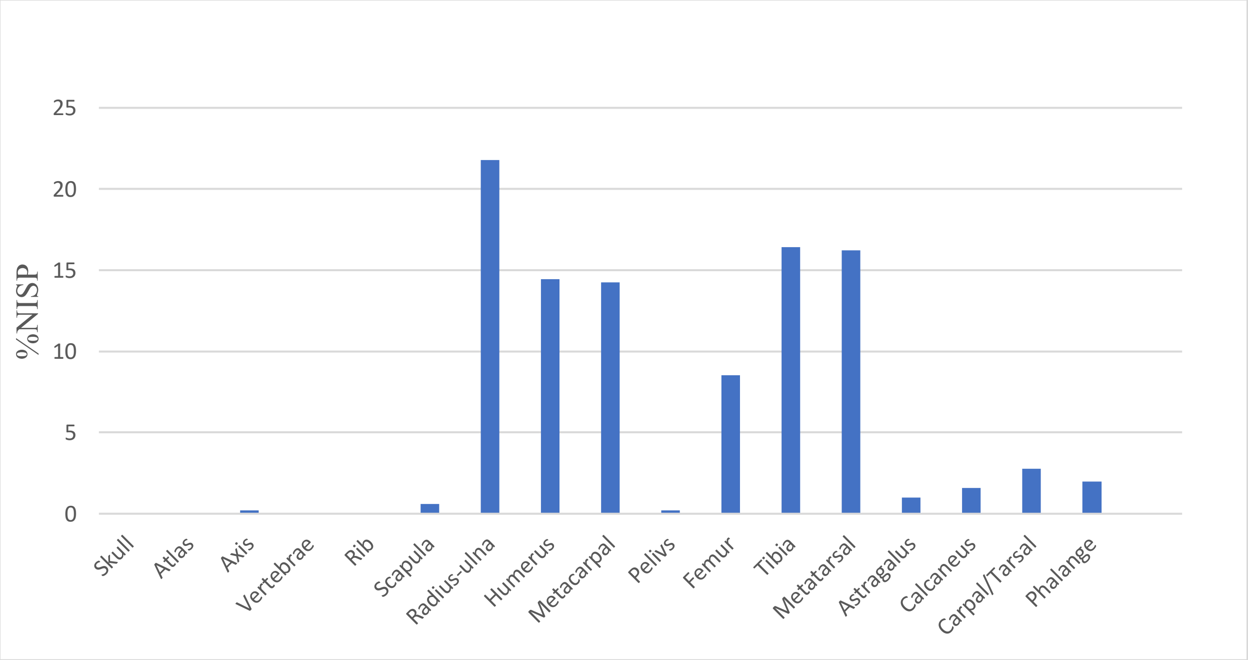


Figure 7.4 Thermal alteration percentage in different elements of aurochs.

The location of burning marks on long bones is suggestive of the technique that was applied in marrow extraction at Houtaomuga. Figures 7.5-7.6 show that most heat-induced alteration in limb bones occurred on the bone shaft, where most bone breakage took place. Because it is important to have a flat surface of the bone on the anvil in order to strike an optimal surface during bone breaking, the breakage pattern is not random. According to the experimental study by Moclán and Domínguez-Rodrigo (2018), (1) the humeri exhibit a pattern which the percussion marks are concentrated only on mid-shafts; (2) the radii-ulnae show the preferential blows on the cranial side and display a pattern in which the majority of marks appear on the central section of the shaft; (3) in the case of femora, the central section of the shaft received the most blows but these show no clear preferential pattern for side; and (4) the middle of the tibial shaft, particularly on the lateral and caudal sides, tends to have the largest number of percussion marks. The distribution of burning marks on long bones from Houtaomuga exhibits a similar pattern to that from bone breakage, indicating that heating on bones may be related to bone breaking. Moreover, some burning marks on the bone shaft display light brown scorching. Similar scorching marks are also found on gopher mandibles at the NAN Ruin in New Mexico, and on cottontail mandibles at Albert Pueblo in the San Juan Basin (Badenhorst 2008; Shaffer 1992). Experimental studies and ethnographic literature reveal that light scorching marks result when whole rodents or small mammals are roasted in fires, because the thin meat of the lips and cheeks is incinerated quickly (Henshilwood 1997; Szuter 1989, 1994). Light scorching marks are also found on limb bones from large ungulates at Houtaomuga, and the mechanism behind these burning marks may be similar. Meat or fascia were likely still attached to the limb bones during roasting, resulting in this type of burning.

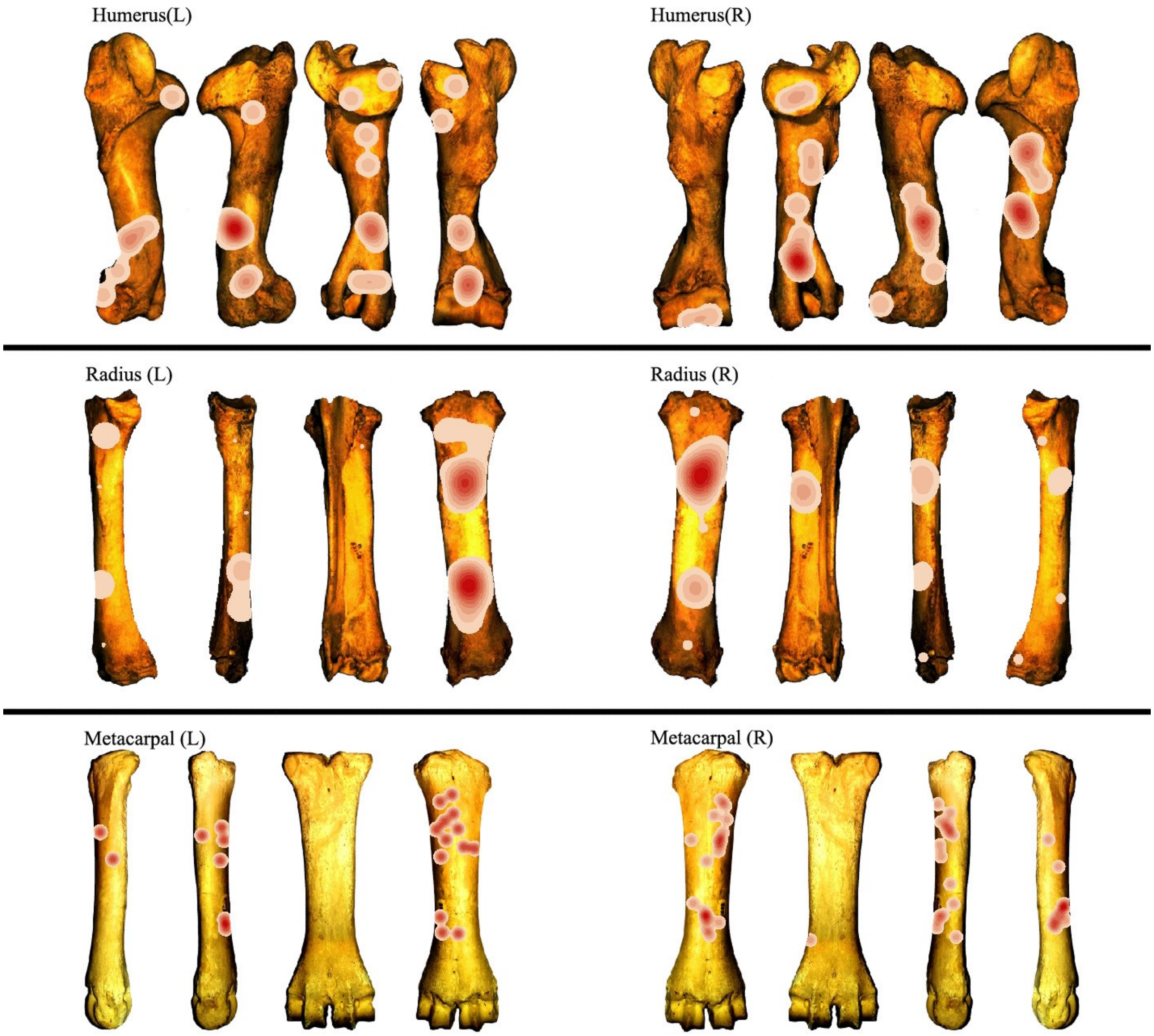


Figure 7.5 GIS Kernel density analysis results of burn mark distributions on humerus, radius, and metacarpal bones (dark red areas indicate the highest concentrations of burning marks).

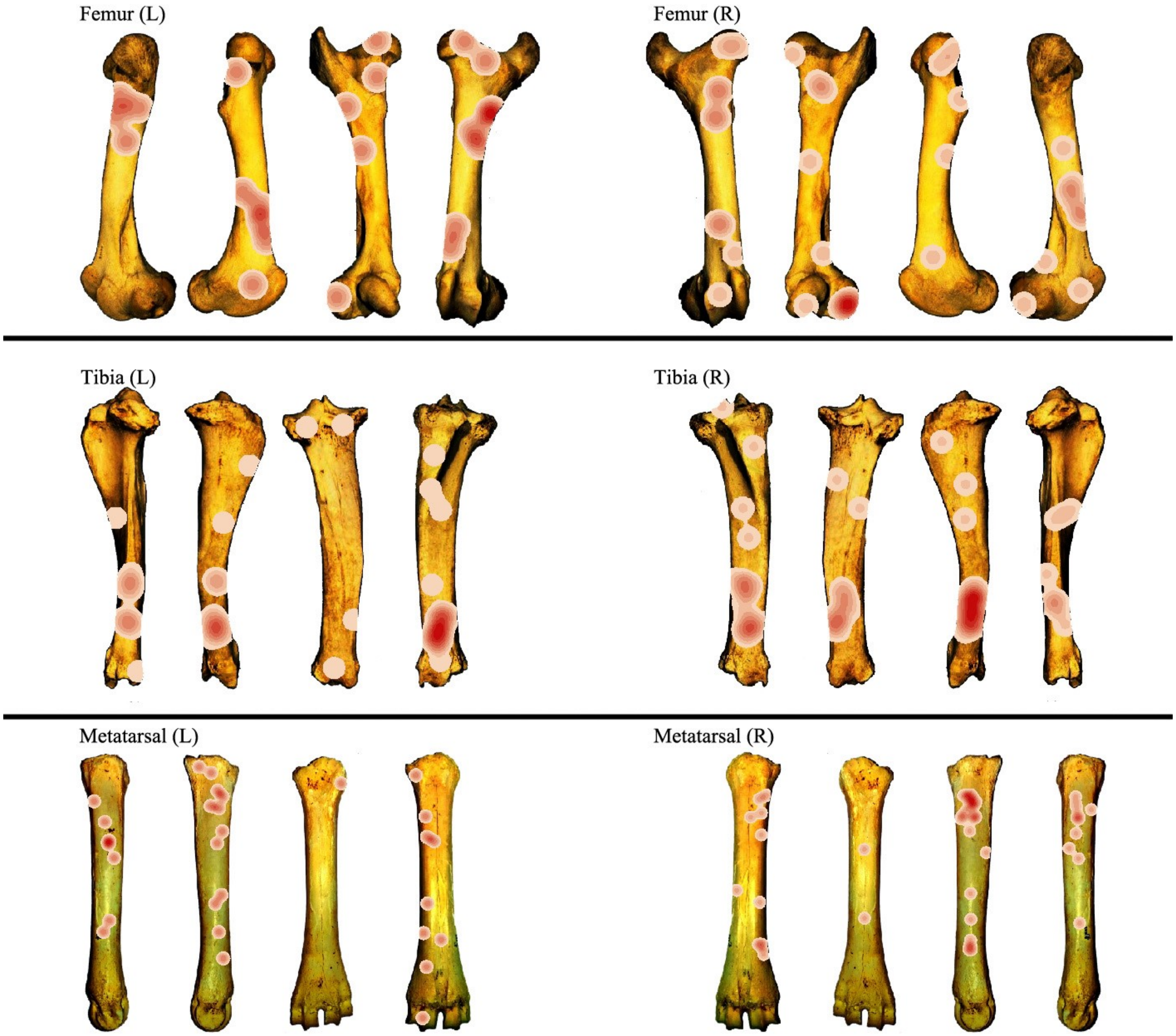


Figure 7.6 GIS Kernel density analysis results for burning mark distribution on femur, tibia, and metatarsal bones (dark red areas indicate the highest concentrations of burning marks).

7.6 Bone Fracture

Only limb bones such as the humerus, radius, metacarpal, femur, tibia, and metatarsal (which are rich in marrow and fat) were selected in this section. I followed the criteria from Outram (1998), and recorded the scores of fracture outline, angle, and texture for all the specimens.

A total of 948 long bone ends were used in the fracture analyses. Figure 7.7 shows the number of fragments from trench G2 at Houtaomuga that reach each of the fracture freshness index (FFI) scores. The mean FFI score for the assemblage is 1.01; scores of zero dominate but scores of one to five were also represented. This suggests that most fractures occurred on fresh bones, and that this fragmentation pattern is likely due to marrow extraction. The frequent representation of scores from one to five indicates that some fractures may occur on dry bones that had lost nutritional value. Based on the burning marks I observed on the long bones, this could be the result of heating bones prior to fracture.

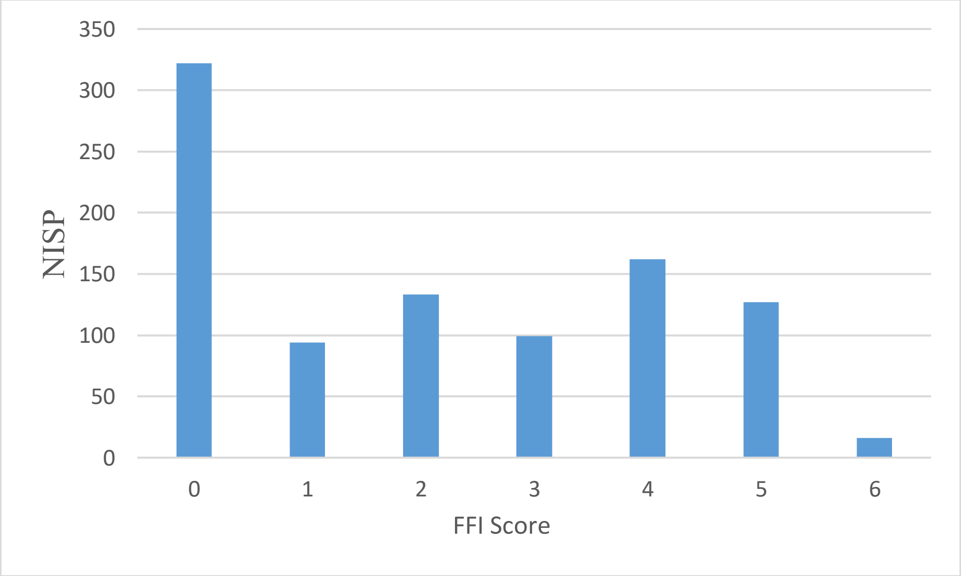
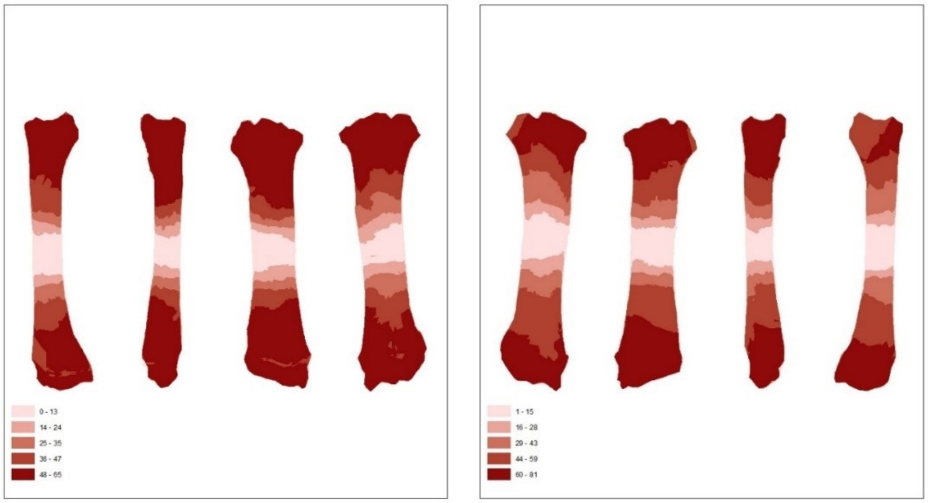


Figure 7.7 A histogram showing the number of FFI scores for aurochs long bones.

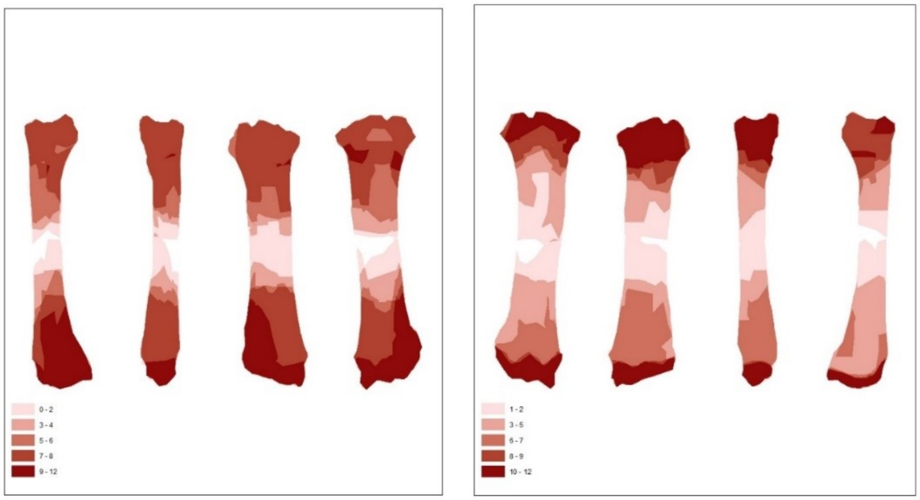
7.7 Bone Portion Survivorship

Figure 7.12 shows the images of the GIS-generated maps of bone portion survivorship for limb bones of aurochs from trench G2 and the house features. Bone preservation in the limb bones shows a tendency for better preservation in the proximal and distal epiphyses than in the middle shaft in both trench G2 and the house features. Although the lack of identifiable landmarks on the diaphysis may result in the poor representation of bone shafts, the techniques which humans used to process the long bones may contribute to this pattern as well. It is likely that humans at Houtaomuga would break the long bone in the middle with a hammerstone or other tool in order to access the marrow inside the bone, making the middle shaft split into smaller pieces that would be more difficult to identify. Although the preservation rate of humerus heads is low in both the trench and houses (perhaps because they have lower bone density and are more prone to damage during the excavation and transportation), the proximal and distal ends of other long bones are well preserved, implying that the demand for grease was not so urgent that humans needed to further smash the spongy parts of the bone for degreasing through boiling.

Although aurochs bones from G2 and the house features share a great similarity in bone portion preservation, some distinctions can be observed for certain parts (Figure 7.8-7.13). For example, the proximal ends of the radii and tibiae and the distal ends of the femurs from G2 trench are well preserved, but these parts from the house features are sometimes destroyed. This is consistent with the higher frequency of gnawing marks that were identified in the house features rather than in G2 trench, suggesting that dogs or other carnivores had more access to bones in the house than in the trench.



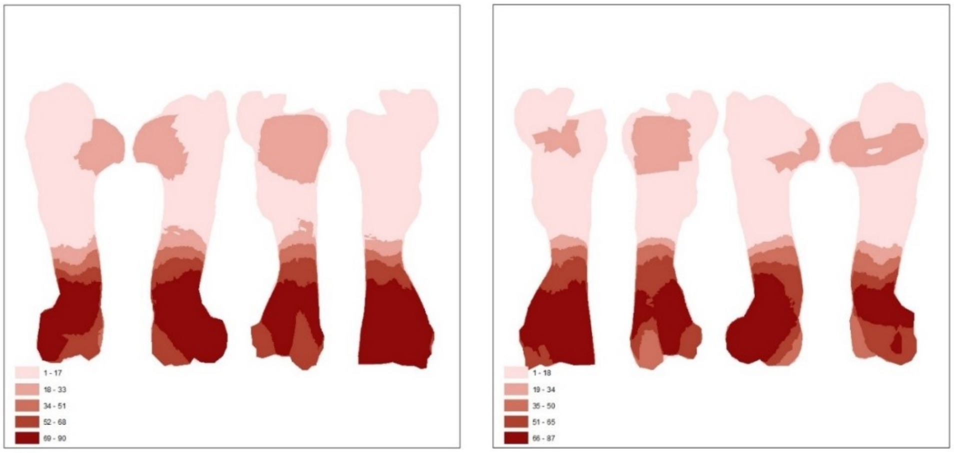
Radius Left (G2) Radius Right (G2)



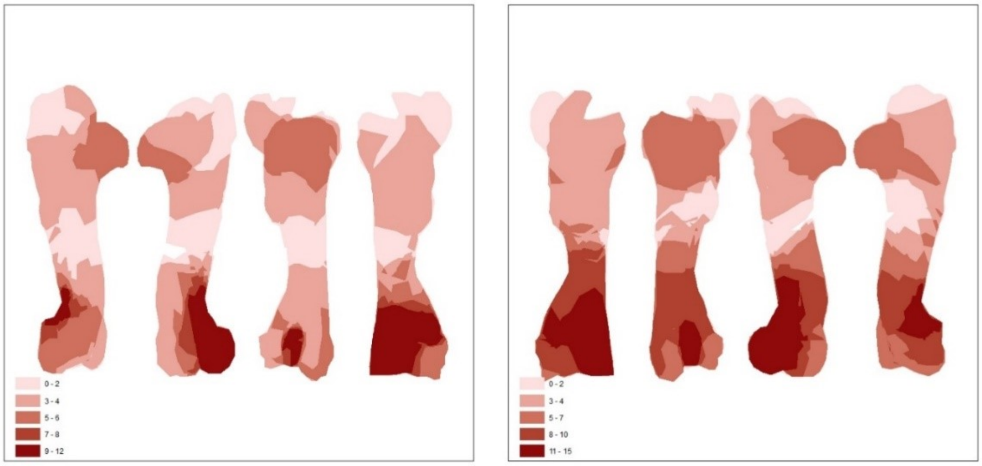
Radius Left (House) Radius Right (House)

Figure 7.8 Bone preservation of aurochs radius from G2 trench and the house features.

Dark shaded areas indicate areas of highest survivorship (highest number = MNE). Light areas indicate lowest survivorship.



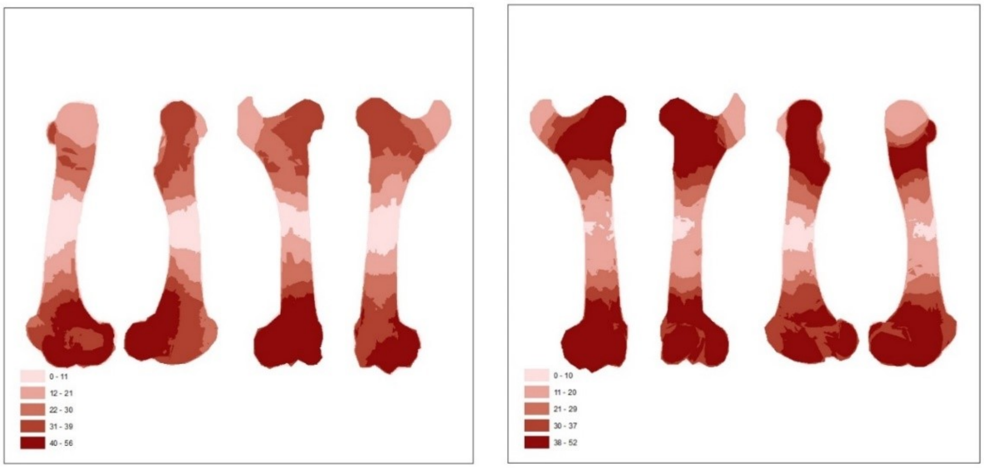
Humerus Left (G2) Humerus Right (G2)



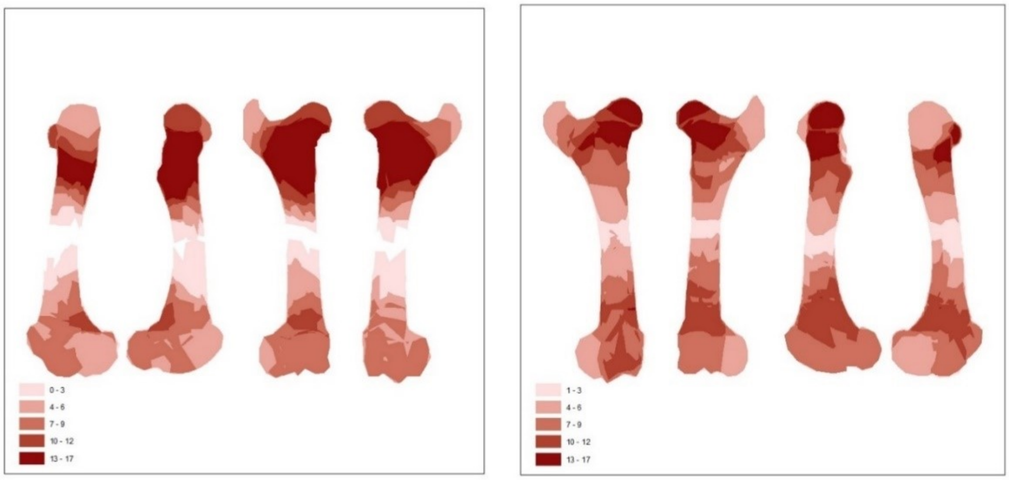
Humerus Left (House) Humurus Right (House)

Figure 7.9 Bone preservation of aurochs humerus from G2 trench and the house features.

Dark shaded areas indicate areas of highest survivorship (highest number = MNE). Light areas indicate lowest survivorship.



