A STABLE ISOTOPIC (CARBON AND NITROGEN) EVALUATION OF REGIONAL DIFFERENCES IN HERDED ANIMAL DIET AND PASTORAL RISK MANAGEMENT PRACTICES DURING THE XIONGNU PERIOD OF MONGOLIA.

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ABSTRACT

During the Xiongnu Period (c. 300 BC- AD 100) of Mongolia, mobile agro-pastoralism constituted the primary form of subsistence. While this fact is supported by the recovery of animal and plant remains from mortuary contexts, there is a dearth of research concerning the variation of mobile agro-pastoralism across the Xiongnu confederacy. This text centers on regional differences in herding patterns during the Xionngu Period (c. 300 BC- AD 100) of Mongolia and how they relate to Xiongnu statecraft through the use of $\delta^{13}C/\delta^{15}N$ bulk sampling of mandibular and maxillary teeth of livestock recovered from mortuary sites in the Egiin Gol Valley of north-central Mongolia (EG) and Baga Gazaryn Chuluu (BGC), an area located within the Gobi Desert. By comparing the $\delta^{13}C$ and $\delta^{15}N$ values of samples from EG and BGC, this study reveals intra-species and inter-regional trends in C3/C4 plant and water consumption during the Xiongnu Period.

BIOGRAPHICAL SKETCH

Asa Sion McInnis Cameron received a B.A. in anthropology from Vanderbilt University in 2012 and has been conducting archaeological research in Mongolia since 2009.

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During the Xiongnu Period (c. 300 BC- AD 100) a confederacy of mobile pastoralists formed the first steppe empire, a state that encompassed modern day Mongolia, Transbaikalia, eastern Kazakhstan, and western Manchuria. The success of the confederacy's cavalry in raiding Qin (c. 221-206 BC) and later, Han (C. 202 BC –AD 220) territories along China's northern border prompted the erection and expansion of the Great Wall. During the Han Empire, the Xiongnu used their military prowess to develop a tributary relationship with China that ensured the flow of goods (e.g., silk, lacquer ware vessels, and bronze mirrors) north in exchange for peace between the two states. These Chinese goods functioned as prestige items and later, as elite mortuary offerings that were often interred along with animal remains in the ramped and stone ring burials that dominate the archaeological record of the Xiongnu Period. In turn, the Xiongnu elite created a centralized political structure (Watson 1993) that, in part, was maintained internally by ensuring the flow of Chinese goods north and controlling their distribution to the disparate groups of mobile pastoralists/agro-pastoralists that made up the confederacy.

Over the last twenty years there has been a shift in our understanding of subsistence practices during the Xiongnu Period in Mongolia. Traditionally, subsistence has been viewed through the lens of Han texts (ibid.) and 20th century ethnographic works on mobile pastoralism (e.g., Barth 1964). Both sets of documents led researchers (e.g., Barfield 1981, 1989, 2001; Khazanov 1994) to conclude that the Xiongnu Confederacy consisted of nomadic pastoralist groups united against the Han Empire and bound to the empire by the perceived inherent inability of nomads to achieve a self-sufficient form of subsistence. Barfield and Khazanov argued that mobile pastoralism represents an intrinsically unstable subsistence practice and form of economy due to the relative inability of herders to accumulate and store wealth and due to the problems that cold weather, access to water and pasture, and disease present to livestock health. Built into this view point was the notion that mobile pastoralists represent a monolithic group, and thus Barfield and Khazanov gave no consideration to the degree to which gathering, small scale farming, and hunting influence the subsistence of mobile pastoralists and herds. Barfield posited that the formation of the Han Empire prompted the creation of the Xiongnu Confederacy and that the impetus behind the confederacy stemmed from the nomads' need to form a military and political structure capable of obtaining silk, grain and other tributary and subsistence goods from the Han through raiding and demands. As Barfield succinctly put it: "Nomadic empires in Mongolia arose as secondary phenomena, responses to imperial expansion by the Chinese. Individual tribes could not hope to effectively confront a unified China to gain access to trade and aid, or to defend themselves against Chinese aggression" (2001:235).

Subsequently, this understanding of Xiongnu Period subsistence has been challenged. A reassessment of Han records (see Di Cosmo 1994) has generated historical proof that by the Xiongnu Period sections of Mongolia relied on local agriculture for subsistence. Di Cosmo's work was later bolstered by a more in-depth approach to the relevant ethnographic source material on pastoralism (e.g., Frachetti 2008), which underscored that some modern ethnographically documented mobile pastoralists practice small-scale agriculture in conjunction with herding (see Fijn 2011 for an example from Mongolia). While this reassessment did not discount the fact that the Han Empire sent foodstuffs and prestige goods north to the Xiongnu Confederacy (Watson 1993: 139), it did highlight the varied nature of mobile pastoralism during the Xiongnu Period.

Recent Xiongnu Period archaeological research has also strengthened this idea. The discovery of walled settlements (Tseveendorj and Turbat 2011, Rogers et al. 2005, and Danilov 2011) and domestic grains (Honeychurch and Amartuvshin 2007, Korolyuk and Polosmak 2010) in Northern Mongolia and Transbaikalia, as well as the previous documentation of millstones and digging sticks in Transbaikalia during the Bronze Age (c. 1400–750 BC) (Honeychurch 2015), has demonstrated that some Xiongnu peoples occupied permanent sites, stored agricultural products, and likely practiced small-scale agriculture. Collectively this research has untethered the Xiongnu from the Han, and in the process generated two conclusions about subsistence during the Xiongnu Period: the Xiongnu practiced mobile pastoralism/agro-pastoralism; and subsistence varied regionally in terms of scale, mobility, and diet.

While our understanding of Xiongnu subsistence has broadly changed through the incorporation of evidence for agriculture and sedentary sites, much of the supporting research has revolved around developing new models of statecraft for the Xiongnu Confederacy that stress the autochthonous potential of mobile pastoralists (e.g., Honeychurch 2013). This focus stems from the broad archaeological importance of the Xiongnu Period and the nature of Mongolia's archaeological record. The Xiongnu Confederacy represents the first state formed by mobile pastoralists and thus studying its statecraft process is seminal to understanding early state formation. Theories of Xiongnu statecraft focus on the accumulation of political and social capital from the pre-Xiongnu Period (c. 1000 to 400 BC) to the Xiongnu Period and how that process allowed the Xiongnu Confederacy to form a political and trade network that incorporated disparate cultural groups (Honeychurch 2015). And because mortuary sites constitute the majority of archaeological sites in Mongolia, the data on which these theories are formed focus on the size, location, and content of mortuary sites through time. Specifically, this research has centered on how mortuary sites during the pre-Xiongnu Period demarcated the landscape and represented stages on which political and social power were constructed. By focusing primarily on the monumentality and location of mortuary sites, research concerning Xiongnu statecraft has left a lacuna in current research on how mobile pastoralism/agro-pastoralism varied across the Xiongnu Confederacy.

Without generating specific regional data and analyzing the differences between areas, our understanding about subsistence cannot move far beyond the simple idea that regional variation existed. A more nuanced understanding of subsistence will enable research to focus on the role mobile pastoralism/agro-pastoralism played in