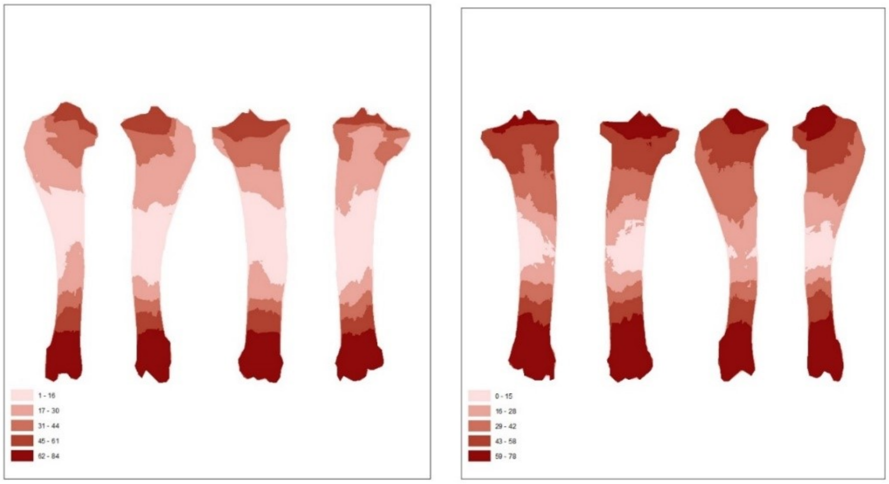
Femur Left (G2) Femur Right (G2)



Femur Left (House) Femur Right (House)

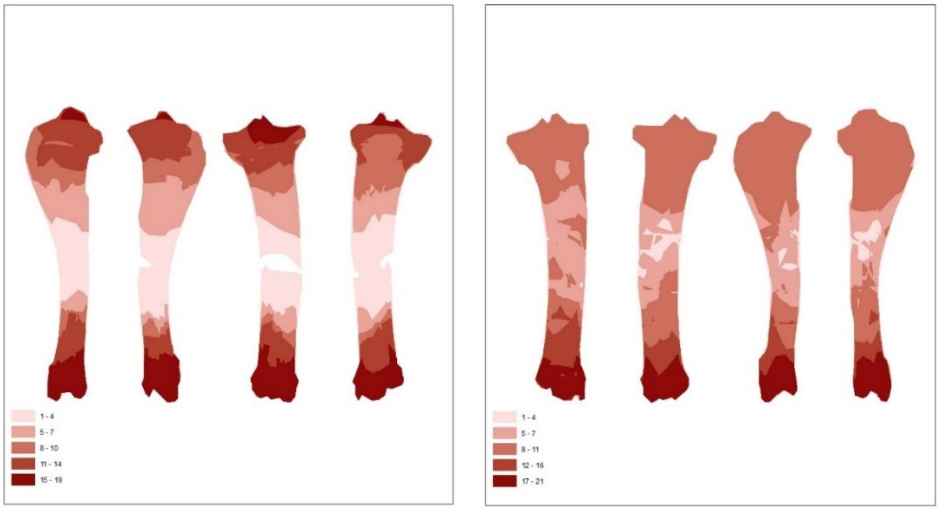
Figure 7.10 Bone preservation of aurochs femur from G2 trench and the house features.

Dark shaded areas indicate areas of highest survivorship (highest number = MNE). Light areas indicate lowest survivorship.



Tibia Left (G2)

Tibia Right (G2)

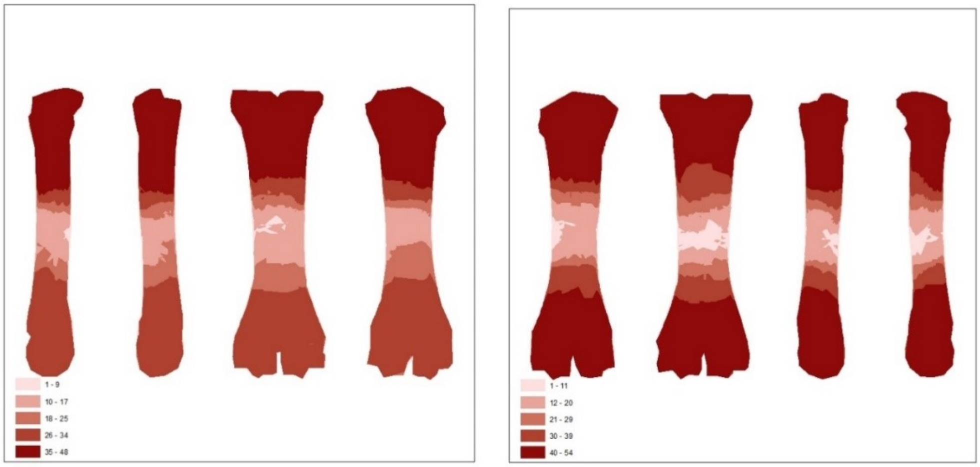


Tibia Left (House)

Tibia Right (House)

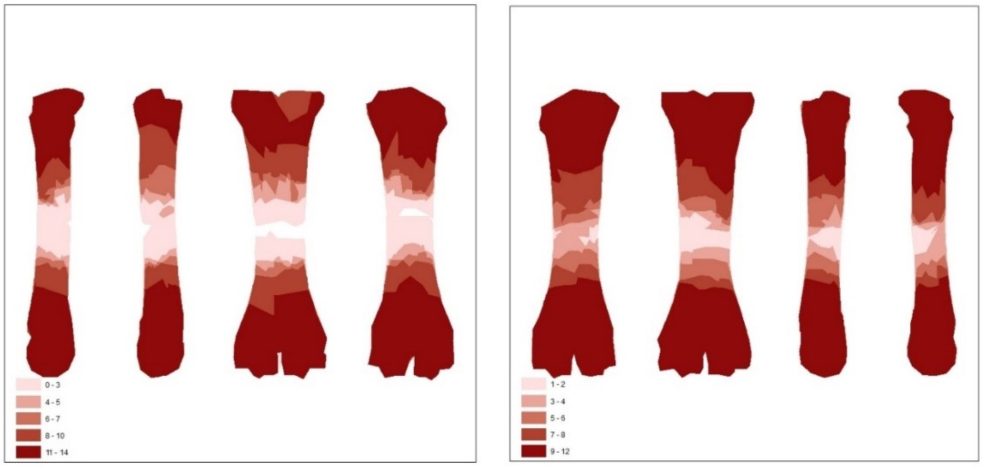
Figure 7.11 Bone preservation of aurochs tibia from G2 trench and the house features.

Dark shaded areas indicate areas of highest survivorship (highest number = MNE). Light areas indicate lowest survivorship.



Metacarpal Left (G2)

Metacarpal Right (G2)

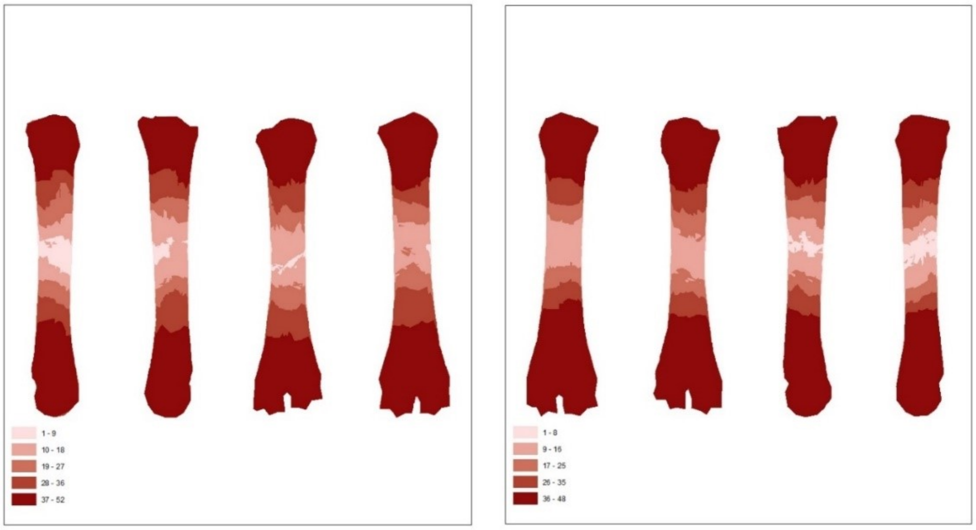


Metacarpal Left (House)

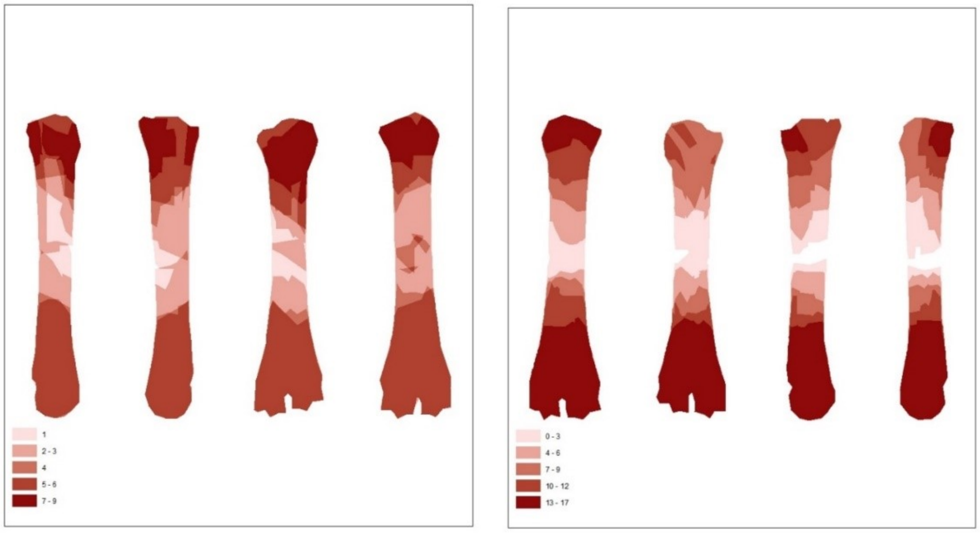
Metacarpal Right (House)

Figure 7.12 Bone preservation of aurochs metacarpal from G2 trench and the house features.

Dark shaded areas indicate areas of highest survivorship (highest number = MNE). Light areas indicate lowest survivorship.



Metatarsal Left (G2) Metatarsal Right (G2)



Metatarsal Left (House) Metatarsal Right (House)

Figure 7.13 Bone preservation of aurochs metatarsal from G2 trench and the house features.

Dark shaded areas indicate areas of highest survivorship (highest number = MNE). Light areas indicate lowest survivorship.

7.8 Articulated Units

A great number of bones were still in articulation when they were uncovered. The presence of articulated units provides evidence of the butchering process and intensity of use.

Although trench G2 was excavated in two quadrants from 2012 to 2015, information on the articulated bones was only preserved in the assemblage from quadrant IV, which was excavated in 2012. There are 108 articulated units in trench G2 from the 2012 excavation year. The only units not from aurochs are four lumbar vertebrae-lumbar vertebrae pairs that belong to dogs.

Table 7.6 shows the number of different articulated units from aurochs. The tibia-tarsal is the dominant unit, followed by the tarsal-tarsal, lumbar-lumbar, and radius-carpal. The abundant lower leg units are consistent with butchery observations from ethnographic studies (e.g., Binford 1978; O’Connell and Hawkes 1988). Lower leg units are often disarticulated early in the butchery process and left at the kill site because they are the least meat-bearing. Vertebrae are also cut into several portions for transportation purposes instead of every joint being dismembered. In the case of Houtaomuga, where butchering and consuming occurred at the same place, the presence of articulated sets indicates that after consuming the meat or marrow, aurochs bones were discarded without further bone processing.

Table 7.4 Number of articulated units from aurochs bones (Hill and Behrensmeyer 1984).

Articulated Units	No.
Atlas-axis	1
Axis-cervical v.	1
Cervical v.-cervical v.	2
Thoracic v.-thoracic v.	7
Thoracic v.-rib	1
Lumbar v.-lumbar v.	13
Tibia-tarsal	30
Tarsal-metatarsal	6
Tarsal-Tarsal	14
Humerus-ulna	2
Radius-carpal	12
Carpal-metacarpal	7
Carpal-Carpal	6
Radius-carpal-metacarpal	1
Tibia-tarsal-metatarsal-phalanx	1

7.9 Skeletal Element Abundance of Aurochs

Skeletal element abundances are important references for examining carcass-acquisition strategies, butchery and transport decisions, and site function. In hunter-gatherer societies, the degree of skeletal completeness reflects the decision-making in food transportation when animals have been killed outside the site; in complex societies, or societies in which the consumption of animal products is primarily from domesticated animals, this also provides information on inter-site trade, food exchange and status. When skeletal frequencies are applied to distinguish ritual and mundane consumption, commensal animals may be more skeletally complete than animals used for food because skeletons of animals with economic value experience more food processing before they are discarded.

There are several ways to examine skeletal completeness. In this research, all the elements of aurochs were calculated in MNE and converted into MAU and %MAU. Only maxilla with tooth sequences were counted as skulls, since other parts of a skull generally break into small fragments. Ribs were not included because they are often fractured into many pieces and thus will underestimate the value of MNE.

Figure 7.14 shows that all elements of aurochs are present in the assemblage, indicating that aurochs were butchered, consumed, and discarded at the site instead of being transported from afar. Limb bones, such as humerus and radius, are the most common elements in the G2 trench. This might be a product of preference for consuming marrow and less intensive carcass processing. The shape and texture of the bone fracture can be used in separating dry bone breakage from the breakage of a green bone. In section 7.7, the high score of FFI in long bones suggests that they were more frequently broken when fresh, likely to extract the marrow. However, the better preservation of the proximal and distal ends of long bones suggests epiphyses were not heavily processed. Therefore, more identifiable features are preserved resulting in a higher MAU count. Calcanei, astragali, and carpals are also very common elements. These elements are the most structurally dense parts, and although they have little utility by themselves, they are also firmly attached to elements with higher values, such as the ulnar carpal (Binford 1978). So, this pattern in the aurochs assemblage reflects the high frequency of limb bones.

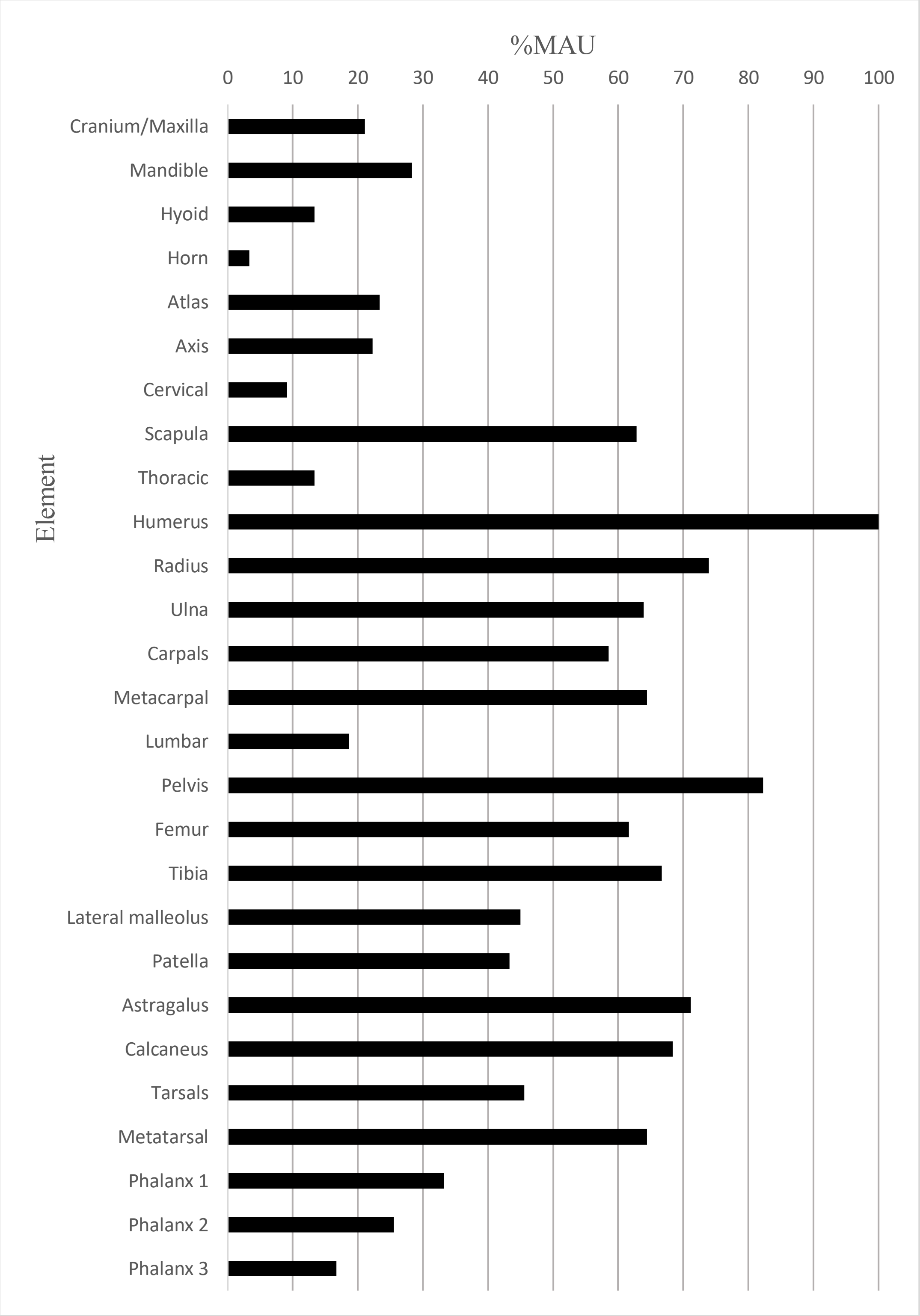


Figure 7.14 G2 trench aurochs %MAU graph.

Table 7.7 presents the degree of correlation between the different features and the Meat Utility Index (MUI), Corrected Food Utility Index (CFUI), Unsaturated Marrow Index (UMI), and Meat Drying Index (MDI). Both Pearson's and Spearman's rank-order correlation coefficients are presented.

Table 7.5 Correlation of aurochs element frequencies in G2 and house features from Houtaomuga with the Meat Utility Index, Corrected Food Utility Index, Unsaturated Marrow Index, and Meat Dry Index.

	Meat Utility Index		Corrected Food Utility Index		Unsaturated Marrow Index		Meat Drying Index	
	r(p)	r_s(p)	r(p)	r_s(p)	r(p)	r_s(p)	r(p)	r_s(p)
G2	-.1648	-.1978	.0078	-.0165	.6851	.6786	-.6223	-.6429
	(.5906)	(.5171)	(.9799)	(.9574)	(.0894)	(.0938)	(.0231)	(.0178)
House	-.2878	-0.4814	-.1088	-.2641	.4546	.2342	-.8577	-.8198
	(.3404)	(.0958)	(.7234)	(.3832)	(.3055)	(.6132)	(.0002)	(.0006)

In the G2 trench, Figures 7.15-7.22 demonstrate a weak negative correlation between the relative abundance of skeletal parts and their MUI and CFUI, but no statistically significant correlation, even though the CFUI yields a weakly positive relationship when computed using Pearson's method. While lower long bones and foot bones are much more frequent than expected, the abundance of vertebrae is lower in comparison with their higher nutritional value. The quantity of marrow in the skeletal elements is strongly positively correlated with their abundance. The relative abundance of the long bones is better explained by the nutrient in the bones than the MUI and CFUI. As shown in appendix 1.2, patterns of anatomical representation are not significantly affected by density-mediated processes. Therefore, rather than the meat or general nutritional value of these elements, the relative overrepresentation of long bones and the relative underrepresentation of foot bones are best explained by considering the proportion of marrow. The correlation coefficients are significant and negative when G2 element frequencies are compared to the MDI. Contrary to the vertebrae, which are underrepresented, the tibia and radius appear to be clearly overrepresented when taking into account their lower meat value. The abundance of these elements may indicate that the assemblage in G2 is made up of discarded body parts either after parts with high food utility were transported away, or easily dried pieces were taken for storage elsewhere.

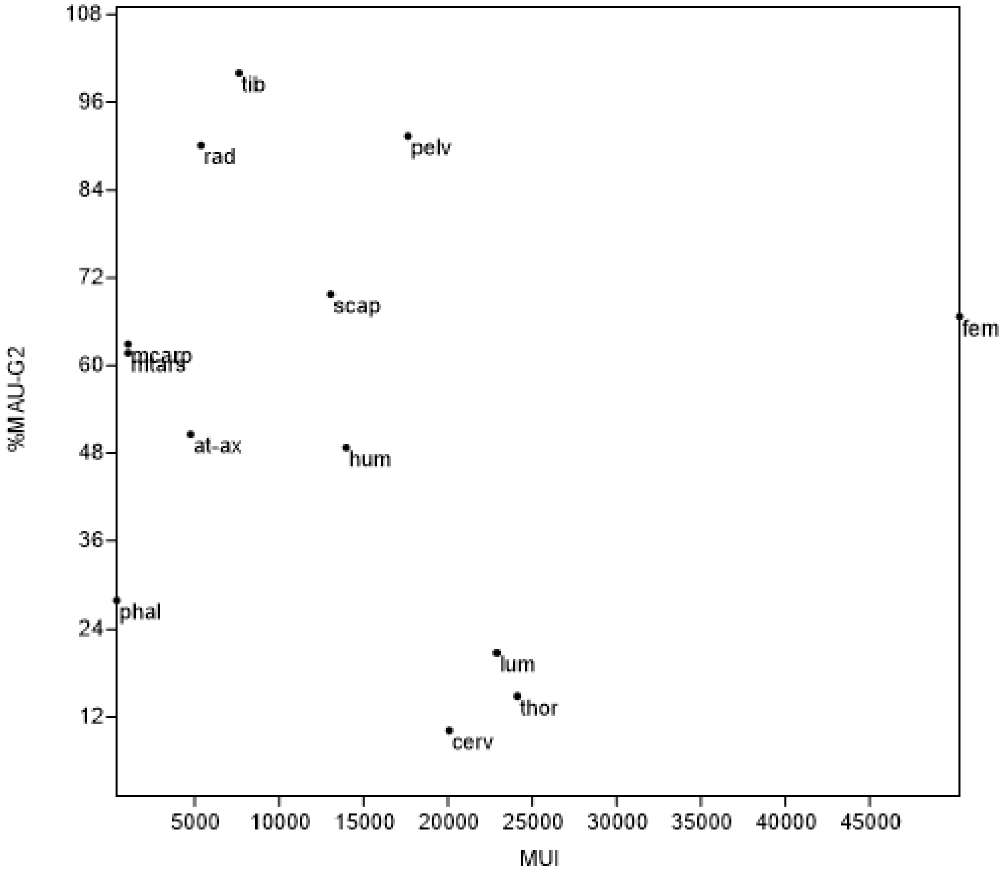


Figure 7.15 Scatterplot illustrating the relationships between G2 and the MUI.

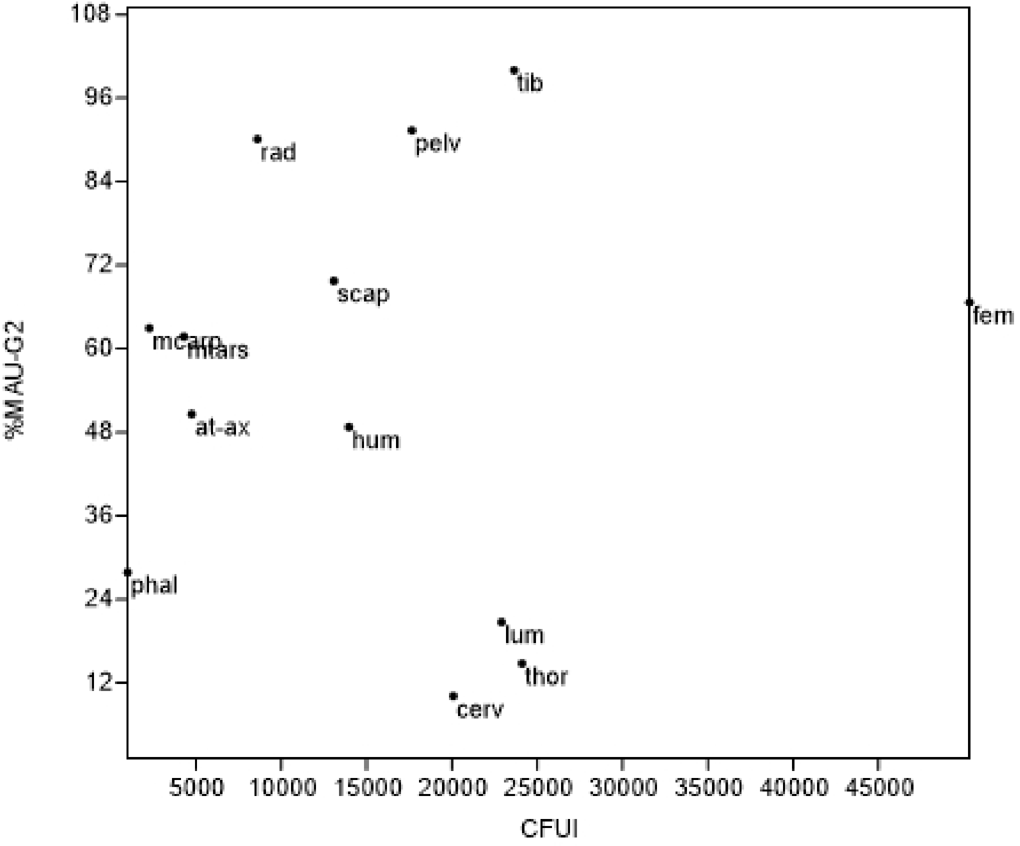


Figure 7.16 Scatterplot illustrating the relationships between G2 and the CFUI.

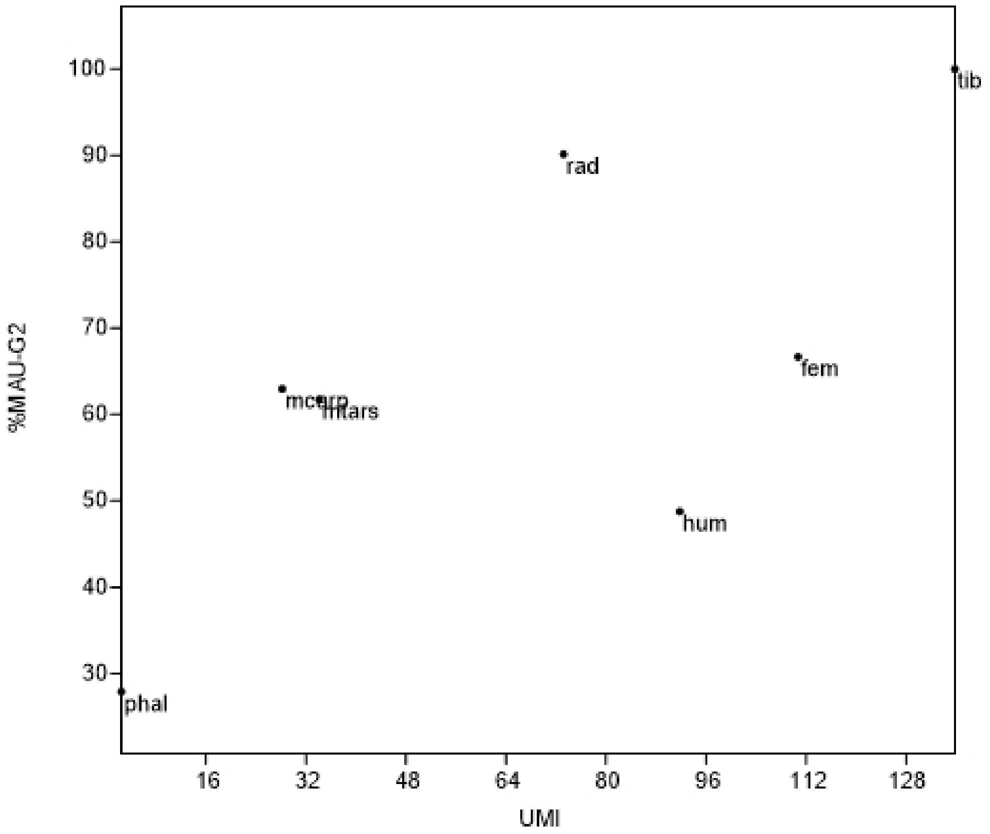


Figure 7.17 Scatterplot illustrating the relationships between G2 and the UMI.

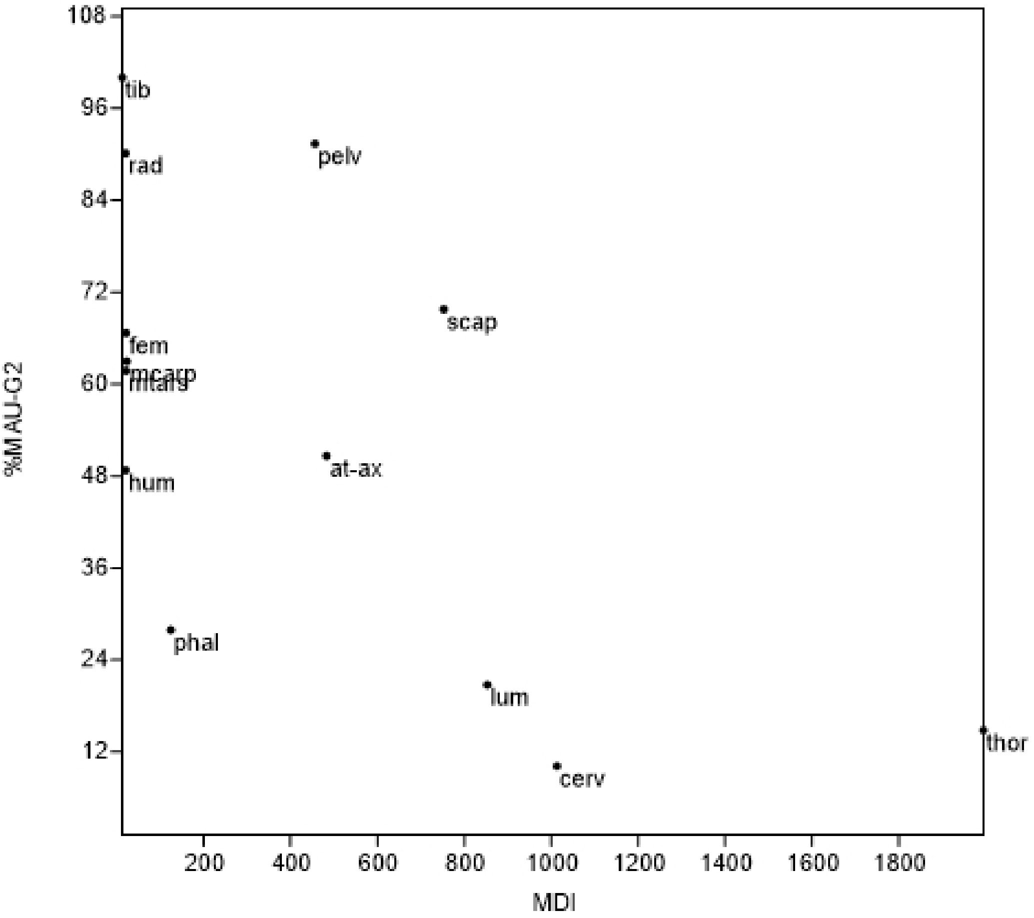


Figure 7.18 Scatterplot illustrating the relationships between G2 and the MDI.

The pattern in houses is quite similar to G2. However, compared to G2, there is a weaker correlation between the abundance of the skeletal elements and the UMI score. The phalanges, which have a lower value in marrow, are over-represented whereas the radius is underrepresented when taking into account its marrow cavity volume (Figure 7.25).

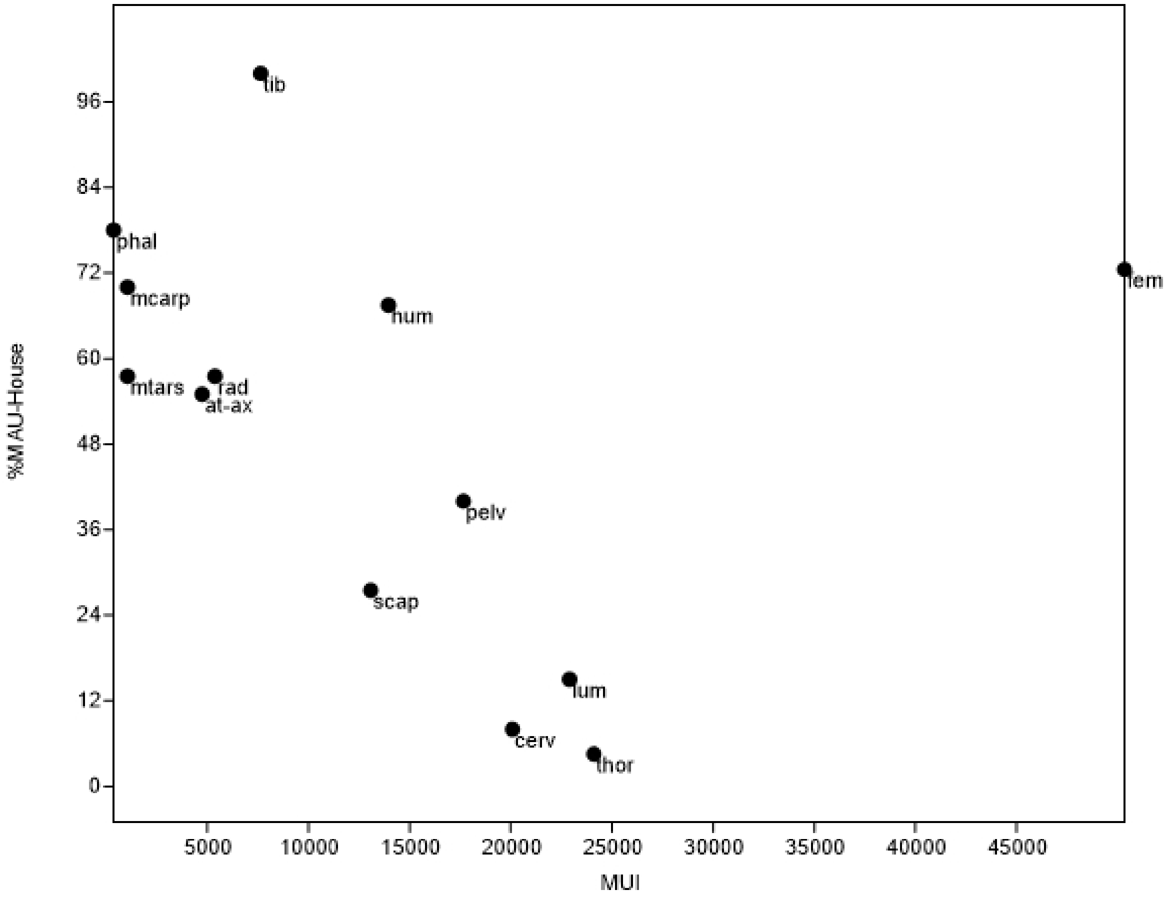


Figure 7.19 Scatterplot illustrating the relationships between house features and the MUI.

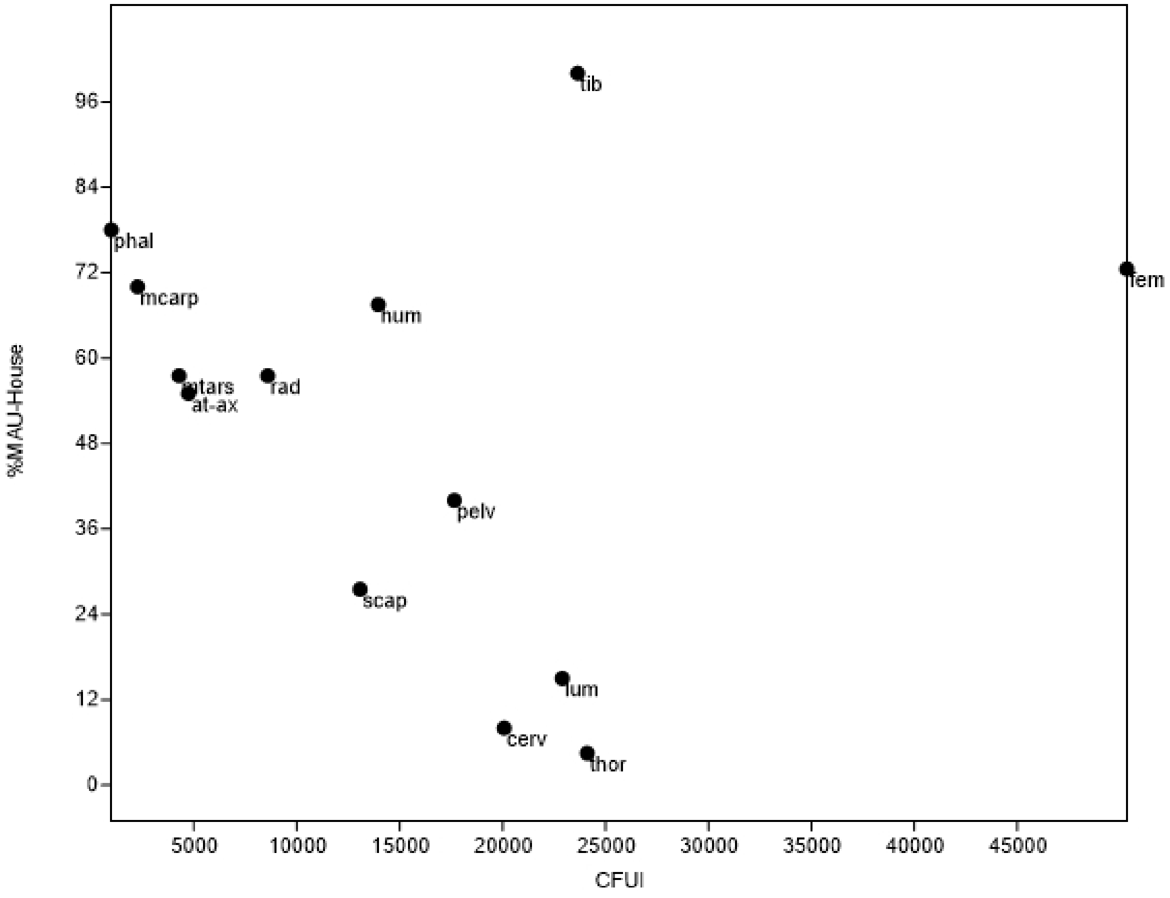


Figure 7.20 Scatterplot illustrating the relationships between house features and the CFUI.

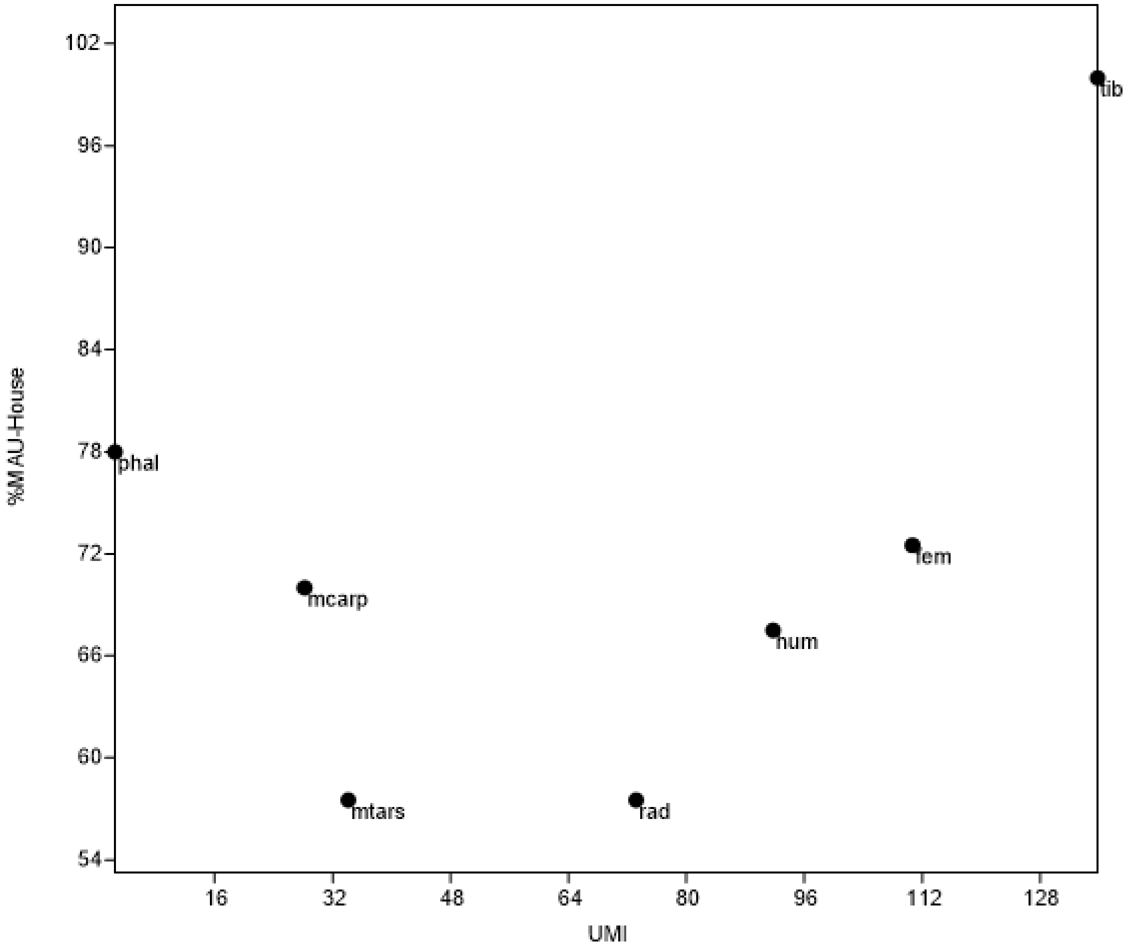


Figure 7.21 Scatterplot illustrating the relationships between house features and the UMI.

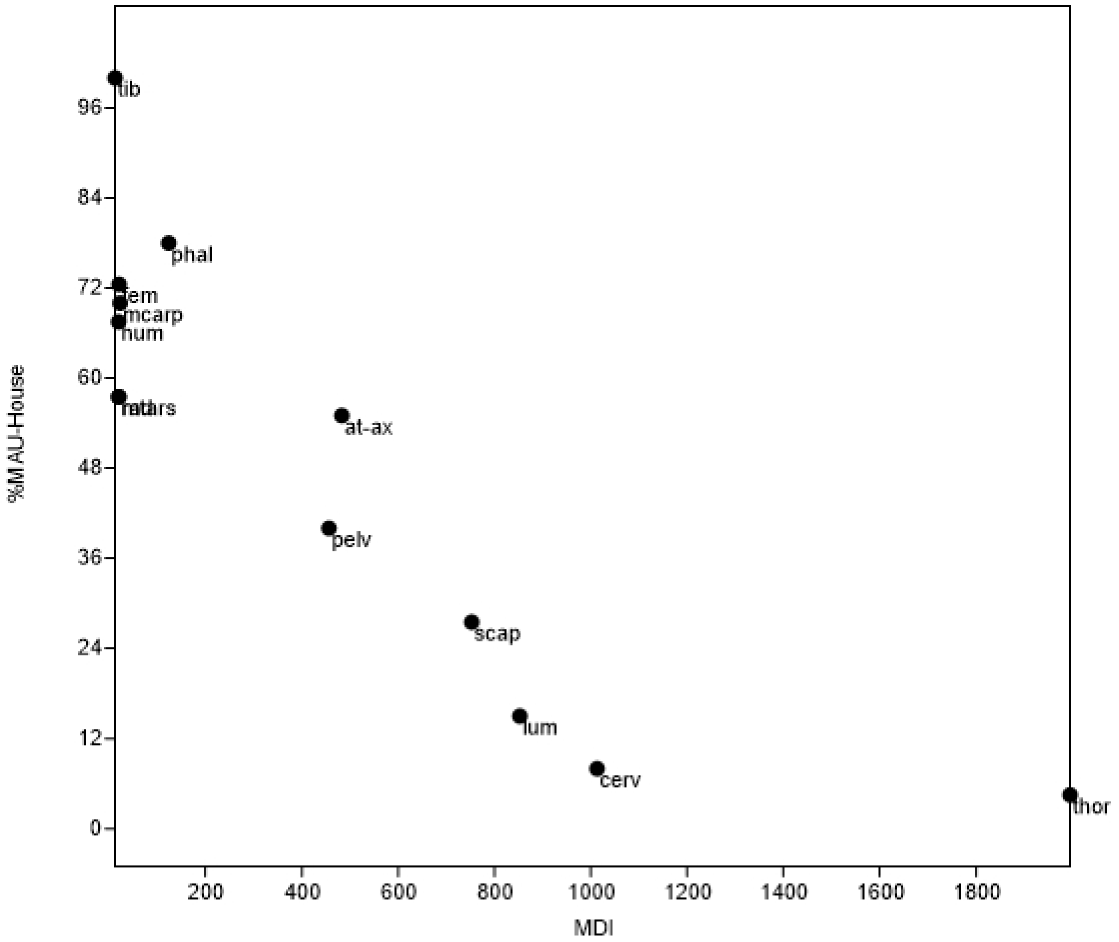


Figure 7.22 Scatterplot illustrating the relationships between house features and the MDI.

7.10 Meat Weight Estimation

The method of calculating the number of butchering units varied according to the frequency of elements in a carcass and the definition of “butchering unit.” For butchering units that contain several elements, the number of butchering units is determined by the MAU. For example, the cervical vertebrae portion is comprised of seven cervical vertebrae including the atlas and axis; thus, the number of butchering units equals the MAU, which results when the total number of cervical vertebrae is divided by the frequency of cervical vertebrae in a complete carcass. The total meat weights for aurochs that were part of trench G2, which was excavated in 2012, are shown in Table 7.6. Based on the bone assemblage from G2, Table 7.6 illustrates that somewhere between ~8306 and 15029 kg of meat was available, huge figures even at the lower end of the range calculated.

Table 7.6 Consumable meat weight by butchering unit.

Butchering unit	Number of butchering units	% Total meat weight (Female)	Consumable meat of butchering unit (Female) (kg)	% Total meat weight (Male)	Consumable meat of butchering unit (Male) (kg)	Total consumable meat (minimal) (kg)	Total consumable meat (maximal) (kg)
SKWOT	25.5	1.40	2.66	1.80	18.26	67.83	465.64
CERV	21	12.90	24.51	12.40	40.42	514.71	828.82
THOR	12	8.70	16.53	9.20	30.00	198.36	360.00
LUMB	16.8	8.90	16.91	7.80	25.43	284.09	427.23
SPEL	74	6.30	11.97	6.80	22.17	885.78	1640.58
RIBS	60.6	14.90	28.31	14.90	48.57	1715.59	2943.34
SCAP	56.5	6.00	11.40	6.80	22.17	644.10	1252.61
HUM	90	5.40	10.26	6.50	21.19	923.40	1907.10
RULC	66.5	1.80	3.42	2.10	6.85	227.43	455.53
FEMP	55.5	23.20	44.08	23.00	74.98	2446.44	4161.39
TIB	60	3.50	6.65	2.90	9.45	399.00	567.00
Total						8306.72	15029.22

SKWOT: head, CERV: cervical vertebrae, THOR: thoracic vertebrae, LUMB: lumbar vertebrae, SPEL: innominate, RIBS: ribs, SCAP: scapular, HUM: humerus, RULC: radius-ulna, FEMP: femur, TIB: tibia). All weights are in kg.

Although excavation in the G2 trench was conducted from 2012 to 2015, some parts of trench are still uncovered. Around 108.0 m^2 of G2 has been exposed during excavation, but the unexcavated portion of G2, around 96.5 m^2, is almost as large as the excavated portion of G2. Therefore, it is reasonable to infer that the total amount of meat products from aurochs from the entire trench could have provided somewhere between 16,000-30,000 kg of meat, a topic to which I will return.

Speth (2020, 2022) argued for the importance of fat in hunting-gathering people from northern America. Therefore, to get a more accurate quantity of food represented by the G2 trench, beyond the measuring of muscle meat weight, I added organ meat weight estimation in this study. The MNI of aurochs from the excavated G2 trench is 92. According to the average bison organ weight that was mentioned in 4.1.7, I then multiply the average organ weight of 10971.5 g to get an approximate total organ weight of 1000 kg. As the excavated part is roughly half the area of the whole G2 trench, the organ weight of aurochs from the whole trench may have reached 2000 kg. This enhances the already huge figures for muscle meat with organ products—some of which may well have been prized.

7.11 Summary

The representation of animal species between trench G2 and the house features suggests decidedly different sets of activity at these two loci. The low frequency of natural surface damage and the weak correlation between bone density and abundance indicates that the predominantly aurochs remains in the G2 trench, which included a number of articulated joints, were likely covered over shortly after they were discarded. This is in contrast to bones from house features inside the G2 trench: there, a greater diversity of bones from various species were subjected to a greater degree of exposure, including ravaging. Bone survivorship patterns, fresh fractures, element abundance, and burning marks observed in G2 aurochs bones provide evidence of marrow extraction in a technique that likely involved some scorching followed by use of heavy implements to fracture the midshaft of long bones. The quantity of meat, which I have estimated based on modern bison weights, is staggering. Fresh meat, or dried meat provisions processed after initial butchering, would have been abundant, apparently resulting from the slaughter and rapid burial of a large number of aurochs. The absence of extensive bone processing to extract fats and greases strongly suggests that food scarcity was not an issue at the time the G2 trench was constructed, filled with aurochs remains, and rapidly buried.

Chapter 8: Spatial Analysis at Houtaomuga

Figure 8.1 shows the plan map of the 4th stage excavation at Houtaomuga. The circular ditch G2 separated the house features into two different groups: one group inside the circular trench, the other outside the trench. However, according to the present information and knowledge, it is hard to determine if the internal and external houses are contemporaneous or not. The analysis in this chapter was undertaken on the assumption that the inside and outside houses were occupied simultaneously, although the possibility that the outside houses might precede or postdate the organized inside village could not be ignored. In this chapter, I consider the significance of the spatial distribution of fauna and other artifacts in house features to provide information useful in examining the possible function of the G2 trench and social conditions at Houtaomuga. Since accurate positions of animal bones were not recorded during excavation, neither the traditional nor the new approaches to spatial analysis, such as nearest neighbour analysis or kernel density analysis, can be used in this study. However, the clear house features found in the site and the assemblages deposited in these structures can also provide information on social differences. I have examined the faunal and artifact differences to measure interhousehold variability in subsistence, material wealth, and social status. Through a comparison of animal species, element distribution, and other material artifacts found among different house features, I attempt to determine (1) whether meat was shared extensively between households inside the trench and outside the trench, and (2) whether each household differed in their access to various resources.

8.1 House Structure

The structure of the Houtaomuga house is similar to the typical Hongshan house, which is rectangular or square in plan with the floor positioned below ground level (Drennan et al.

2017). Like other Neolithic villages in West Liao River Valley, the doorway is ramped up to ground level on one side and usually opens in a southeast or south direction. During the excavation from 2011 to 2015, 16 dwellings were discovered in the interior section, while 8 house structures were found in the exterior section. Inside the trench, excluding F1, F11, and F12, other houses were roughly organized in three rows. Seven house features at the Haminmangha site (IMCRA and RCCFA 2012), which shares a similar cultural tradition with Houtaomuga, preserved part of the superstructure because of burning (Figure 8.2). Although the building materials have completely decayed at Houtaomuga, the postholes remaining in the floor and the evidence from Haminmangha imply there was a timber-frame superstructure, and probably a thatched roof.

Table 8.1 shows the floor area and the number of other features (hearths, pits, burials) inside each house structure. The smallest house structure inside the trench is 27.4 m^2, the largest is 74.5 m^2, while the average size is 43.4 m^2. However, except for F11, which is the largest one, most of the house features inside the trench are between 30 and 50 m^2. The smallest house outside the trench is around 23.5 m^2, the largest is 83.8 m^2, while the average value is 50.5 m^2. Median, inter-quartile range, and maximum and minimum values for house area are also given which show the house features outside the trench have much more variation in size than the inside houses (Figure 8.3).

The most common house features, whether inside or outside the trench, include at least one hearth and pit. Although no hearth was uncovered at F7, F9, F19, F20 and F29, this is mostly because their hearths were likely destroyed by the subsequent houses built over them. The absence of a pit in F8, F9 and F19 probably results from the same factor. However, the situation in F3 and F31 is different. They are fully uncovered and were not impacted by later structures, but still no pits were found in these two houses. Meanwhile, the amount of animal bones discovered from F3 and F31 is relatively small, indicating a possible difference with other house assemblages (Table 8.1 and 8.2).

Table 8.1 Animal remains, prestige goods (jade), hunting tools, processing tools and pottery vessels found in the interior houses.

	Animal remains	Prestige goods	Hunting tools	Processing tools	Pottery vessels
F2	21	0	1	0	0
F3	22	0	0	2	8
F4	377	0	1	8	20
F5	203	0	1	2	5
F6	1173	1	5	3	24
F7	18	0	0	2	3
F8	136	0	0	5	1
F9	115	0	0	0	0
F10	842	1	5	1	8
F11	60	0	2	3	10
F12	131	0	0	1	2
F13	21	0	0	0	12
F18	236	1	3	3	10
F20	38	0	0	0	0
F26	60	0	0	2	1
F27	58	0	1	0	9

Table 8.2 Animal remains, prestige goods (jade), hunting tools, processing tools and pottery vessels found in the exterior houses.

	Animal remains	Prestige goods	Hunting tools	Processing tools	Pottery vessels
F14	39	0	0	0	1
F16	73	0	2	2	4
F17	36	1	0	4	3
F19	9	0	1	6	0
F23	104	0	2	0	0
F28	90	0	2	0	0
F29	32	0	0	0	0
F31	6	0	0	0	0

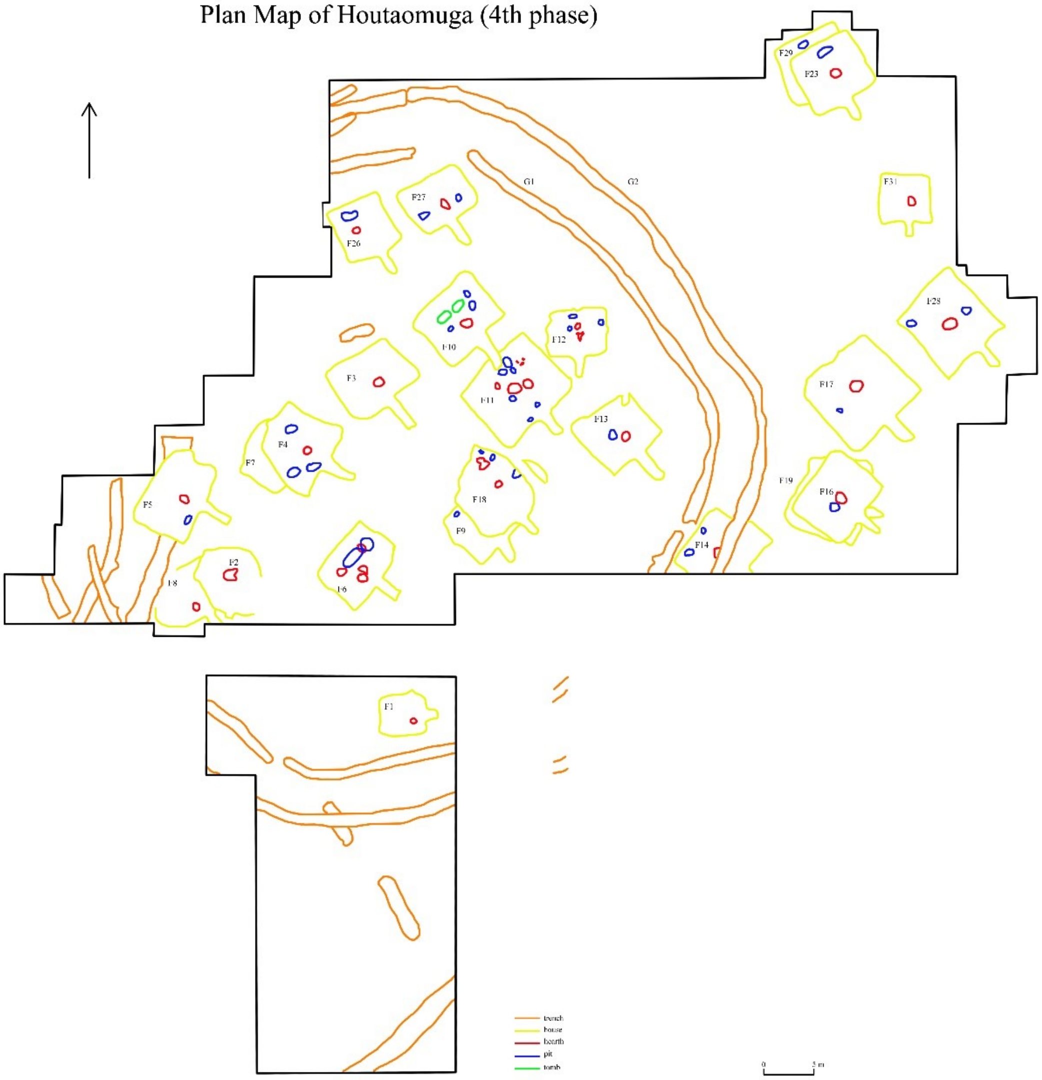


Figure 8.1 Plan map of Houtaomuga showing ditches and house features from 4th cultural period.

Figure 8.2 Haminmangha house showing timber-frame structure (after IMCRA and RCCFA 2012).

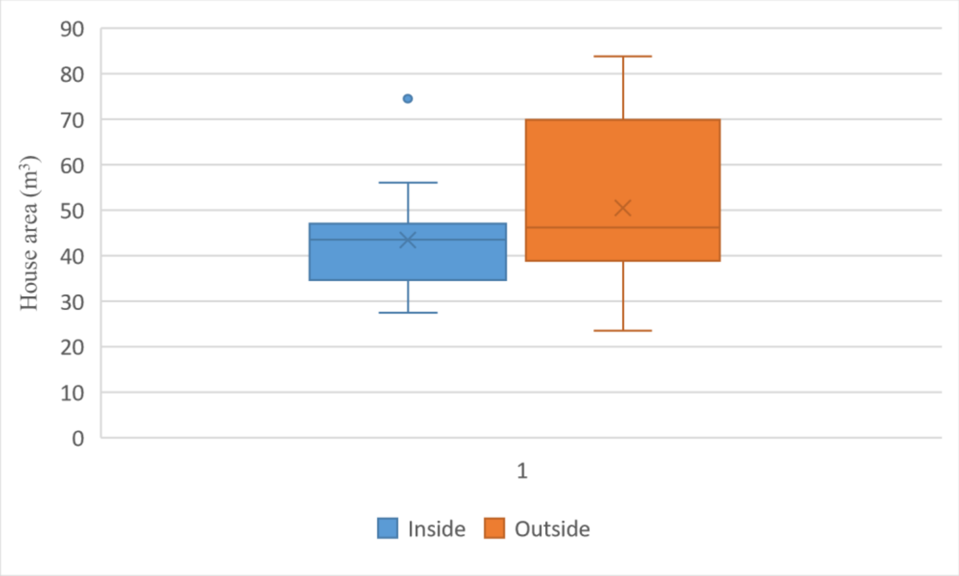


Figure 8.3 Boxplots showing median, inter-quartile range, and maximum and minimum values for inside and outside house areas (m^3).

Table 8.3 Areas of excavated house floors and the archaeological features unearthed inside the house features.

		Area (m^3)	Hearth	Pit	Burial
Inside G2 Trench	F2*	(43.5)	1	2	?
	F3	45	1	0	0
	F4	41.6746	1	3	0
	F5	46.75	1	1	0
	F6	42-45	4	2	0
	F7*	16(32.5)	?	?	?
	F8	24.64-32.4	1	0	0
	F9*	(43)	?	1	?
	F10	47	1	3	2
	F11	74.5	4	7	0
	F12	27.36	2	3	0
	F13	38.28	1	1	0
	F18	57.5	2	3	0
	F20*	4.3	?	2	?
	F26	35.7	1	2	0
	F27	49.38	1	2	0
Outside G2 Trench	F14*	40.2(47.5)	1	2	?
	F16	45	1	2	0
	F17	76.45	1	1	0
	F19*	(50)	?	?	?
	F23	38.44-40.34	1	2	0
	F28	83.8	1	2	0
	F29*	14.27(38.9)	?	1	?
	F31	22.36-25.22	1	0	0

The asterisk denotes that the house feature was not fully excavated. A number without the parentheses means the area of the excavated part, while a number inside parentheses represents the area when houses were excavated completely.

8.2 The Formation Process for Houtaomuga Houses

Reconstruction of the formation processes within house structures, where the family's principal daily activities would take place, is critical for inferring previous behaviours from the current archaeological record. A house structure is not a one-time use facility, and it is constantly reused and renovated during its habitation. This characteristic of house structures raises a difficult problem: domestic archaeological remains indicate diachronic processes, but not synchronic behaviour (Alexander 1999). Before looking at the differences between households at Houtaomuga, it is important to understand the nature of deposition and formation sequences represented by house features and assemblages, so we can tell if we are comparing the deposition resulting from a single habitation period or the accumulation of different habitation periods.

Because a residential structure goes through a variety of development processes before it comes into contact with archaeologists, the habitation, abandonment, and post abandonment sequence should be carefully examined. The construction of F4, F2, and F18 impacted significant parts of the F7, F8, and F9 structures. F10 broke the back wall of F11 with its doorway, according to the stratigraphic sequences; in the excavated area outside the trench, F16 and F23 were formed on the locations of F19 and F29. Based on ethnographic observations from the Maya highlands, this situation was likely similar to that described by Wauchope (1938) and Deal (1985). According to Wauchope (1938), the Precolumbian Maya would usually build a new house atop an old one. According to observations on Tzeltal households, more than half of new structures were built on top of old structures, or the old structures contributed to the new ones in some way. Other new structures were built near old ones, although in separate positions (Deal 1985). As a result, the stratigraphic relationships among house features at Houtaomuga can be interpreted as the reuse and abandonment of residential structures. The F7, F8, F9, F11, F19, and

F29 structures were occupied earlier than the corresponding F4, F2, F18, F10, F16, and F23 structures.

An assessment of the chronology of residency is more challenging for buildings that did not contain disturbance information in the stratigraphic record. The objects deposited in the house features, on the other hand, may provide some information in the time sequence as a result of formation processes. Despite archaeologists' eagerness to discover the cultural deposition that occurs within house structures during their habitation phase, with the exception of rare occurrences such as Pompeii, the majority of archaeological records have come from the stages of abandonment and post-abandonment. Schiffer (1987) claimed that scavenging *de facto* refuse is a widespread process described in ethnoarchaeological and archaeological records in the post-abandonment stage. Portable artifacts and construction materials are both desirable items that later people would scavenge from abandoned constructions, especially in the early stage after abandonment. Few artifacts were discovered at F31, indicating that it either had another function which led to limited artifact deposition, or it was abandoned earlier than the other dwelling structures outside the trench at Houtaomuga and perhaps scavenged for useful artifacts. Furthermore, F31 is the only house with a south-facing doorway, indicating its distinction from the other outside houses.

All of the inside houses (in contrast to the outside houses) have relatively rich floor deposits. All houses except F11 and F12 were arranged in three parallel rows, indicating that the residency time of those first two houses was likely different from the other houses. Meanwhile, F12 had a similar doorway direction as F31, indicating that it may have had a closer relationship with F31.

It would be dangerous to treat the floor assemblage found in each house as an accurate representation of the deposition that occurred during the house's use period because clearly not all objects used in a house were deposited in the space bounded by that structure, and not all objects deposited in a house were necessarily used there when the house was inhabited. Based on observations from ethnographic literature, animal bones, for example, which are the major objects that will be examined in the following section, were typically removed from the activity areas due to their low value and potential for causing a hazard (Hayden and Cannon 1983; Murray 1980). The distribution of faunal bones, however, is not random; they tend to be concentrated within a community or a campsite. Gordon (1980) conducted a study of the modern abandoned Fireman winter camp and discovered that bone was commonly discarded in household dumps, burned or suspended in trees around the campsite. At Canadian fur trade posts, extensive faunal remains accumulated along fortification walls and abandoned cellar and ice house depressions (Pyszczyk 1978). As a result, we can say that looking at the species/element representation and artefacts per house feature could provide some information about social differences, although animal bones from house features may not reflect purely domestic activities.

Acknowledging that it is difficult to recreate the exact usage and abandonment chronology, the above study based on stratigraphy and formation process painted an ambiguous image for them. That said, it is not unreasonable to speculate that house structures F2, F3, F4, F5, F6, F10, F13, F14, F16, F17, F18, F23, F26, F27, and F28 were abandoned in a short interval, and the faunal remains and artefacts from these features were utilised in the study that follows.

8.3 Species Distribution by Houses

About 13 mammal species were identified at Houtaomuga, but only eight species (aurochs, dog, boar, roe deer, badger, raccoon dog, elk, and hare) were included in this analysis since they appeared most frequently in house features. Figure 8.4 shows the NISP percentage for each species from the houses inside and outside the G2 trench. Aurochs is the dominant taxon in the inside houses, accounting for 43.0% of the total mammal remains, while in the outside houses, the proportion of raccoon dogs (33.9%) was highest, followed by dogs (31.1%).

Figures 8.5 - 8.19 plot the distribution of these eight species in all the selected houses. It can be seen that there is substantial variation among the houses. When comparing the species distribution from the inside houses, although aurochs is the dominant taxon in most of the households, the second and third most abundant species differ—some households have a relatively high proportion of dog and boar (F2, F3, F6, F10, F18, F27), while others have a substantial amount of small animals, like raccoon dog and hare (F4, F5, F13, F26), possibly representing the differing abilities or status associated with hunting or receiving animals of different sizes.

The difference in the animal species distribution (%NISP) between the inside and outside houses can be seen using a hierarchical cluster analysis (Figure 8.20). There are two distinct clusters, one containing the houses from inside and the other containing outside houses. Except for F18 and F27, the animal profiles of the other interior dwellings are more comparable. The three houses nearest to the trench (F14, F16, F17) fall in the same cluster which shows a different profile from houses (F23 and F28) located on the periphery.

Table 8.4 expresses the species density per cubic meter excavated for each of the 15 houses. The density values suggest that the inside houses are relatively high in aurochs and are also abundant in other animals, while the outside houses show a fairly even distribution of major taxa. If these deposits reflect everyday consumption, the density values would tend to indicate that the inside houses may have had a superior diet in which more meat was consumed than other families. To the extent that some of the materials from the inside houses might represent ritual activities, the density values might also provide information about differences in social or religious status. Correlation matrices, which represent the co-occurrences of species in the inside and outside houses, show a different picture. Russell (1993) proposed that extensive symmetrical sharing will tend to produce an even distribution of species among the features. All the correlations are quite high in both the inside and outside houses, and appear to imply taxa occurred in similar proportions in most houses. Aurochs and elk show a certain clustering in the outside houses, which may indicate that they were not shared to the same degree among households outside the circular trench. However, the small sample size of elk (only one specimen) could skew its significance within the correlation.

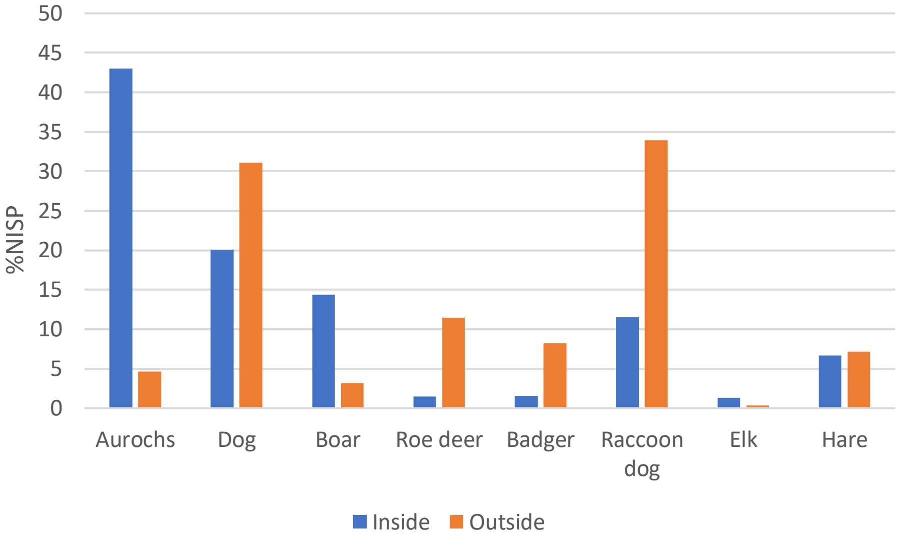


Figure 8.4 The NISP percentage of each taxon from the inside and outside houses.

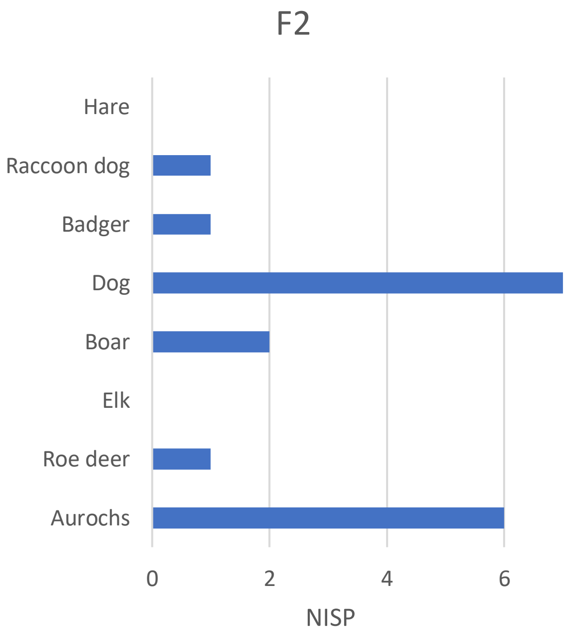


Figure 8.5 Distribution of taxa in F2 house.

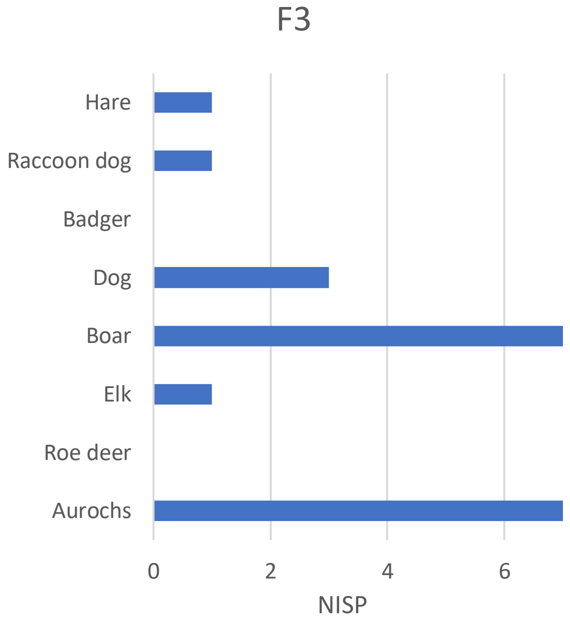


Figure 8.6 Distribution of taxa in F3 house.

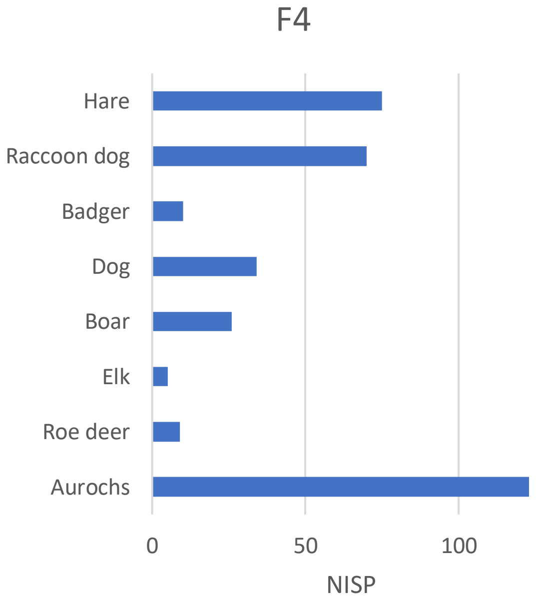


Figure 8.7 Distribution of taxa in F4 house.

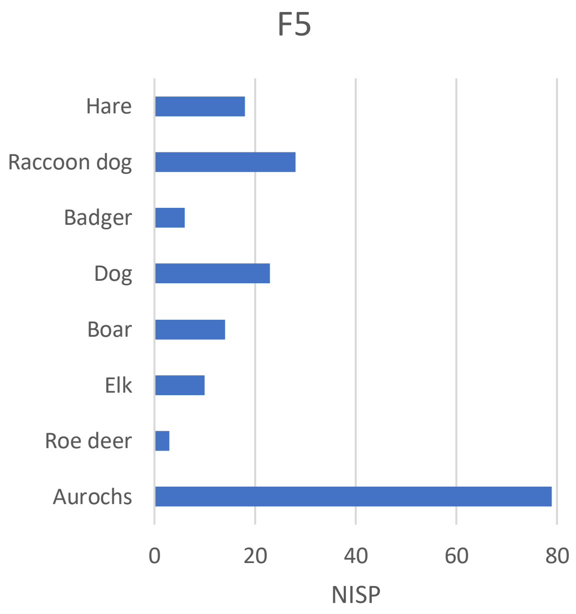


Figure 8.8 Distribution of taxa in F5 house.

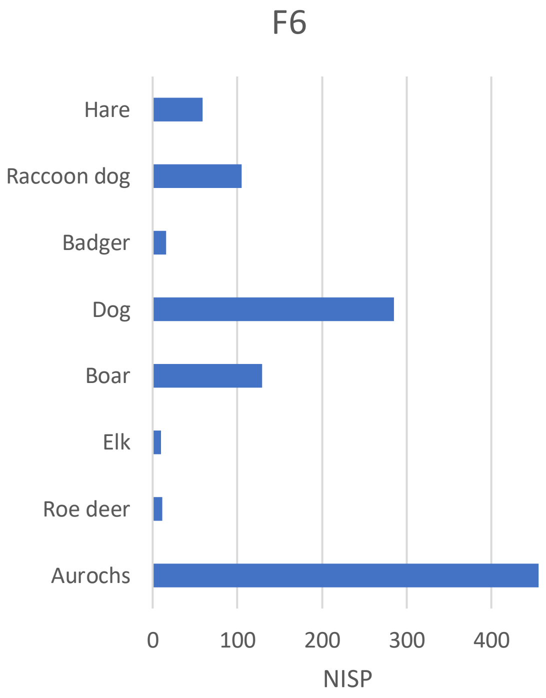


Figure 8.9 Distribution of taxa in F6 house.

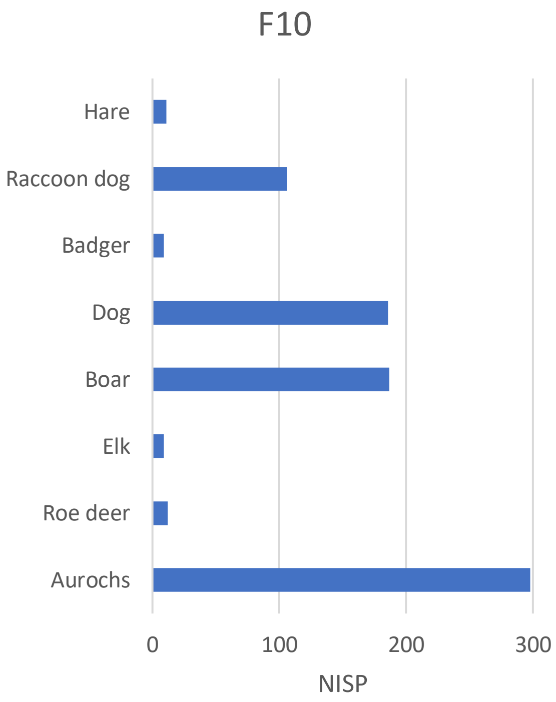


Figure 8.10 Distribution of taxa in F10 house.

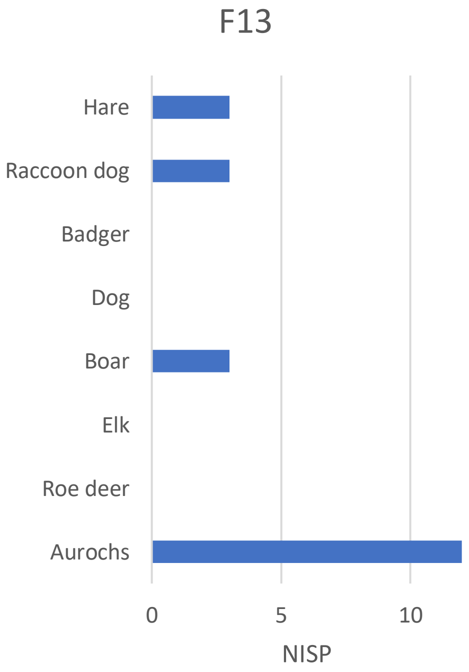


Figure 8.11 Distribution of taxa in F13 house.

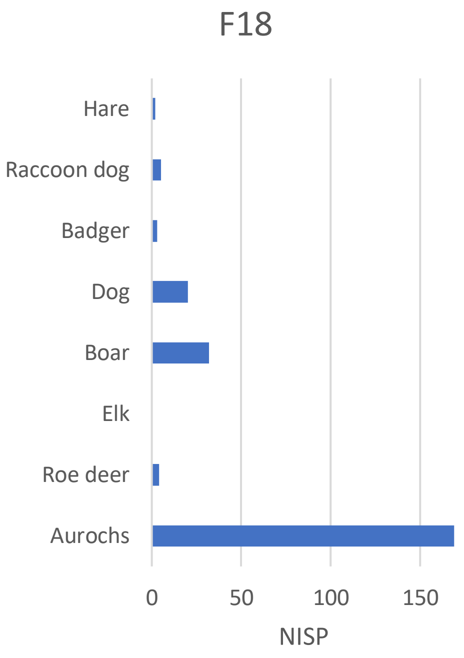


Figure 8.12 Distribution of taxa in F18 house.

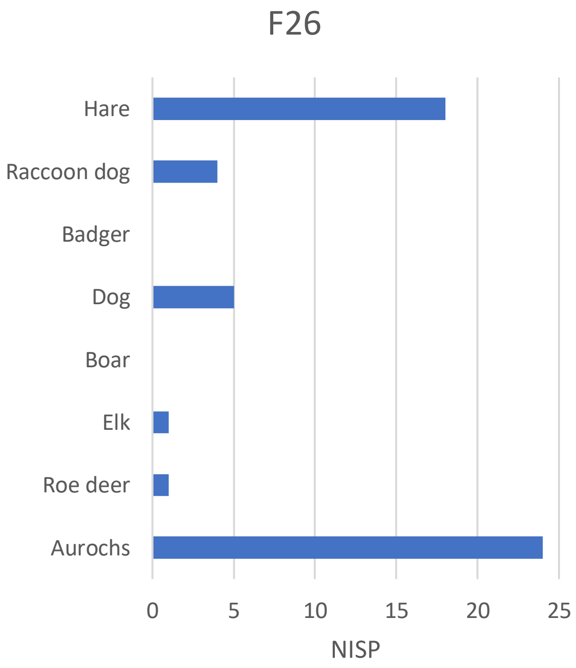


Figure 8.13 Distribution of taxa in F26 house.

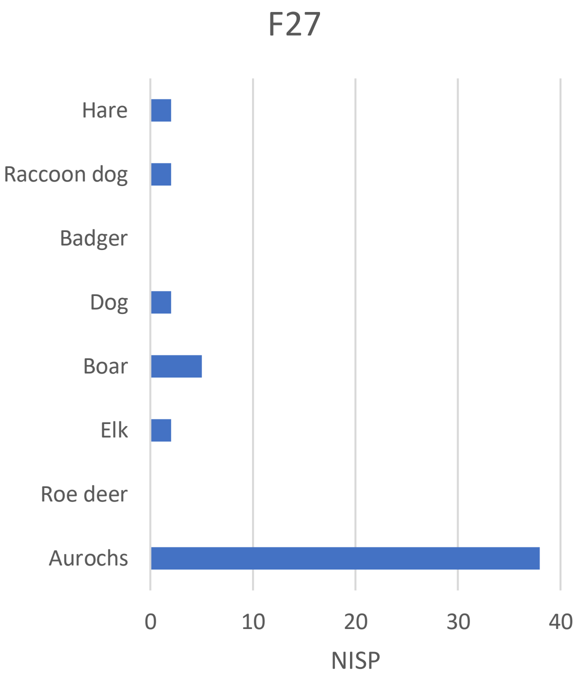


Figure 8.14 Distribution of taxa in F27 house.

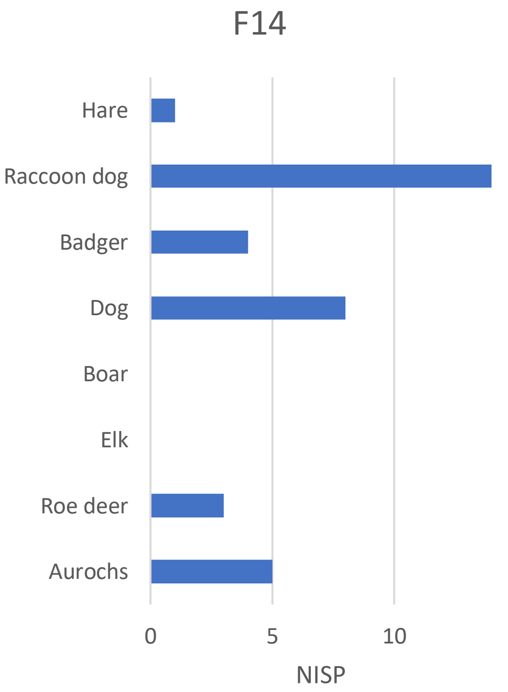


Figure 8.15 Distribution of taxa in F14 house.

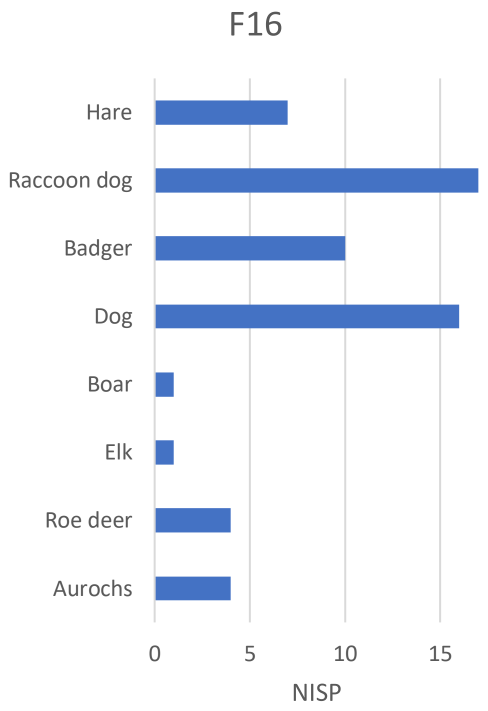


Figure 8.16 Distribution of taxa in F16 house.

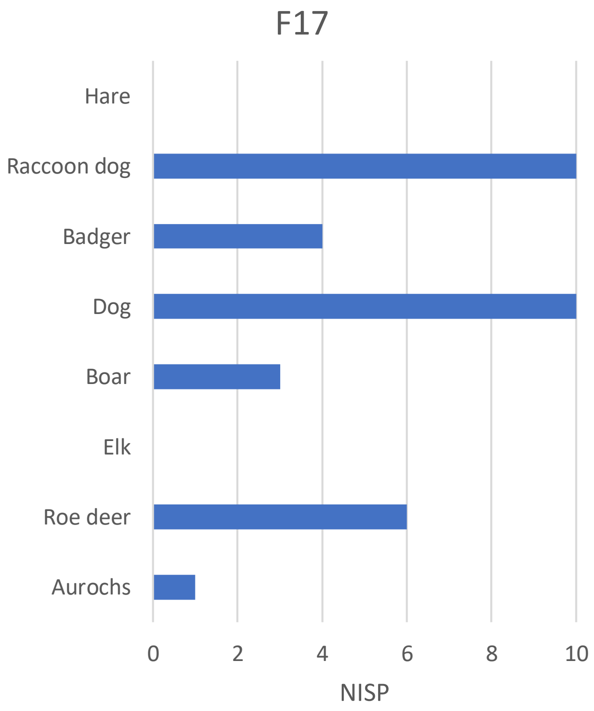


Figure 8.17 Distribution of taxa in F17 house.

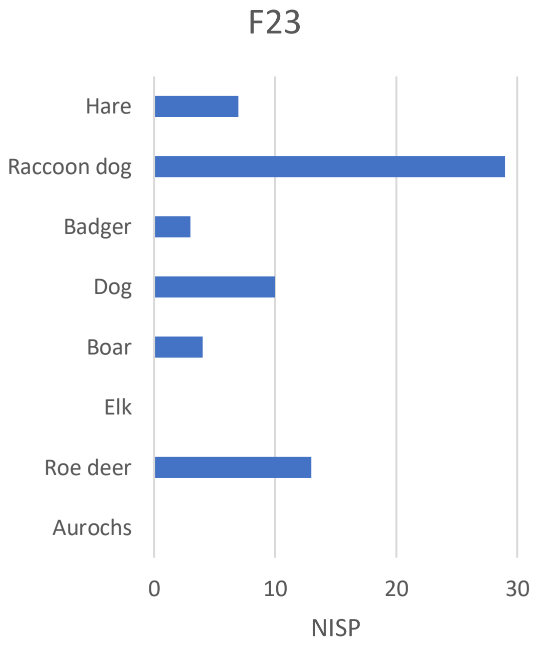


Figure 8.18 Distribution of taxa in F23 house.

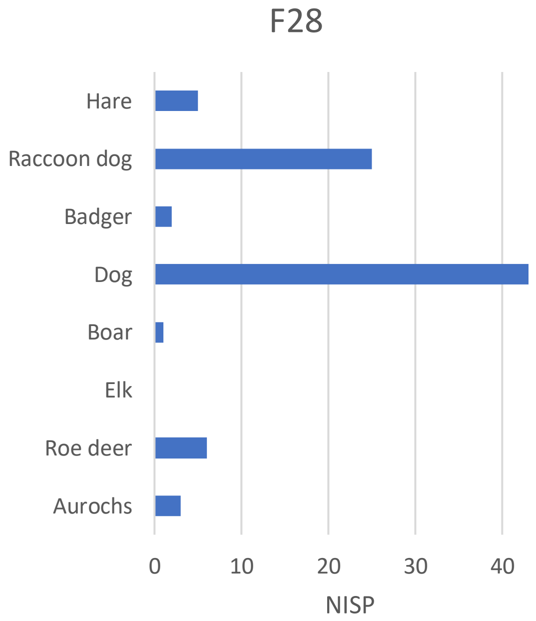


Figure 8.19 Distribution of taxa in F28 house.

Table 8.4 Densities per cubic meter of taxa in inside houses.

	Aurochs	Dog	Boar	Roe deer	Badger	Raccoon dog	Elk	Hare
F2	0.28	0.32	0.09	0.05	0.05	0.05	0.00	0.00
F3	0.19	0.08	0.19	0.00	0.00	0.03	0.03	0.03
F4	3.17	0.88	0.67	0.23	0.26	1.80	0.13	1.93
F5	1.88	0.55	0.33	0.07	0.14	0.67	0.24	0.43
F6	13.79	8.62	3.90	0.33	0.48	3.18	0.30	1.78
F10	12.68	7.91	7.96	0.51	0.38	4.51	0.38	0.47
F13	1.30	0.00	0.33	0.00	0.00	0.33	0.00	0.33
F18	6.53	0.77	1.24	0.15	0.12	0.19	0.00	0.08
F26	1.68	0.35	0.00	0.07	0.00	0.28	0.07	1.26
F27	1.40	0.07	0.18	0.00	0.00	0.07	0.07	0.07

Table 8.5 Densities per cubic meter of taxa in outside houses.

	Aurochs	Dog	Boar	Roe deer	Badger	Raccoon dog	Elk	Hare
F14	0.28	0.44	0.00	0.17	0.22	0.77	0.00	0.06
F16	0.18	0.71	0.04	0.18	0.44	0.76	0.04	0.31
F17	0.04	0.43	0.13	0.26	0.17	0.43	0.00	0.00
F23	0.00	0.49	0.20	0.64	0.15	1.43	0.00	0.34
F28	0.07	1.03	0.02	0.14	0.05	0.60	0.00	0.12

Table 8.6 Correlation matrix for taxa in inside houses.

	Aurochs	*Dog*	*Boar*	*Roe deer*	*Badger*	*Raccoon dog*	*Elk*	*Hare*
Aurochs	1	0.982432	0.97447	0.988298	0.98935	0.98544395	0.967977	0.933182
Dog	0.982432	1	0.978093	0.959935	0.961384	0.97446479	0.949268	0.900536
Boar	0.97447	0.978093	1	0.970986	0.953043	0.97864532	0.94863	0.871617
Roe deer	0.988298	0.959935	0.970986	1	0.993775	0.99444066	0.973345	0.952664
Badger	0.98935	0.961384	0.953043	0.993775	1	0.98971425	0.981359	0.966324
Raccoon dog	0.985444	0.974465	0.978645	0.994441	0.989714	1	0.978733	0.951148
Elk	0.967977	0.949268	0.94863	0.973345	0.981359	0.97873284	1	0.932016
Hare	0.933182	0.900536	0.871617	0.952664	0.966324	0.95114776	0.932016	1

Table 8.7 Correlation matrix for taxa in outside houses.

	Aurochs	*Dog*	*Boar*	*Roe deer*	*Badger*	*Raccoon dog*	*Elk*	*Hare*
Aurochs	1	0.881555	0.709954	0.78347	0.924743	0.86493603	0.696598	0.851891
Dog	0.881555	1	0.84165	0.895969	0.880522	0.95084093	0.581578	0.925143
Boar	0.709954	0.84165	1	0.982803	0.87062	0.93571768	0.512148	0.905229
Roe deer	0.78347	0.895969	0.982803	1	0.893681	0.98149474	0.533621	0.952428
Badger	0.924743	0.880522	0.87062	0.893681	1	0.92155571	0.810981	0.940686
Raccoon dog	0.864936	0.950841	0.935718	0.981495	0.921556	1	0.595167	0.979649
Elk	0.696598	0.581578	0.512148	0.533621	0.810981	0.59516714	1	0.723385
Hare	0.851891	0.925143	0.905229	0.952428	0.940686	0.97964933	0.723385	1

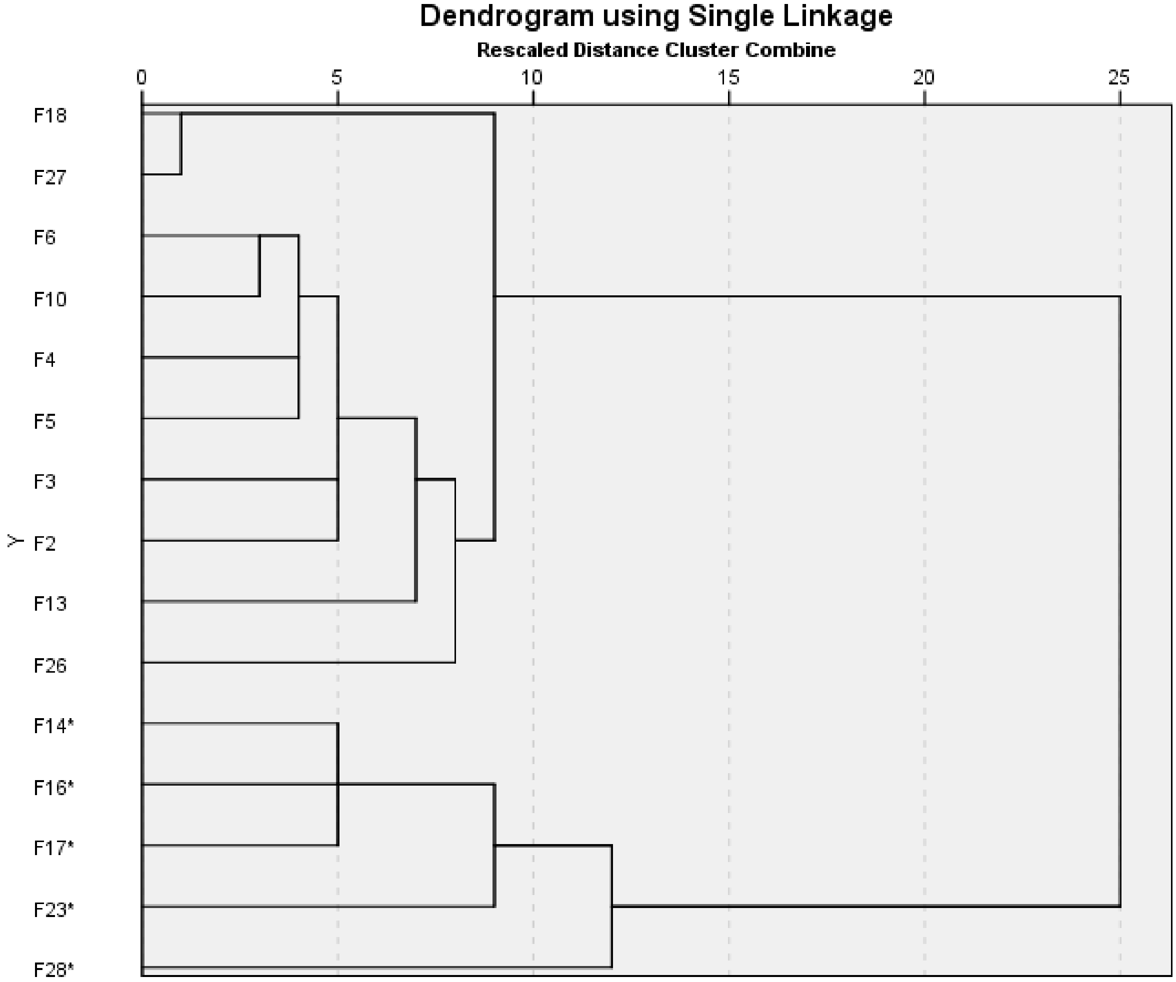


Figure 8.20 Hierarchical clustering of animal taxa profiles for household units at Houtaomuga.

*The asterisk denotes houses located outside the trench.

8.4 Element Distribution among the Inside Houses

Whether in egalitarian or hierarchical societies, meat sharing is a common way to both distribute resources and foster social networks (e.g., Hawkes et al. 2001; Kent 1993; Lokuruka 2006). Large animals rather than small game animals are more often shared with other households during feasting, and the distribution of different meat cuts can reflect social status. Therefore, I hypothesize that social differences at Houtaomuga might be represented by differential element distributions among the house features.

Due to the sample size, only aurochs bones from some inside house features were selected in this section. I have divided the diagnostic zones into right and left as the side might also be an indicator for identifying status and the age grades in the homestead. For example, in the Turkana culture, the senior wife receives the right pelvic wing and right hindleg, while the junior wife receives the left portions (Lokuruka 2006). The elements are limited to bones with more edible, or higher value, meat or marrow. Animal mandibles and heads were often trophy accumulations in many societies. Therefore, the mandible, although it is not a highly valued part, was also selected in this analysis (Rowley-Conwy 2018).

It is hard to detect a clear pattern in element distribution among households except for the obvious fact that there are more aurochs bones in F6 and F10 than in other houses (Figure 8.21-8.27). Table 6.6 shows the correlation matrix for the aurochs elements from different house features. If the meat was distributed in units, we would expect to observe a higher correlation between adjacent bones. Only the left humerus and the radius/ulna show a lower correlation, which may indicate the left foreleg was divided at the elbow and shared separately. The dichotomy of right-left may be an important code in meat sharing. The preference in side at Houtaomuga could be represented due to this variance in treating the left foreleg. However, we should note that most elements, even the non-adjacent parts, show a high correlation. This is probably because that majority of the bone samples were from only two houses. Therefore, we should treat the possible distribution pattern with caution.

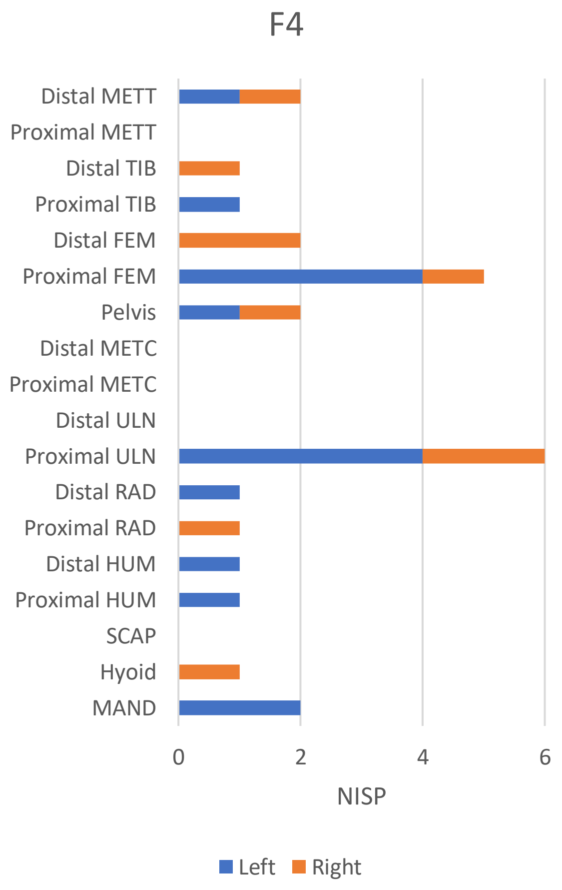


Figure 8.21 Aurochs element distribution in F4 house.

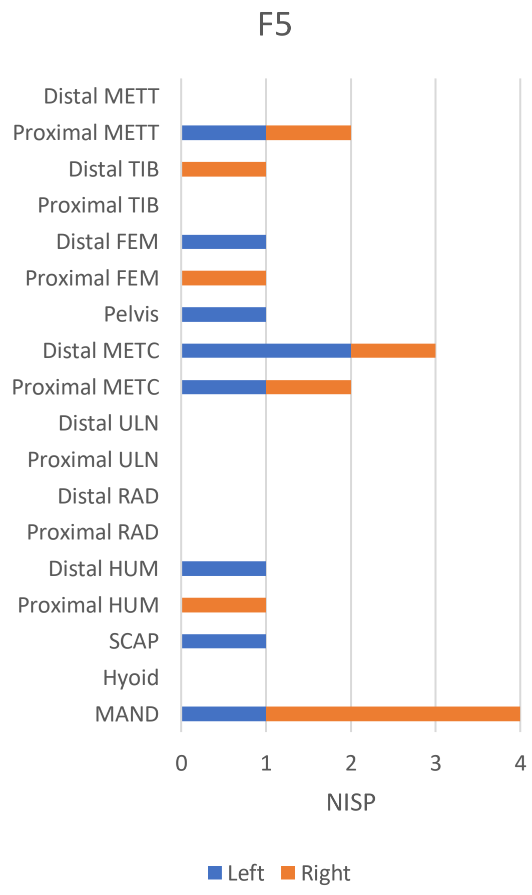


Figure 8.22 Aurochs element distribution in F5 house.

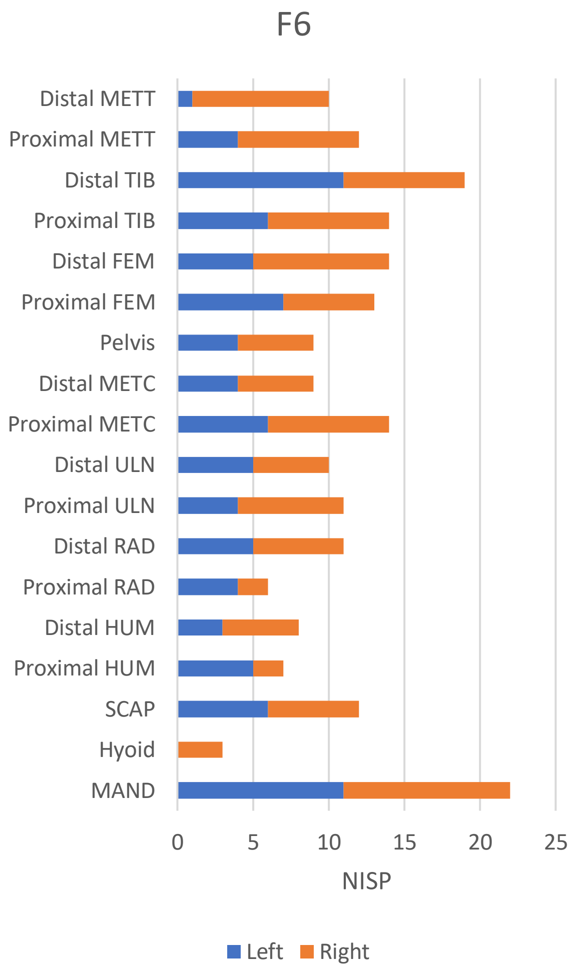


Figure 8.23 Aurochs element distribution in F6 house.

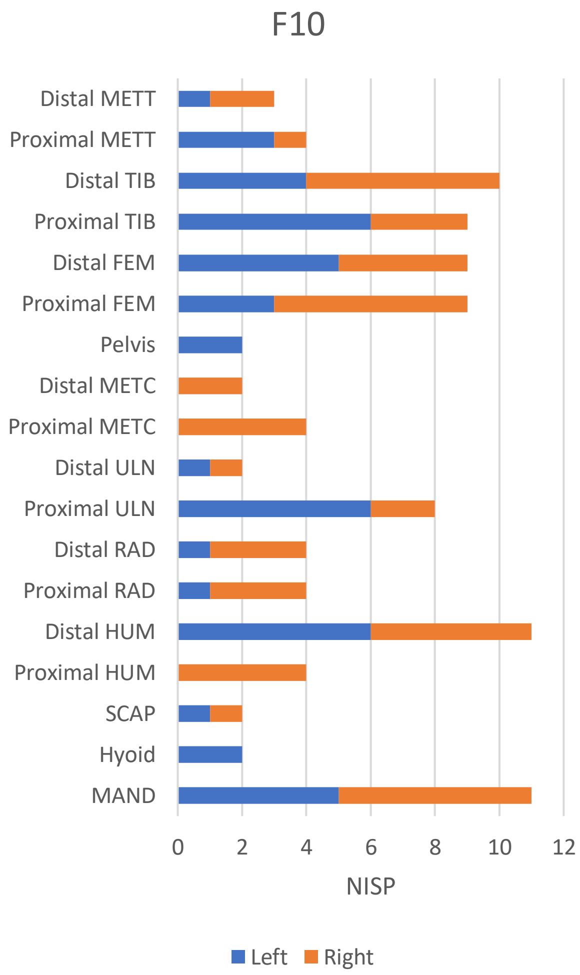


Figure 8.24 Aurochs element distribution in F10 house.

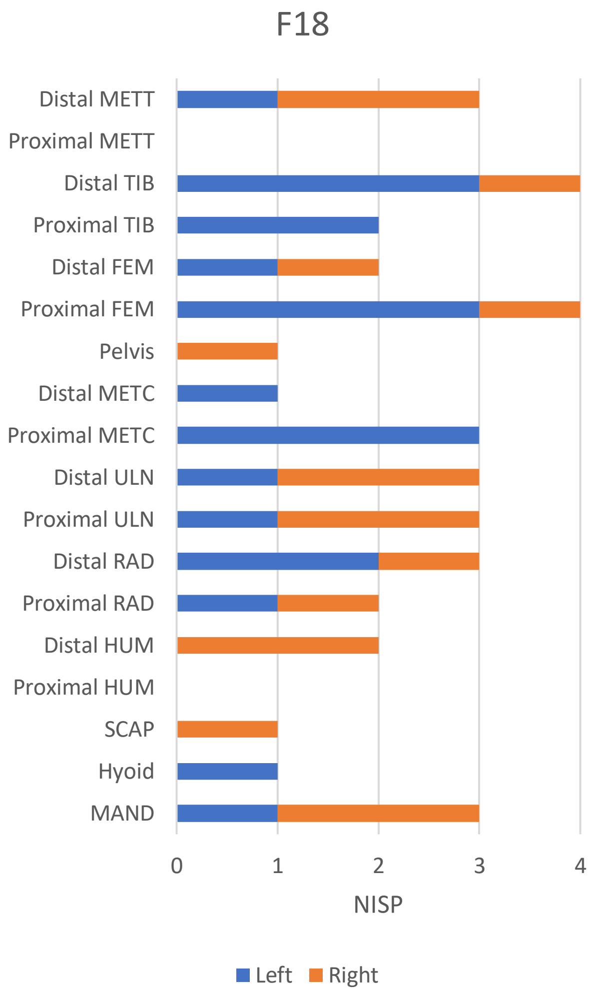


Figure 8.25 Aurochs element distribution in F18 house.

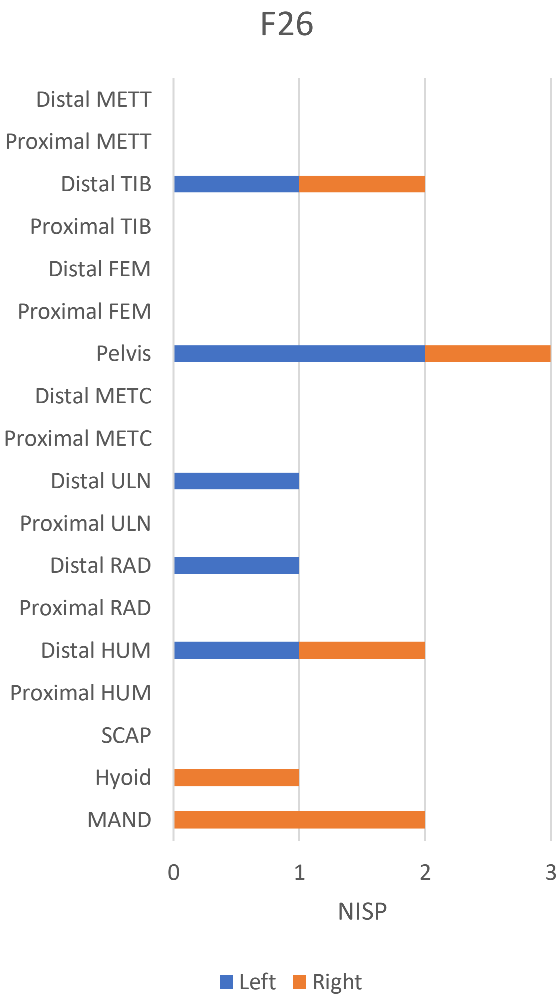


Figure 8.26 Aurochs element distribution in F26 house.

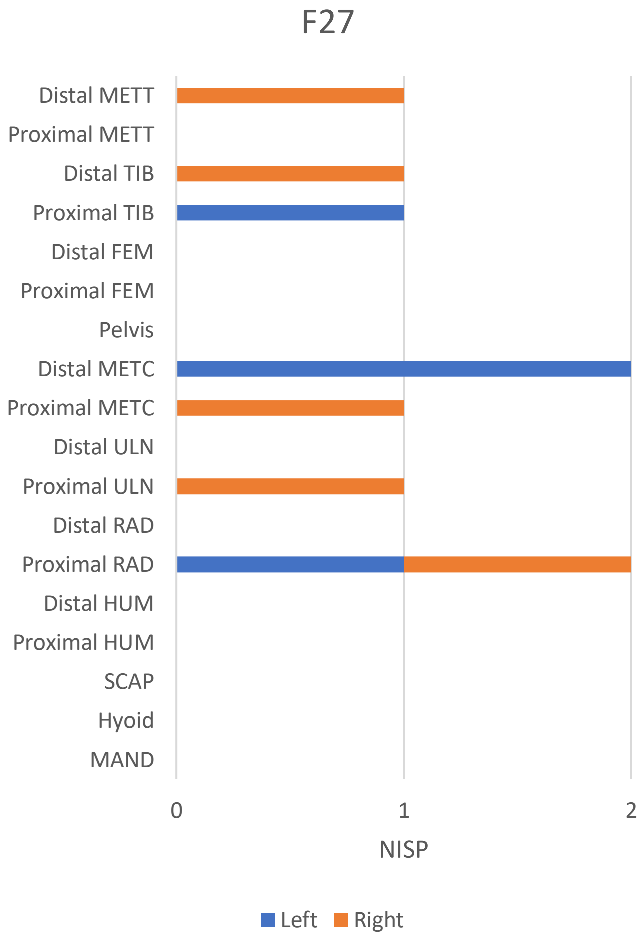


Figure 8.27 Aurochs element distribution in F27 house.

8.5 Measuring Variability with Material Wealth

Archaeologists are increasingly interested in social and economic inequality. Despite the fact that several models have been suggested by scholars, little agreement has been reached on why and how inequality emerged in prehistoric societies (e.g., Ames 1985; Hayden 2014; Smith and Choi 2007). Although assessing the archaeological records of the houses is not the primary focus of this study, it is important to understanding the G2 trench. Therefore, I use the faunal remains, as well as material artefacts and residential architecture to explore in a preliminary way possible socioeconomic disparities across Houtaomuga households.

House size is a critical indication in determining household wealth because larger houses cost more material, time, and labor (Smith et al. 2014). The simplest measurement of a house's size is its floor area. I included the number of hearths per house as an additional variable for house size because the number of persons in a family is generally proportional to the number of hearths. As markers of personal property, prestige artifacts (jade), hunting tools (e.g., arrowheads), pottery vessels, and aurochs' bones were chosen. Principal components analysis (PCA) was conducted to get a better understanding of the correlation between variables and house features. The first two components explain more than 70 percent of the variation (Table 8.8). The two components were rotated through the Varimax method (Table 8.9), and factor scores were captured for each house feature (Table 8.10).

For component one, the rotated score of aurochs, arrowheads, prestige objects, and hearths was above 0.5. The positive correlation suggested component one primarily measures the variability in material wealth and the density of people per household. F6 contributes very strongly to this component and was followed by the much weaker F10 and F18. Component two is hard to interpret since it has a strong positive association with vessel amount but a large negative correlation with house area, which contradicts the assumption that a large house in general would have more inhabitants and more utensils. F17 and F28, which are both outside houses, contribute most strongly on this positive dimension.

Table 8.8 Initial PCA statistics.

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	3.042	50.707	50.707
2	1.418	23.63	74.336
3	0.738	12.296	86.632
4	0.482	8.028	94.66
5	0.254	4.235	98.896
6	0.066	1.104	100

Table 8.9 Rotated component matrix.

	Component	
	1	2
Aurochs	0.932	0.259
Arrowhead	0.864	0.025
Prestige	0.84	-0.316
Hearth	0.746	0.289
Area	0.134	-0.867
Vessel	0.298	0.689

Table 8.10 Factor scores.

House Features	Component 1	Component 2
F2	-1.15059	-0.49611
F3	-1.02512	0.030001
F4	-0.22333	-0.00494
F5	-0.91884	0.044322
F6	4.200193	-0.50084
F10	2.470277	-0.63834
F13	0.607209	0.122934
F18	1.997251	-0.00124
F26	-1.0805	-0.45275
F27	-0.6221	0.108423
F14	-1.25461	0.117451
F16	-0.74922	-0.71551
F17	0.127321	1.539715
F23	-1.15836	-0.79214
F28	-1.21958	1.639032

8.6 Summary

It must be noted that more information, such as radiocarbon dates from inside and outside houses, is still needed to determine the occupational sequence of houses at Houtaomuga. Although we cannot get the actual house chronology, some cautious speculations can still be made. If the internal and external houses are contemporaneous, the distribution of animal species shows different patterns between the house groups inside and outside the trench, indicating that these two groups could be from differing social or ethnic communities. If the internal and external houses are actually from differing time periods, somewhat different practices are being reflected for occupations that preceded or post-dated one and other. Meat sharing probably occurred in both inside and outside households at Houtaomuga, however the combination of the second and third most frequent animals divided the inside houses into two groups, suggesting a possible distinction in social status. Except for the low correlation in the left forelimb, the high correlation among most body parts suggested most meat was concentrated in several dwellings among the inside households.

Artifacts and house structures provide evidence of possible wealth variation at Houtaomuga. There does appear to be a concentration in material wealth among house features, especially for the inside houses. These may in part reflect differences in wealth accumulation and access to resources.

Chapter 9: Conclusions

Based on the data sets I discussed in chapters 6, 7, 8, I now return to the central research questions of this dissertation presented in chapter 1.

9.1 Are the Aurochs Domestic or Wild?

The discovery of a considerable number of aurochs bones has caused me to consider whether the Houtaomuga aurochs remains might be domesticated animals. Domestication is a notable evolutionary transition in human history, regardless of whether it occurs in plants or animals. However, beyond the agreement that domestication involves a relationship between a domesticator and a domesticate, reaching a consensus on the definition of domestication is challenging. Instead of just describing the relationship between humans and nonhumans as wild or domestic, more and more scholars are accepting that there is a continuum or spectrum of relationships, with wild and domestic being the two extreme ends of the scale, and no arbitrary boundary (e.g., Marshall 2014).

Archaeological approaches to discovering animal domestication must take into account both biological and cultural processes. The most common evidence of animal domestication is a change in body size. Therefore, the Log Size Index (LSI) technique was used to combine measurements from different specimens and elements onto a single scale by means of comparison with a standard animal. The standard animal used here was a female adult aurochs from the Mesolithic Ullerslev site in Denmark. Although it is an individual from Europe, the comparison between Ullerslev aurochs and Dabusu aurochs from China indicated their similarity in size.

LSI values for the majority of Houtaomuga aurochs were smaller than the standard animals. This result is in line with a decreasing trend for documented cattle sizes that dates back to the Middle Neolithic period. The presence of small-sized cattle at sites in the middle Yellow River Valley, according to Chong (2015), is proof of China's earliest possible domestic cattle. Body size change in animals, however, is frequently influenced by various factors. Rising temperatures during the Pleistocene-Holocene transition may have had an impact on animal size, resulting in aurochs shrinking in size at Houtaomuga. In North America for example, bison chronospecies underwent a notable diminution in size during the Holocene because of changing grassland forage conditions during the Holocene (e.g., Lewis et al. 2010; Olsen and Janelle 2022). Another aspect that influences size change is the gender ratio. Although cattle are smaller and more gracile than the wild aurochs, the overlap in size between female aurochs and male cattle makes the morphological differentiation between these two groups difficult to detect. The unimodal tendency with light shoulders which was represented in density plot of LSI values for bovid bones in Houtaomuga suggested a higher proportion of female individuals, indicating that the small size of this aurochs population more likely resulted from a higher proportion of females.

The majority of aurochs lived to adulthood, indicating that humans were selective in taking aurochs. The focus on adults between 4-6 years was different from the pattern of meat production that would result from a substantial killing of young and sub-adult animals between 6-18 months. This would suggest that this mortality pattern is not the result of herding methods aimed at meat production. Specialised milk production is characterised by slaughtering profiles with two peaks for both 4 to 8 year old cows and 5 to 9 month old juveniles based upon modern sheep herds in Turkey (Payne 1973); the single slaughtering peak in Houtaomuga indicates that dairy products were not the main requirement at Houtaomuga either. Figure 8.1 depicts a prime-dominated mortality pattern, which is unusual in nature, implying that human selection is the most likely cause of this pattern.

There is no evidence of intensive millet use at Houtaomuga (Tang et al. 2020), but aurochs at Houtaomuga also had a mixed C_3/C_4 diet, likely because they were consuming wild C_4 plants in nearby wetland habitat.

The ancient DNA analysis of the 23 HT samples identified as *Bos primigenius* clearly clustered within haplogroup C, which was first identified in a *Bos primigenius* mandible from Heilongjiang in northeast China (Zhang et al. 2013). One unexpected result (sample HT31) was DNA-identified as domesticated *Bos taurus;* it belonged to haplogroup T3 (Cai et al. 2018). While certainly intriguing, a single outlier aDNA result is not sufficient to indicate that the Houtaomuga G2 trench population involved domestic cattle, especially when all other aDNA indications indicate the presence of wild aurochs.

Haplogroup C likely represents wild aurochs indigenous to China and East Asia, indicating most bovid bones from trench G2 were from the wild aurochs. Although the HT31 sample may represent the appearance of earliest known domesticated *Bos taurus* specimens in China, haplogroup C has not been reported among the mtDNA sequences that have been obtained from modern and ancient domesticated cattle from China (Cai et al. 2014; Lai et al. 2006; Lei et al. 2006), suggesting that indigenous Chinese aurochs made no genetic contribution to ancient or modern domesticated cattle in China.

That being said, it is worth bearing in mind the situation for horse domestication that Outram (2023) described in warning of the “fallacy of presentism” in genetic studies. Remarking on the clear indications of horse husbandry in central Asian Botai sites, Outram reviewed evidence that 5500 year old Botai equids were ancestors to Przewalski's horse. Domesticated horse in east Asia (and elsewhere) instead had DOM2 ancestry from the Pontic Caspian region, arising along with strong selective pressures for equestrianism in the third millennium BC. The absence of Przewalski heritage in subsequent domesticated horse populations does not mean, Outram argued, that husbandry was not occurring with earlier Botai equids. Outram (2023:9) then discusses "push and pull" factors likely to be involved in complex regional pathways to domestication. Significant episodes of introgression of wild boars during the introduction to Europe of domestic pigs from the Near East and of European dogs into North American dog populations after contact obscure initial demographic conditions (cf. Outram 2023; Larson et al. 2007; Ní Leathlobhair et al. 2018). Outram suggested (after Zeder 2011, 2015) that a "prey pathway" could lead to increasing game management and husbandry, especially for prey populations fragmenting as Holocene (and perhaps anthropogenic) conditions advanced. Recent reports suggest that there may be more to learn about east Asian aurochs. Brunson (et al., 2023) indicated that ancient Chinese cattle from the Bronze Age site of Shimao show evidence for gene flow from Mongolian aurochs, but that this ancestry signal is lost in modern East Asian cattle. There is room for caution, then, in simply asserting that the modern lineage of domestic cattle in east Asia rules out any involvement of an east Asian aurochs lineage in incipient steps toward game management or husbandry.

Although body size reduction and the stable isotope results cannot provide conclusive evidence of cattle domestication at Houtaomuga, the potential for early efforts toward aurochs management should not simply be dismissed. The presence of all skeletal elements, regardless of their low or high food value, would suggest that aurochs were slaughtered and butchered at or near the site. MNI values also document a rather large number of aurochs in a time range when they were once considered to be extinct in this region (Table 9.2).

Although reduced body sizes were detected among aurochs from Houtaomga, along with what could be a selective slaughtering pattern and somewhat unusual stable isotope results, it would be premature to conclude cattle domestication had appeared at Houtaomuga. That said, it could well be that the unusually large aurochs assemblage at Houtaomuga falls somewhere along the middle range between fully wild and fully domesticated. For these patterns to emerge, it would seem the aurochs had been living in significant numbers quite near the site and that they were a significant terrestrial meat resource in the lives of inhabitants. This suggests quite an intimate relationship between these animals and the Neolithic community at Houtaomuga ca. 5,500 years ago.

These unusual features of Houtaomuga, coupled with the presence of one animal (sample HT31) identified through aDNA testing as domesticated *Bos taurus*, suggest that the Houtaomuga villagers and the aurochs present there could have been moving somewhat along the spectrum of activities leading to domesticated cattle raising. It could be that the villagers undertook activities like selective provisioning of wild fodder and perhaps tethering (of a domesticated individual) that kept still free-ranging wild animals nearer, in efforts that amounted to a degree of taming without outright domestication.

9.2 Mass Procurement and Feasting

9.2.1 Mass Procurement in Houtaomuga

Although a genuinely substantial quantity of bone was found in the G2 trench, whether this large number of aurochs bones represents mass procurement is still unclear. It is risky to infer that a large number of bones in a deposit is simply the consequence of a single event because thick bone beds can also be caused by frequent or continuous use of a site. For example, at Runnymede, although a large quantity of bone was recovered from the site, the highly fragmented limb bones dominated by cattle and pigs, the intensive chop marks on most bones, and the high percentage of dog gnawing marks indicated that these assemblages accumulated over a long period of time and were most likely the refuse from everyday meals. In contrast, the presence of articulated joints, as well as the unimodal, limited weathering pattern on bone and the low incidence of scavenger's damage to the bones show that bone remains were buried rapidly at Houtaomuga. Additionally, gnawing marks are more common on aurochs remains from dwellings than in the trench suggesting the existence of different ways of disposing of bones in the two areas. All of the above factors, along with the tight clustering in radiocarbon dates, indicate the large quantity of aurochs remains deposited in the G2 trench resulted from either a single depositional event or a few depositional events that formed in a short period of time.

At the present time, there we have no clear indication of how this large number of aurochs could be acquired in such a short period of time. Our limited knowledge of aurochs ethology would suggest that strategies like those used to capture a more gregarious bovid, the North American bison, seem unlikely. It is conceivable that difficult to detect but incipient herd management activities designed to attract wild aurochs, as discussed below, might have been involved, allowing for capture of larger numbers of aurochs near Houtaomuga. The large number of aurochs present also raises another possibility that merits future research, namely that these one or a few large kill episodes were not in fact sustainable.

9.2.2 Feasting and the Archaeological Record

According to ethnographic evidence, most feasting activities should leave a material record to some extent, allowing archaeologists to distinguish past feasts from daily consumption (Hayden 2001).

The majority of the characteristics of feasting have originated from ethnographers' observations. Hayden (2001) was one of the first scholars to propose specific signatures as a method of recognizing feasts in the archaeological record. His criteria were fairly broad, and included rare or labour-intensive food, vessels in unusual types, sizes and numbers, particularly constructed facilities, and associated prestige and ritualized items. Twiss (2008) compiled a more thorough archaeological list of feasting traits based on the work of Hayden and other ethnographers. This list includes practically all of the characteristics that most archaeologists have used to characterize feasting, but some criteria are a little fuzzy and do not establish a threshold for defining something unusual. Furthermore, this list makes it difficult to determine both the scale of feasting and the social and political functions it served.

Food and drink are frequently used as highly symbolic media in political and symbolic expressions. Dietler (2001) suggested that the distribution and consumption of food and drink in the communal events is analogous to the practice of gift exchanges, in which both contribute to the formation and moulding of social relationships. Feasts, as a common form of communal activity, always include the consumption of food and drink. Despite the fact that both food and drink are highly perishable forms of goods, the preservation of animal bones more often provides the possibility of detecting feasts in the archaeological record. Based on the analysis of animal remains from the Neolithic and Early Bronze Ages of southern Britain, Serjeantson (2011) summarized several standards that suggested feasting took place, including large quantities of bones, the presence or absence of parts of the carcass, special butchery and culinary methods, and the selection of specific animals. Considering that animal remains are the primary materials in this research, most evidence for identifying feasting will come from the perspective of zooarchaeology. I evaluate the prospects that feasting took place at Houtaomuga based on Serjeantson's research by looking at different patterns of (1) animal selection; (2) animal quantity; and (3) food preparation and consumption.

As a feast is often described as an eating event that is deliberately distinguished from an everyday meal, it should have attributes making it possible to recognize from material records. It should be noted, however, that "feast" is a broad concept covering a variety of definitions and categories, resulting in an unbalanced level of detectability. Kassabaum (2019) developed a dual-dimensional model that characterized group size and level of sociopolitical competition, in which both factors could contribute to social and material outcomes that could result from feasting at a specific site. Although Hayden (2020) criticized her model as an oversimplification in describing competitive feasting, it does provide a useful framework for categorizing feasting. A feast in which there is both a large group size and a high level of sociopolitical competition, according to her model, often leaves impressively large and unusual materials visible in the archaeological record. On the contrary, a feast in which there is both a small group size and a low degree of sociopolitical competition is difficult to distinguish from a regular meal. As a result, although I have proposed a series of signatures for animal remain correlates of feasting based on the ethnographic and archaeological literature, it is crucial to keep in mind that not all forms of feasting are readily observable in archaeological contexts.

(1) Animal Selection

The consumption of food that is infrequently consumed or expensive to produce is one common feasting feature. In both the Tana Toraja and West Sumba cases in Indonesia, water buffaloes and pigs are generally butchered only for feasts (Adams 2005). Meat is regarded as a delicacy among the Akha of northern Thailand; it is included in a feast, whereas the regular diet consists primarily of rice and vegetables (Clark 2001). Beer and beef are generally reserved for large feasts in Luo society (Dietler 2001). Tikopia people also make unique puddings for feasts (Kirch 2001). Meat, especially meat with high fat content, has long been regarded as a special delicacy. As a result, the bones of rare animals or animals the procurement of which is labor-intensive are good indicators of feasting.

The most prevalent large animals identified in the Neolithic period in northeast China are *Bos*, *Sus*, and *Cervidae*. Despite the decline of *Cervidae* bones in the Middle Neolithic period, cervid remains still hold a strong position in the West Liao River Valley. *Sus* is the second most abundant species in this area, and its proportional growth during the Middle Neolithic period corresponds to the development of agriculture at that time (Table 9.1). The genus *Bos*, however, does not have a prominent role in either the Early or Middle Neolithic in this region. Suid remains account for more than 70% of the bones of the three major large mammals found in Haminmangha in the South Songnen Plain (Chen et al. 2016). More than 80% of the suid remains discovered in Haminmangha are skull fragments, with the majority of the fragments collected in just a few pits. Pigs are ideal animals for producing meat for feasts in both prehistoric and modern time since they have few secondary products and grow quickly. Meanwhile, the considerable number of skulls, which can be treated as trophies in some societies (Rowley-Conwy 2018), suggests that a high proportion of suid remains at Haminmangha were probably the consequence of special events. Turning back to Houtaomuga, almost 10,000 animal bones were recovered from the G2 trench, where *Bos* is by far and away the dominant large mammal (NISP = 96.11%). In comparison to the faunal assemblages from West Liao River Valley, the proportion of the G2 mammal assemblage made up of bovids is unexpectedly high, while the identified number of cervids is low. Serjeantson (2006) described a similar situation at the Runnymede site in Great Britain, where cattle apparently were not being consumed by individual households and were instead shared across the entire community. The proportion of aurochs remains at Houtaomuga is spectacularly different from roughly contemporaneous Chinese Neolithic instances.

Table 9.1 The NISP% of three major mammals in Neolithic sites of northeast China.

Site	Bos (NISP%)	Sus (NISP%)	Cervidae (NISP%)
Xiliang	2.44	7.32	90.24
Baiyinchanghan (Early)	6.54	4.09	89.37
Baiyinchanghan (Mid)	2.59	15.52	81.90
Zhaobaogou	0.41	28.34	71.25
Weijiawopu	1.12	34.83	64.04
Haminmangha	4.00	78.34	17.67
Houtaomuga (G2)	96.11	2.92	0.97

(2) Animal Quantity

Feasts entail the gathering of people in order to demonstrate authority, construct relationships, or reinforce solidarity within or among communities. During feasting, large quantities of food and drink are required, otherwise crowds would disperse quickly (Wiessner

2001). Some 300-500 pigs were slaughtered for the bigger feasts in Enga society (Wiessner 2001). Kirch (2001) claimed that one of the distinctive signatures of Tikopia feasts was quantitative rather than just qualitative, although the special pudding which is offered in Tikopia feasts would be unlikely to leave traces in the archaeological record. Those feast guests need to offer the clan chief at least 40 baskets of pudding as a gift. Oliver (1989) also stated that, among the islanders of Oceania, feasts generally consisted of larger amounts of food than usual domestic meals since they involved a larger number of eaters. One would expect archaeological records of feasting in these contexts to feature a proportionately large number of containers.

Feast size through meat weight

According to ethnographic literature, an exceptional amount of food was a general indicator of feasting. In archaeological practice, however, it is difficult to decide upon a threshold that would separate everyday accumulations from feast events. With regard to daily human consumption needs and based on modern observation, each Australian aboriginal hunter-gatherer had only 85 g of meat available to them each day (Smith and Smith 2003). Among the !Kung Bushmen from the Kalahari Desert, adults averaged 230 g of meat each day (Lee 1968). The average daily consumption of caribou is 2.5 lb (1133 g) per individual for the Nunamiut people, who have little alternative but to eat animal food due to the inaccessibility of plant food (Binford 1978). Among Inuit people, whose economy has depended heavily upon hunting of sea and land mammals and fishing, an adult could consume an average of 2.3 kg of fish and meat per day (Krogh and Krogh 1915). During the season when seals are in great abundance, young and robust adults may potentially consume 4 kg of meat per day. In the absence of many carbohydrates in northern settings, fats and greases are the important energy source (Speth 2010). Each officer at the Hudson’s Bay Company’s Fort Vermilion in Northern

Alberta ate approximately three pounds (1.4 kg) meat each day (Pyszczyk 2015). In addition to the enormous amount of fresh meat that was consumed in a Fort Vermilion of Peace River Post during the season of 1826-1827, 2469 pounds of grease played a significant role in the daily meals (Ives, 1990).

The aurochs remains stand out among other species in trench G2 at Houtaomuga. Aurochs provide more than 80% of the animal bones, allowing for a quantitative examination of the meat available. The excavated aurochs remains would supply at least 8000 and perhaps as much as 15000 kg of meat, based on the comparable liveweight of bison and meat distribution in cattle. If most of the flesh from these aurochs was not preserved through drying (something for which archaeological evidence is more difficult to adduce), a considerable quantity of meat was immediately available, and it far exceeded human demands for daily consumption.

Other than the meat from associated bone units, the internal organs, such as the heart, liver, kidney, and tongue, were often eaten by prehistoric and historic people. For example, in North America, Assiniboine people relished the buffalo tongue, liver, kidneys and rennet. The tongue was cooked before being eaten while the liver, kidneys and tripe were eaten raw (Kennedy and Stevens 1972). Among Blackfoot peoples, buffalo bull tongues were the sacred food to be used in ceremonial context (Ewers 1958). Although the traces of handling and consuming organ meat are difficult to observe since they generally have no bones that can be preserved, the stylohyoid, which is the largest bone of the hyoid complex located at the base of the mandible in most ungulates, is a rare bone that does preserve and may provide evidence of the consumption of tongue. At Houtaomuga, 10 out of 34 stylohyoid specimens of aurochs display butchery cutmarks, implying the aurochs tongues at Houtaomuga were butchered and removed intentionally. Chinese cuisine has a long tradition of using organ meat, and all parts of the animal, including organs, blood, and skin, are utilized in modern Chinese cooking (Nam et al. 2010). Therefore, it is reasonable to believe that not only muscle meat, but organ meat was also involved in the recipes of the Houtaomuga people. According to the estimation in section 7.11, the entire trench may contain approximately 2000 kg of organ meat adding an additional quantity of rich food for the Houtaomuga people that would need to be consumed in a short period of time.

Demirergi (2015) assumed that a portion size may range from a piece as small as a meatball (30g) to a piece as large as a 500 g steak, and then estimated the number of people and families possibly served at feasts in Çatalhöyük with portion sizes 30, 265 and 500 grams. Based on the daily consumption of Nunamiut, Inuit and the fur trade, however, Demirergi's estimation of meat size served in feasts may be too small for a more northerly site like Houtaomuga. I propose that gradations of 1 kg, 2 kg, and 4 kg of animal products would be more appropriate quantities consumed per participants in feasting at Houtaomuga. Table 9.2 illustrates the huge number of people that could be served varying proportions based on muscle meat and organ meat weight. If all the aurochs muscle and organ meat were consumed in a single event, even the smallest number of people consuming the largest portions would reach roughly 4500 individuals, which far exceeds the population in this village.

Table 9.2 Number of people represented by the muscle meat and organ meat weight.

	Portion (kg)	Usable muscle meat weight (kg)	# of people	Usable organ weight (kg)	# of people
Excavated trench	1	8306-15029	8306-15029	1000	1000
	2		4153-7515		500
	4		2077-3757		250
Whole trench	1	16000-30000	16000-30000	2000	2000
	2		8000-15000		1000
	4		4000-7500		500

It should be noted that additional visitors from neighboring villages could also be invited to attend the feast. The raw materials used for lithic tools provide a glimpse of this. Obsidian, which is mostly found in the Changbai Mountain region, was used to make nearly 21.24% of the lithic tools from Houtaomuga, indicating possible exchange or long-distance transit (Kong 2021). An additional source of evidence lies with the jade ornaments. Nephrite use in Northeast Aisa can be traced back to the Upper Paleolithic. According to Tang et al. (2016), there are two nephrite mineral resources in the wider region. One is from the Cis-Baikal region and contains both light and dark green colored nephrite; the other is a yellow-green variety known as Xiuyan type nephrite that is from west Liaoning and is also found in the Hongshan culture (Tang et al. 2018; Tsydenova et al. 2015). The jade accessories discovered in Houtaomuga, however, were made of white translucent nephrite, which is not present in Xiuyan, raising the possibility that the prehistoric inhabitants transported or exchanged nephrite from other areas, such as Baikal region, to Houtaomuga. Although it would be difficult to distinguish prestige and exotic items for feasting from simple direct exchange for practical purposes, it should be considered that feasting might serve to attract people from surrounding villages or perhaps a much wider region.

Population estimation through house number and size

Although it is difficult to assess accurately the Houtaomuga Neolithic population from the archaeological materials, some proxies, such as the number and sizes of houses within settlements, the areal extent of settlements, and the economic potential of the catchment areas around population centers, can be used for estimating relative population size and density (Chamberlain 2009). One of the most important and widely used methods has focused on relating the population to household size. This method involves estimation regarding the size of the average family inhabiting the individual dwellings based on ethnographic analogy. In Houtaomuga, around the G2 trench, many house structures were also excavated, providing data for estimates of the relative population.

The structure of Houtaomuga houses is similar to houses in the Hongshan culture: most houses are between 20 and 50 m^2; they are square in plan, and in most cases, have only one central hearth in the whole dwelling (Drennan et al. 2017, Peterson et al. 2010). Given this structure and size, it might be reasonable to assume that each house was occupied by a nuclear family rather than a large extended family.

The next problem is to decide the size of the average family size associated with the residential unit. Based on the 12 examples from the American Southwest, Cook (1972) reported that the normal nuclear family ranged from 4.5 to 6.0 persons, and suggested that the figure of

5.0 persons was suitable for the average nuclear family size. Haviland (1972) suggested an average of 5 people per nuclear family as the safe estimate of the average size of the group which lived in a single house at the Maya site Tikal. After reviewing the ethnohistoric and ethnographic evidence on household size and dwelling area in Mesoamerica, Kolb et al. (1985) proposed a little higher figure, 5.5 persons per household, for archaeological applications in the Mesoamerican highlands. Nutini (1967) examined the communities from diverse ecological zones throughout Mesoamerica and proposed that the mean average household varied perhaps from 5.5 to 7.5. At Baiyinchanghan, a Hongshan village in northeast China, the nuclear family size was assumed to be 3 to 6 people per house (Drennan et al. 2017). Given the variation between different ethnographic regions and groups, it is difficult to be certain of a universal family size value that can be used in estimating the population from different archaeological cultures and sites. For Houtaomuga, because the house size is bigger than Hongshan houses (most Hongshan houses are between 20 to 30 m^2), 3-7 people would provide a reasonable range for estimating the average size of the family that lived in a single house.

Houtaomuga has a total surface area of 1,410,000 m^2 and shows a high density of finds across an area of 550,000 m^2. The 2011 to 2015 excavations exposed 6450.71 m^2. In the excavated part, 24 dwellings, which were from the same culture phase of the G2 trench, were uncovered. However, not all the uncovered houses were occupied simultaneously, and based on the discussion in section 8.2, one could suggest that 15 houses might potentially have been used concurrently. If each house contained 3-7 people, the 15 houses might have contained between 45 and105 people; because this is one-ninth of the area with a high density of archaeological materials, the site may have had anywhere from 405 to 945 inhabitants.

Where did the meat go?

The scale of feasts varies greatly. They can be held by a nuclear family and perhaps a few more individuals to commemorate important events, including birth, death, house construction and renovation, in a family's lifecycle. Clark (1998) observed a small ancestor offering feast among the Akha of northern Thailand. It was held inside a family home and only one chicken was killed in this event. Feasts can also be inter-community events that may involve hundreds or thousands of people. Among western Enga, a sizable Kepele cult feast was documented by Wiessner (2001). It is the most significant event for the whole tribe, and between 300 and 500 pigs were butchered during the single event.

Looking back at the available meat products that can be extrapolated from the excavated aurochs bones, the total quantity of meat is immense. If those products were consumed in a single feast, the number of people they would feed far exceed the population of the whole village. How then did Houtaomuga people treat the surplus that would exist after even extensive feasting?

The most common strategy for coping with huge food surpluses was food storage. Storage was a crucial socioeconomic response to get through times of scarcity even in forager communities, which were characterized by limited food storage in the past (Kuijt 2009; Stopp 2002). According to the historic documents from early Aboriginal groups in the northeastern subarctic, however, indigenous people could ensure food supplies through dehydration, freezing, fermentation, and preservation of fat and oils (Stopp 2002). Binford (1978) suggested that the Nunamiut selected animal parts for drying relative to conditions deemed optimal for preservation. He then established the Drying Utility Index (DUI) to predict which carcass portions would be selected for storage by drying. Friesen (2001) simplified Binford's derivation and presented the Meat Drying Index (MDI). Although the negative correlation between MDI and aurochs element frequency likely implies the absence of meat drying (see section 7.10), other lines of evidence indicated that we should not overlook the possibility of meat storage at Houtaomuga.

Meat drying requires that a maximum amount of surface area be exposed in order to ensure the rapid desiccation. Therefore, the highest value parts in meat drying, according to Binford (1978), include the vertebrae, ribs, scapulae and pelvises, where the meat is distributed in a relatively thin layer on the bone. Additionally, he observed that Nunamiut people would frequently place the complete vertebral column with the ribs still attached on their drying racks before stripping the meat. The large number of articulated vertebrae units discovered in the G2 trench may suggest that those elements were treated as a single unit that could possibly have been suspended on drying racks. Although no features of drying racks, such as postholes, were revealed in the current excavation area, the possibility of discovery in the much larger unexcavated areas cannot be ruled out.

The high proportion of scorched burning marks on the middle shaft of long bone indicated that thin meat layers were likely attached to the bones during exposure to heat. This pattern would suggest that Hougmuga people stripped the meat from the limb bones before exposing them to heat.

Even though aurochs in G2 provided a large amount of muscle meat, Houtaomuga residents might not have favored those products. The heating and fracturing of abundant skeletal elements demonstrated that Houtaomuga people had great interest in securing marrow (see section 7.10). According to Hennepin (1698), indigenous people living near the Great Lakes "…sometimes kill'd forty or fifty, but took only the tongues, and some other of the best pieces." McKenzie witnessed the great slaughter of Buffalo at the Missouri (Wood and Thiessen 1985).

Around 250 cattle were killed in hunting, and other parts were left on the field aside from the tongues, which were dried for the feast. According to Smith (1975), caribou were killed in huge numbers by the Chipewyan in the Arctic for their hides, and only small parts, such as tongues, were consumed while the remaining parts were left to rot. Speth (2022a) argued that traditional northern foragers very much appreciated the fatty meat cuts, such as those where fat is concentrated around the neck, hump, and rump, as well as internal organs and marrow. Based on the aurochs meat product estimates for Houtaomuga, the number of people who could have been served at a single event feast could range from 4500 to 32000, assuming generous portion sizes ranging from 1kg to 4kg per day, and no differentiation of the meat products. This figure is much bigger than the Houtaomuga population which was estimated from dwellings. The higher end of the estimate would be large even for a regional population. The majority of the meat products would nevertheless be extremely lean, making their food value to a certain degree illusory. If, the Houtaomuga villagers were focused upon organ meat, bodily fat deposits and marrow, the energy rich portions of the carcass, then aurochs remains from G2 could reflect a feast for just the whole village in closer accord to the population I have estimated here. Therefore, it would be reasonable to infer that the extensive number of aurochs were killed and butchered so that the marrow and organ meat became the initial and favored food consumed during feasting.

The much larger proportion of muscle meat at Houtaomuga could perhaps have been stored, through meat drying. Beyond that, as Speth (2022b) argued persuasively, the very large quantity of muscle meat, massive though it would be, was typically not highly valued by northern hunter-gatherer populations. It could have ended up being used as dog food or left behind to be consumed by other predators and scavengers. In his 2022 Kroon-Voordrach lecture, Speth (2022b) raised another possibility. Modern sensibilities lead us to think that spoiling or decomposing meat products are both unpalatable and potentially dangerous from a health perspective. Speth reviewed extensive historical literature showing that old and decomposing meat in various forms was very often regarded as a delicacy in Inuit, Plains and other societies, and was frequently consumed without ill effects. Even without extensive storage provisions such as smoking and drying, it is conceivable that significant quantities of muscle meat were consumed at a later time. The skeletal element abundances from numerous other pits at Houtaomuga may provide relevant evidence for such practices.

Besides the G2 trench, there are also some pits that contained a large quantity of aurochs bones at Houtaomuga. More than two hundred pits were uncovered, and according to the information from excavation records, several of them showed a bone deposition pattern resembling that for the G2 trench, indicating a possibly related feasting behaviour (Figure 9.1).

Figure 9.1 A photo of pit H31; note the vertebrae are still in articulation.

The initial identification of the bones from pits was completed by Chen (2019) in her dissertation. Based on her work, pits that have signs of feasting are: H9, H18, H19, H22, H25, H31, H129, H257, H258, H261, and H263. Appendix 3 presents the degree of correlation between the pits and the MUI and UMI. With the exception of pit H129, aurochs skeletal element abundances from other pits are positively correlated with MUI values (r range: 0.4573 to 0.9511; p-value:0.3022 to 0.0037; r_s range: 0.5045 to 0.9910; p-value: 0.3503 to 0.0000), a pattern that is consistent with the scenarios we saw in G2 trench and house features. Contrary to the negative correlation between trench G2 and the MUI, the abundances of the skeletal elements in the majority of pits are either strongly or weakly positively correlated with MUI (r range: 0.1046 to 0.5875; p-value: 0.7338 to 0.0348; r_s range: 0.0991 to 0.6778; p-value: 0.7404 to 0.0054), showing a preference for meat bearing parts in pit depositions. This would imply that some pits may play a different role in feasting compared to the G2 trench. Houtaomuga people either intentionally cached meat in pits or dumped bones in pits after consuming the meat on them. The intentional caching of leaner meat or meat rich butchering units in other pits might explain where some of the surplus meat products went during or after a feasting event.

In addition to the idea that all the meat was consumed in a single event, another possible scenario at Houtaomuga would be that the structure of the G2 trench suggests that a sequence of feasting events may have occurred over several years or even a few decades. Based on the excavated area, G2 is not a continuous trench and was divided into at least three segments (Figure 1.2). If each segment represented the midden after one feast event, then the quantity of meat would not seem so tremendous. Radiocarbon dates from different segments might provide more evidence of this in the future, although the calibration “wiggle” at this particular interval would be a challenge to clearer resolution.

(3) Food preparation and consumption

The special treatment and consumption of feasting food can help us have a better understanding of feasting behaviour. This different pattern is mostly due to the fact that the provision and consumption of ample food takes place in short term ritual or social contexts where food takes on special meanings. Large quantities of prestige goods, such as blankets and canoes were accumulated and redistributed or even destroyed in competitive feasts on America’s

Northwest Coast, for example, in order to express personal power and wealth (Hayden 1996). Pronouncements of authority and social position were also accompanied by conspicuous display and consumption of food, or even its wastage. Among Polynesians, the kumara (the sweet potato) was produced in large quantities and displayed on conical food stages or towers (Leach 2003).

Although the assemblage from the G2 trench at Houtaomuga has all aurochs parts, there is a high number of limb bones in contrast to the few skulls and vertebrae. According to the density study in appendix 1.2, post-depositional attrition had little effect on preservation of aurochs bones at Houtaomuga. It is possible that some skulls and vertebrae were deposited in a part of site that is still uncovered. Whether or not this is true, however, the pattern for the G2 trench clearly resulted from human selection. Depending on the locus of procurement, these elements may have been rarely transported to this part of the site because of their low utility as food resources. It is also possible that the skulls were displayed as trophies, as can be observed among modern people or at major bison kills (Adams 2005; Brink 2008; Hayden 2001). While brains are a fat rich food source, they also provide raw materials for tanning processes, where human needs for hide processing and clothing are significant considerations (for examples of specific, seasonal prey targeting for caribou, antelope and bison hides for clothing and lodge purposes, see Binford 1978; Brink 2008; Grinnell 1972; Shirazi et al. 2022; Speth 2022a). Stone tools offered the other clue to hide processing at Houtaomuga. At the fourth phase at Houtaomuga, Kong (2021) observed a large increase in stone scrapers, particularly end scrapers, indicating a rise in the demand for hide processing during this time (Figure 9.2). This provides more evidence that, in addition to food products, the acquisition of hide was an important consideration in the mass killing of aurochs.

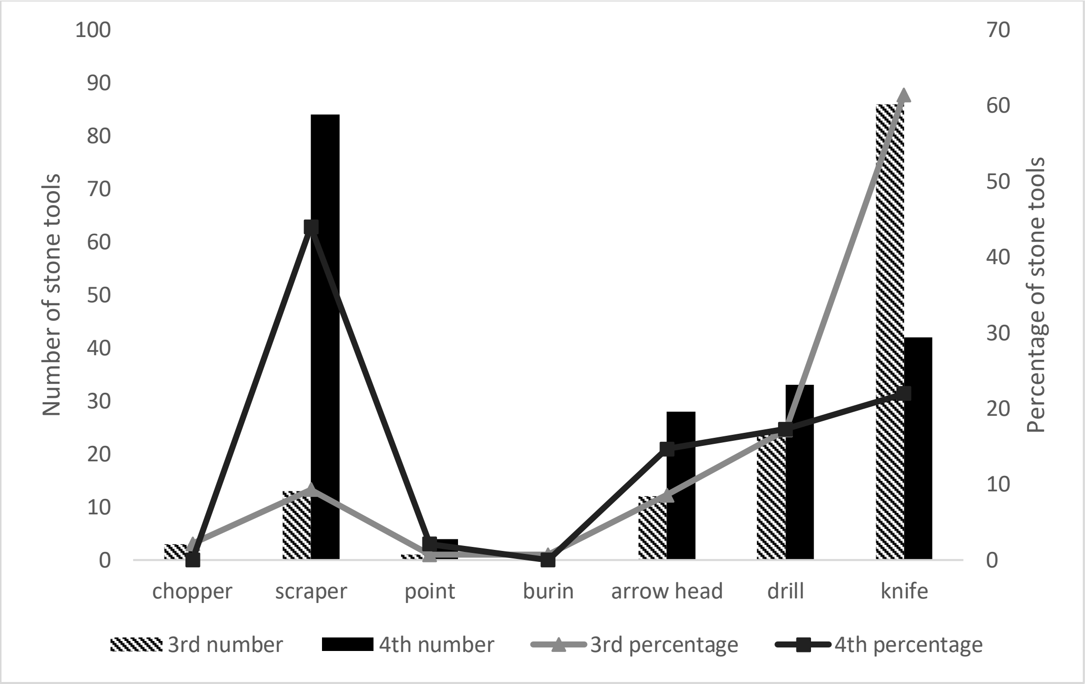


Figure 9.2 The number and percentage of stone tools in 3rd and 4th phase from Houtaomuga (made from Kong 2021).

In the absence of regular dietary carbohydrates, the crucial nutritional element that is required to support human existence is animal fat. This is especially true for northern Indigenous peoples who must primarily rely on animal foods and cannot rely on carbohydrates from plant foods (Speth 2022a). Inuit hunters typically break up the caribou long bones into small pieces before boiling them to extract fat. By mid-Holocene times, severe comminution of bone with greases being extracted through the use of hide-lined boiling pits became a significant part of many North American Plains economies (e.g., Brink 2008). These fats and greases were used to prepare pemmican, which could be preserved for a few months or even years (Loring 1997). However, at Houtaomuga, butchery marks, primarily cut, chop, and scrape marks, are uncommon on aurochs from the G2 trench. Most limb bones exhibit better preservation for distal ends than the shaft. The comparable fracture of pig long bones from Haminmangha was a result of marrow extraction according to Chen et al. (2016), and I believe this to be true for my sample as well. The presence of articulated units also provides supporting evidence. Unlike the bone breakage pattern among northern Indigenous peoples, the aurochs carcasses were apparently butchered and processed less intensively at Houtaomuga, where tangible signs like boiling pits and large quantities of comminuted bone are absent.

Scorching marks on the mid-shaft of long bones, which are generally yellow or brown but never black or calcined white, are the most common thermal alterations on aurochs bones at Houtaomuga. These marks are often adjacent to breaks, indicating that they may be related to a marrow extraction technique. Zierhut (1967) observed precisely this technique among the Calling Lake Cree (Neheyaw) people who often roasted moose bones over an open fire for a brief time to soften them before striking the bone in the middle with the blunt end of an axe to extract the marrow. The scorch marks on bones at Houtaomuga look very much like the result of a similar procedure. Researchers also noticed this pattern of burn marks at both the Durrington Walls and Runnymede sites (Albarella and Serjeantson 2002; Serjeantson 2006). They proposed that cattle bones were heated before extracting marrow. Of course, marrow may be viewed as a delicacy and consumed in the context of feasting.

Another crucial indicator of feasts is pottery vessels. However, it is currently challenging to obtain evidence along these lines because there is not yet a thorough analysis of Houtaomuga ceramics. If unusual quantities and sizes of pottery are documented during future research, this could contribute another perspective regarding what happened to the copious meat products at Houtaomuga.

9.3 Aurochs, Feasts, and the Circular Trench

Houtaomuga has two concentric ditching rings that separate the pattern of dwellings in the village into inside and outer regions, as seen in figure 8.1. The inside ring is the G2 trench, the main research focus in this study. In light of the faunal and other information that has been presented, I return to the last question that I posed in Chapter 1 referring to the practical purpose and possibly the symbolic and social implications of the G2 trench.

In many regions of the world, ditches, sometimes known as moats or causewayed enclosures, are common constructions (Andersen 2004; Carr 2005; Darling 2016; Diachenko and Menotti 2017; Everhart 2021; Henry et al. 2020; Márquez-Romero and Jiménez-Jáimez 2013; Parkinson and Duffy 2007; Pärssinen et al. 2009; Peña-Monné et al. 2014; Saunaluoma 2012; Saunaluoma et al. 2018; Scott and O'Reilly 2017; Usman 2004; Zhuang et al. 2017). Their functional roles are frequently emphasized. This is the case for the common early interpretations of these features as defensive moats. Three defensive moats from Puig Pelegrí, Cabezo de la Cruz, and Carrassumada in northeast Spain were studied to reconstruct their evolution and construction processes (Peña-Monné et al. 2014). These examples were generally part of a larger defensive system, and their appearance was frequently accompanied by walls or palisades. The moats are generally built outside of embankments to increase defensive effectiveness. This is also true among several prehistoric moats found in north China (Zhuang et al. 2017). Late Neolithic moats and rammed-earth walls are extensively discussed among Chinese archaeologists for their defensive purposes. Another significant component for defensive purposes is the width and depth (Pärssinen et al. 2009; Peña-Monné et al. 2014). The moat at Cabezo de la Cruz was around 4 m wide, reaching 5 m in its widest position; the Carrassumada moat is considerably broader, with an upper width of 13 m, a basal width of 9 m, and a depth reaching 9 m (Peña-Monné et al. 2014). However, there is no trace of a wall or other defensive structure near the G2 trench at Houtaomuga, which is only about 1 m broad and less than 0.5 m deep. These are modest dimensions that could not functionally support defensive purposes.

During the last 20 years of archaeological research on enclosures, with increasing concerns about the roles such structures could have with respect to symbolism and monumentality, non-functionalist interpretations began to be seriously considered in ditch studies (Andersen 2004; Everhart 2021; Parkinson and Duffy 2007). It is reasonable to assume that the G2 trench was not used for defensive purposes based on its construction and bone infilling. We cannot entirely exclude the potential of other functions: such massive quantities of bone (and likely, adhering tissues) would be attractive to scavengers and predators, factors that might make it practical to undertake immediate reburial given that intensive bone comminution for fat and grease extraction did not take place.

That said, the likelihood of large-scale feasting, which in this case would have been accompanied by one or a very few slaughter events, raises the matter of the motivations and other social dimensions that might have been involved in the selective, perhaps communal hunting of so many aurochs, and their subsequent rapid consumption and burial.

The construction of circular enclosures was prevalent in Western Europe throughout the Neolithic period. The infill assemblages discovered in ditches, which include local or non-local soil, artifacts, and ecofacts, are assumed to have been the consequence of intentional human activities (Márquez-Romero and Jiménez-Jáimez 2013). Massive numbers of faunal remains have also been discovered, similar to those found in trench G2 at Houtaomuga. The well-known Late Neolithic henge enclosures of Durrington Walls were found in southern Britain. The Southern and Northern Circles were discovered during the main excavation in 1966-67, with significant bone remains uncovered in the Southern Circle's trench (Wainwright and Longworth 1971). The henge enclosures have been interpreted as ceremonial, or at least partially ceremonial, sites in general. The bones of the two primary species – pigs and cattle – were analysed by Albarella and Serjeantson (2002), who confirmed the original hypothesis that the site was utilized for ceremonies and feasts on a large scale.

Given that the rapid deposition of massive quantities of aurochs bones in the G2 trench is consistent with evidence for feast events, it is crucial to devote some thought to the role this circular ditch may have had with respect to feasting at Houtaomuga. Some practical benefits, such as resource redistribution, mobilization of labour, the shaping of inter- or intra-community social relationships, and the creation of political power are typical of feasts resulting from episodes of communal gathering (Dietler 2001).

Periodic ceremonial feasts, such as funerals, weddings, and new house constructions serve a significant role in advancing sociopolitical interests and reinforcing social group cohesiveness (Adams 2005). Based on the current excavation, the G2 trench is approximately 86 meters long. Despite the fact that the ditch is not extremely deep or wide, digging such a long trench required a substantial amount of labour. Because large-scale ditched enclosures demand a large labour force, Parkinson and Duffy (2007) concluded that the act of constructing these enclosures may have been an important social event in and of itself, and thus, one impetus for feasting.

Feasts may have also allowed social groups to emphasize their commonalities and differences with activities that could enhance alliances or reinforce ethnic identities (Dietler 2001; Hayden 2001). Ethnic groups, according to Barth (1998), do not form simply on the basis of shared underlying cultural values; instead, they only persist as different units if they entail significant behavioural differences. Feasting, as a communal event, is frequently employed in the creation of a shared image to increase sensory memory so that social group identification can be stressed in this process. If the house structures at Houtaomuga are contemporaneous, the circular G2 trench split the households into two groups, with one group occupying the internal space and the other occupying the exterior space. The species distribution is clearly different between the house features in internal and external spaces, as I described in Chapter 8. In the internal dwellings, aurochs dominate the animal assemblage, but in the external houses, raccoon dogs take their place.

If both the interior and external dwellings were built and used at the same time and belong to the same population, both feasting and the G2 trench could have played a role in highlighting variations in social status reflected in the two sets of structures, or in emphasizing the group boundary between two groups when living at Houtaomuga. One would expect to find differences in the use and consumption of objects (serving vessels, decorative objects, etc.) that are materialized signs of a particular social identity. If the trench represented the boundary between two communities with different subsistence strategies, such as existed with the interdependent relationships between sedentary Palanan farmers and their Agta hunter-gatherer neighbors in the Philippines, we would expect to find features and artifacts with the characteristics of different peoples.

If we assume that the internal and external house locations were occupied sequentially, the difference in animal species could be due to the deposition from distinct behaviours arising from developmental processes. For example, the houses outside the G2 trench might reflect a simpler, earlier community that then engaged in the more elaborate layout of the interior houses, accompanied by trench digging and feasting. On the other hand, the structured layout of houses inside the G2 trench might have resulted when an earlier, somewhat more complex social setting broke down in time, leading to the more loosely aggregated exterior structures. Further research seeking to see if vessels of unusually large size, number, and quality are associated with interior structures in contrast to structures outside the G2 trench with a smaller number of normal size and quality vessels would be valuable, as would be further efforts to refine a well-dated chronology for the internal and external house structures.

9.4 Conclusion

The mammal bones discovered in the G2 trench and house features of the 4th cultural phase provide unique insights into living conditions at Houtaomuga during this part of the Neolithic. The substantial number of aurochs bones, quickly deposited in the lengthy G2 trench, as well as the massive quantity meat and other products this would represent, must have resulted from communal consumption, most likely large-scale feasting. The placement of the G2 trench, separating internal and external house structures, strongly suggests that it was built for symbolic and social reasons rather than for purely functional purposes. While there is no conclusive evidence of aurochs domestication arising from the Houtaomuga record, the circumstances are unusual: a large number of aurochs were acquired, butchered and consumed in a short period of time, after which these wild animals would be rare. This is suggestive of an intimate relationship between the Houtaomuga villagers and an aurochs population that might reflect incipient interests and activities capable of leading to the eventual presence of domesticated cattle, a topic of broader Neolithic interest. Yet more detailed studies of pottery and lithic assemblages, along with further radiocarbon dating, will be required to build a more complete picture of the fascinating circumstances at Houtaomuga some 5500 years ago. Houtaomuga promises to be an important site in larger comparative studies as our understanding of economic, social and political conditions in Neolithic northeast China continues to grow.

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Appendices

Appendix 1: Biometric dataset of modern cattle from Zooarchaeology Laboratory of Jilin University.

		Cattle (male) (mm)		Cattle (female) (mm)	
Element	Measurements	L	R	L	R
Scapula	HS	310.76	310.72	327.18	325.14
	DHA	315.28	319.52	330.01	330.02
	Ld	192.69	193.79	192.62	194.24
	GLP	87.74	87.16	69.84	68.49
	LG	74.54	73.53	59.51	58.42
	BG	59.88	60.42	48.89	48.57
Humerus	GL	296.66		284.53	284.76
	GLC	281.28	281.48	248.01	245.71
	BP	111.09		96.17	96.72
	Bd	111.12	107.05	81.01	80.24
	BT	95.31	95.19	75.81	75.84
Radius	GL	294.14	295.32	265.62	264.63
	Bp	100.72	100.91	81.83	82.94
	BFp	87.44	88.7	73.75	73.69
	Bd	88.45	88.28	75.32	76.21
	BFd	78.1	80.22	62.69	62.27
Ulna	GL	356.3	358.12	321.84	320.98
	LO	74.24	74.87	93.66	92.23
	DPA	51.59	53.27	49.32	48.28
Femur	GL	383.34	382.12	344.64	346.01
	GLC	374.7	374.54	323.89	323.95
	Bp	142.92	141.77	126.52	125.79
	Bd	115.61	115.53	97.68	97.02
Tibia	GL	369.04	369.3	323.56	324.12
	Bp	113.88	14.84	98.88	99.19
	Bd	81.19	81.75	65.02	65.29
Metacarpal	GL	230.74	228.78	228.09	227.86
	Bp	73.57	73.35	71.91	71.58
	Bd	71.44	70.27	69.09	68.87
Metatarsal	GL	255.39			257.78
	Bp	67.59		63.09	63.29
	Bd	60.94	60.88	67.63	66.36
Calcaneus	GL	140.04	140.09		
	GB	59.84	58.98		

Astragalus	GLl	87.58
	GLm	80.67
	Bp	56.49
	DI	53.12
	Dm	52.41

Appendix 2: Bone Density Mediation

Bone preservation is affected by many factors, such as carnivore ravaging, soil acidity, weathering, or even different collection strategies, and these factors appear linked, in part, to physical properties. Thus, an interpretation of the relationship between animal skeletal representations and human decision making requires assessment of post-depositional attrition influences.

Many researchers have observed that structural density exerts a strong influence on the frequent discovery of skeletal parts (Brain 1967, 1969; Guthrie 1967). Lyman introduced the photon densitometry (PD) technique to derive bone mineral density for specific parts of skeletal elements (Lyman 1984). Subsequent researchers used the same method and generated a different index of bone structural density for marmot, bison, seal, camelids, leporids and so on (Elkin 1995; Kreutzer 1992; Lyman 1994; Lyman et al. 1992; Pavao and Stahl 1999; Stahl 1999). Lam et al. (1998) argued that the technique of photon densitometry underestimated bone mineral density values because it ignored the effects of different shapes and the presence of cavities. Lam employed computed tomography (CT), which produces a clear radiographic image of the cross-section of the bone and allows the medullary cavity to be excluded from the calculation of bone density.

Because aurochs is the dominant species in the G2 trench, it was selected for the investigation of the role of density-mediated attrition at Houtaomuga. Several structural density values are available for examination. Kreutzer (1992) measured bison bone density using a dual energy X-ray densitometer; compared to Lyman et al. (1992), who only provided the measurement of the bone mineral mass of the scan length, Kreutzer measured the bone mineral density in three dimensions (width, length, and thickness). As Lyman's density values for deer are more highly correlated to the marmot derived from the same method than Kreutzer's bison values from a different method, Lam proposed that methodological differences are bigger than the intertaxonomic differences in bone density patterns (Lam et al. 1999; Lam et al. 2003). Therefore, he suggested that density values of caprid long bones can be used in the study of other ungulates. In this study, I selected both Kreutzer and Lam's data, which were obtained from different methods, to test the influence of bone density in skeletal frequencies (Appendix 2.1-2.2).

Appendix 2.1 Percent survival of G2 trench aurochs scan sites (Kreutzer 1992; Lam et al. 2003)

Element	Scan site	MNE	MAU	%Survivorship	Density (PD)	Density (CT)
Mandible	DN6	11	5.5	6.1	0.57	
	DN7	31	15.5	17.2	0.49	
	DN8	31	15.5	17.2	0.79	
Hyoid		24	12	13.3	0.36	
Thoracic	TH2	156	12	13.3	0.38	
Scapula	SP1	113	56.6	62.9	0.5	
	SP2	9	4.5	5.0	0.48	
Humerus	HU1	79	39.5	43.9	0.24	0.3
	HU2	18	9	10.0	0.25	0.341
	HU3	61	30.5	33.9	0.45	1.152
	HU4	180	90	100.0	0.48	0.982
	HU5	157	78.5	87.2	0.38	0.559
Radius	RA1	133	66.5	73.9	0.48	0.662

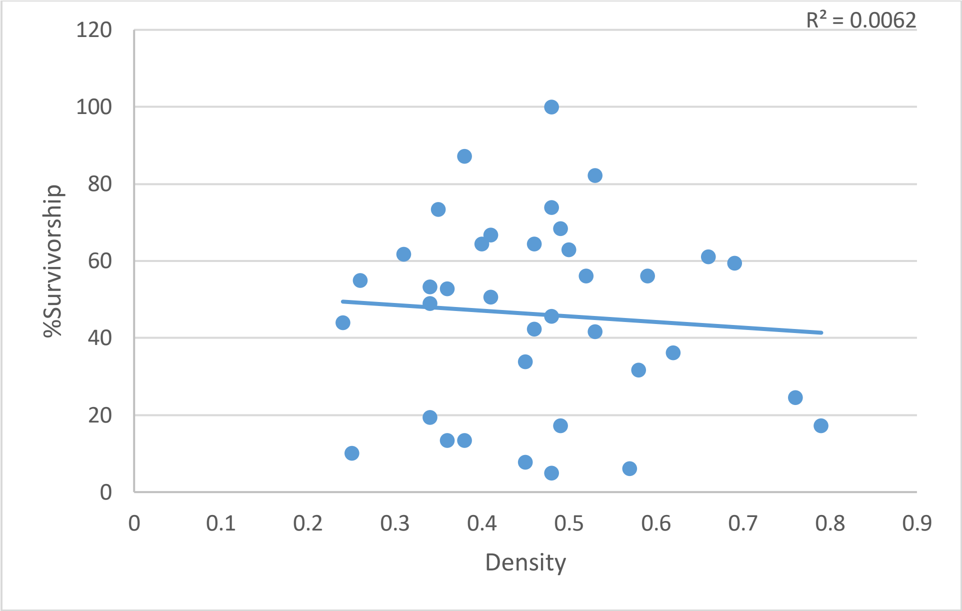
	RA3	65	32.5	36.1	0.62	1.169
	RA5	132	66	73.3	0.35	0.515
Ulna	UL1	96	48	53.3	0.34	
	UL2	107	53.5	59.4	0.69	
Acetabulum	AC1	148	74	82.2	0.53	
Femur	FE1	111	55.5	61.7	0.31	0.597
	FE2	35	17.5	19.4	0.34	0.614
	FE3	88	44	48.9	0.34	0.655
	FE4	14	7	7.8	0.45	1.327
	FE5	95	47.5	52.8	0.36	0.557
	FE6	99	49.5	55.0	0.26	0.497
Tibia	TI1	120	60	66.7	0.41	0.597
	TI2	57	28.5	31.7	0.58	0.757
	TI3	44	22	24.4	0.76	1.238
	TI5	91	45.5	50.6	0.41	0.601
Metacarpal	MC1	101	50.5	56.1	0.59	
	MC5	116	58	64.4	0.46	0.482
	MC6	75	37.5	41.7	0.53	0.607
Metatarsal	MR1	101	50.5	56.1	0.52	0.854
	MR5	116	58	64.4	0.4	1.133
	MR6	82	41	45.6	0.48	0.63
Calcaneus	CA1	76	38	42.2	0.46	
	CA3	123	61.5	68.3	0.49	

	CA4	110	55	61.1	0.66	

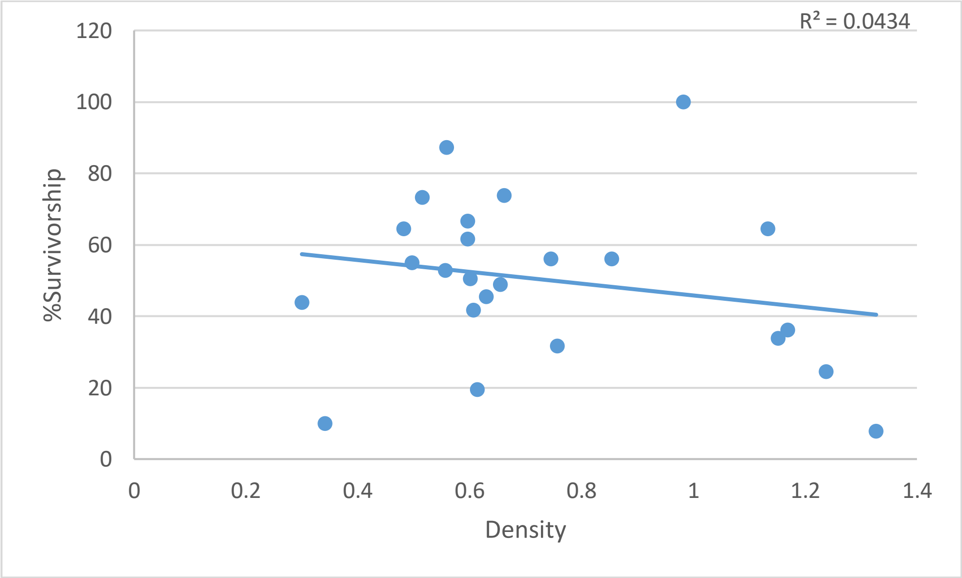
Appendix 2.2 Percent survival of house features aurochs scan sites (Kreutzer 1992; Lam et al. 2003)

Element	Scan site	MNE	MAU	%Survivorship	Density (PD)	Density (CT)
Mandible	DN6	1	0.5	2.4	0.57	
	DN7	9	4.5	22.0	0.49	
	DN8	10	5	24.4	0.79	
Hyoid		9	4.5	22.0	0.36	
Thoracic	TH2	8	0.6	2.9	0.38	
Scapula	SP1	10	5	24.4	0.5	
	SP2	1	0.5	2.4	0.48	
Humerus	HU1	13	6.5	31.7	0.24	0.3
	HU2	5	2.5	12.2	0.25	0.341
	HU3	7	3.5	17.1	0.45	1.152
	HU4	27	13.5	65.9	0.48	0.982
	HU5	23	11.5	56.1	0.38	0.559
Radius	RA1	19	9.5	46.3	0.48	0.662
	RA3	12	6	29.3	0.62	1.169
	RA5	23	11.5	56.1	0.35	0.515
Ulna	UL1	18	9	43.9	0.34	
	UL2	16	8	39.0	0.69	
Acetabulum	AC1	16	8	39.0	0.53	

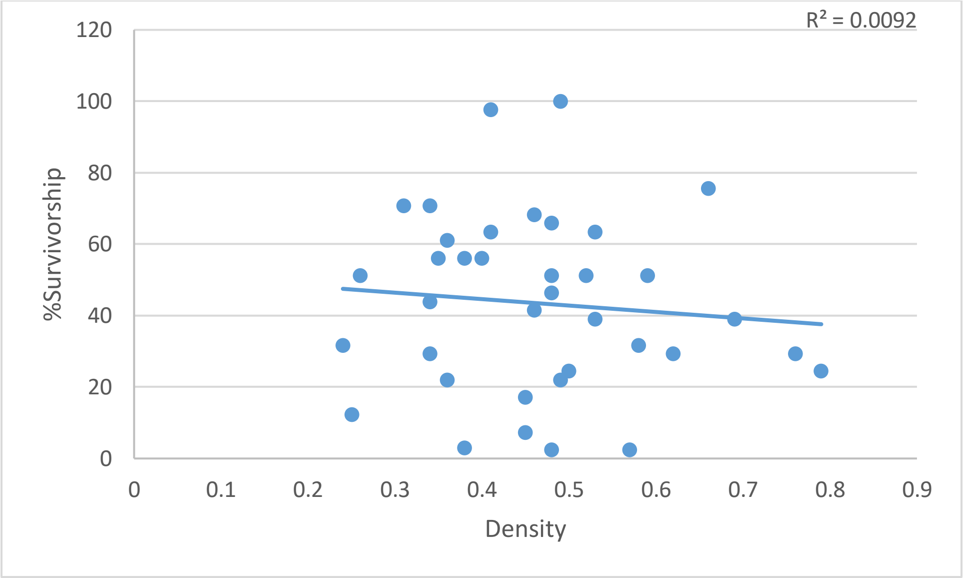
Femur	FE1	29	14.5	70.7	0.31	0.597
	FE2	12	6	29.3	0.34	0.614
	FE3	29	14.5	70.7	0.34	0.655
	FE4	3	1.5	7.3	0.45	1.327
	FE5	25	12.5	61.0	0.36	0.557
	FE6	21	10.5	51.2	0.26	0.497
Tibia	TI1	26	13	63.4	0.41	0.597
	TI2	13	6.5	31.7	0.58	0.757
	TI3	12	6	29.3	0.76	1.238
	TI5	40	20	97.6	0.41	0.601
Metacarpal	MC1	21	10.5	51.2	0.59	0.745
	MC5	28	14	68.3	0.46	0.482
	MC6	26	13	63.4	0.53	0.607
Metatarsal	MR1	21	10.5	51.2	0.52	0.854
	MR5	23	11.5	56.1	0.4	1.133
	MR6	21	10.5	51.2	0.48	0.63
Calcaneus	CA1	17	8.5	41.5	0.46	
	CA3	41	20.5	100.0	0.49	
	CA4	31	15.5	75.6	0.66	



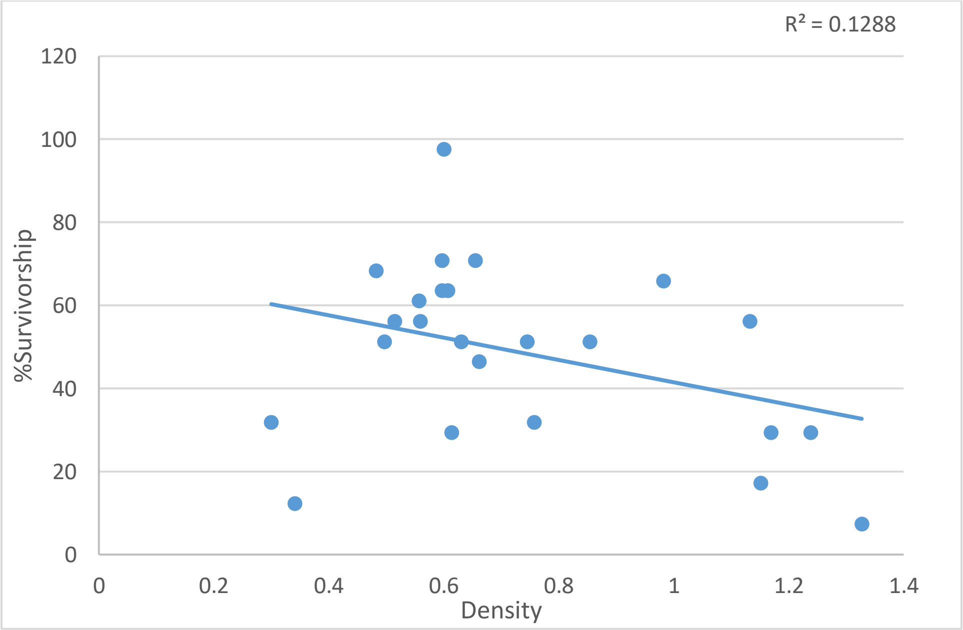
Appendix 2.3 Density vs. % survivorship of aurochs scan sites (using PD data) from the G2 trench (Rs=-0.0212, p=0.901).



Appendix 2.4 Density vs. % survivorship of aurochs scan sites (using CT data) from the G2 trench (Rs=-0.2393, p=0.260).



Appendix 2.5 Density vs. % survivorship of aurochs scan sites (using PD data) from the house structures (Rs=-0.1088, p=0.521).



Appendix 2.6 Density vs. % survivorship of aurochs scan sites (using CT data) from the house structures (Rs=-0.3368, p=0.108).

The scatter plots in Appendix 2.3-2.6 show some negative correlation between aurochs bone density and the percentage of survivorship in both the G2 trench and in the house features. Spearman's rho is used here to represent the statistical significance. When compared with the bison volume densities, the density correlation of aurochs in trench G2 and the house features is very weak (p=0.910; p=0.521). When using Lam's values for reference data, although the correlation value increases, the statistical significance is still weak (p=0.260; p=0.108). This result indicates that the post-depositional attrition does not appear to significantly mediate the preservation of aurochs bones at Houtaomuga. It is important to evaluate the influence of bone mineral density in bone preservation before making further interpretations that rely on the relative abundance of bones with different densities in future study.

Appendix 3: Correlation of aurochs element frequencies in pits from Houtaomuga with the Meat Utility Index and Unsaturated Marrow Index.

	Meat Utility Index		Unsaturated Marrow Index	
	r(p)	r_s(p)	r(p)	r_s(p)
H9	.1935 (.5265)	-.0220 (.9432)	.9166 (.0037)	.8929 (.0068)
H18	.2331 (.4433)	-.1466 (.6327)	.8786 (.0092)	.8929 (.0068)
H19	.4850 (.0929)	-.0028 (.9929)	.8678 (.0113)	.9285 (.0025)
H22	.3119 (.2995)	-.1583 (.6056)	.8473 (.0161)	.8571 (.0137)
H25	.2116 (.4876)	.1269 (.6795)	.9511 (.0010)	.9910 (.0000)
H31	.5215 (.0674)	.0991 (.7472)	.7833 (.0372)	.9286 (.0025)
H129	-.4717 (.1037)	-.4321 (.1404)	-.4501 (.3109)	-.4183 (.3503)
H257	.5875 (.0348)	.6778 (.0054)	.6031 (.1516)	.6667 (.1019)
H258	.5084 (.0760)	.1433 (.6406)	.7336 (.0585)	.7500 (.0522)
H261	.5321 (.0612)	-.1407 (.6466)	.4573 (.3022)	.5045 (.2482)
H263	.1046 (.7338)	.1019 (.7404)	.7960 (.0322)	.8649 (.0112)

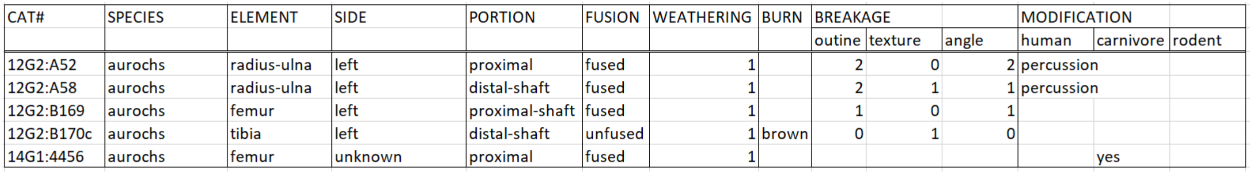
Appendix 4: Analytical Categories for Zooarchaeological Analysis of the Houtaomuga Fauna

Comprehensive faunal data for the Houtaomuga faunal collections for the G2 (1) trench and associated houses can be found at: https://docs.google.com/spreadsheets/d/12ts6GHy0LzQcgrdgpLcA_m2YxRl1sNhI/edit?usp=sharing&ouid=105072314627967534527&rtpof=true&sd=true

Researchers interested in the raw data may also contact the author at: zzhang5@ualberta.ca.

All the faunal material was analyzed using the modern comparative skeletal collection housed at Jilin University. Owing to the extinction of aurochs, the size data of aurochs from Denmark Neolithic sites (Degerbøl and Fredskild 1970), was also used as a guide. Appendix 4 provides a sample of faunal data.

Appendix 4: Sample of raw faunal data.



CAT#	SPECIES	ELEMENT	SIDE	PORTION	FUSION	WEATHERING	BURN	BREAKAGE			MODIFICATION		
								outine	texture	angle	human	carnivore	rodent
12G2:A52	aurochs	radius-ulna	left	proximal	fused	1		2	0	2	percussion		
12G2:A58	aurochs	radius-ulna	left	distal-shaft	fused	1		2	1	1	percussion		
12G2:B169	aurochs	femur	left	proximal-shaft	fused	1		1	0	1			
12G2:B170c	aurochs	tibia	left	distal-shaft	unfused	1	brown	0	1	0			
14G1:4456	aurochs	femur	unknown	proximal	fused	1						yes	

CAT#

Cataloguing information is marked on the bone surfaces. This information provides the excavation year, the archaeological feature where animal bones were uncovered, and the unique assigned number for each bone specimen. For example, 14G1: 4456 represents that the bone was discovered in trench (G)1 in the year of 2014, with an assigned number of 4456. Bones with different CAT designations must not recorded on the same sheet.

Species

The identification of animal specimens was made to standard zoological classifications, such as species, genus, or family. If some specimens were difficult to identify into zoological classifications, less formal categories such as “small deer” were used.

Element

The identification of a bone element followed the standardized name for the individual bones in vertebrate skeletons.

Side

These were coded as left, right, unknown, or side not relevant (e.g., for the axial bones).

Portion

Long bone fragments were coded as proximal, proximal-shaft, shaft, distal-shaft, or distal. Where other bone fragments could not be coded in this fashion, there were coded as complete or incomplete.

Fusion

In this column, I recorded the state of fusion condition as fused, unfused, unknown, or not relevant.

Weathering

These codes refer to the degree of bone surface weathering as described in the main text. Those categories are numbers 1, 2, and 3 which correspond to light, medium, and heavy weathering based on the different degrees of bone surface condition. Light weathered bones represent either no cracking or a little longitudinal cracking on the bone shaft and mosaic cracking on the articular surfaces; medium weathering shows long thin flakes on the outermost bone; while in the heavy weathered bones, most of the outermost bone is gone, and some of the bone may even crumble.

Evidence of Burning

This refer to the description of thermal induced color change. I recorded the burning marks as brown, brown and black, and calcined white. These represent light, medium, and heavy burning stages based on the colour sequence that was caused by heat. Another special category in this column is spotted yellow, which indicates the light yellow scorching marks. This category also belongs to the light burning stage.

Breakage

This category was divided into three sub-categories: outline, texture, and angle. Each aurochs long bone received a number (0, 1, or 2) in each sub-category. For each sub-category, 0 denotes a fresh fractured bone, 1 indicates that the specimen shows a mix of fresh and unfresh features and 2 represents a mainly unfresh fracture feature.

In the outline column, a bone with only spiral fracture will get 0; 1 exhibits a combination of both spiral and straight fracture outline type; 2 means the presence of no spiral fracture.

For the fracture texture, 0 denotes an absence of roughness; 1 means some roughness but mainly smooth; 2 means mainly roughness.

For the fracture angle, 0 means an absence of right angle fracture; 1 means the combination of both acute and right angle fracture, but the right angle fracture is less than 50%; 3 means more than a 50% right angle fracture.

Modification

These refer to human, carnivore or rodent caused alteration to the bone. I recorded human modification on the bone surface as cut, chop, percussion, polish, saw, scrape, and snip marks. For carnivore and rodent modification, I recoded "yes" if a bone specimen presented carnivore or rodent marks.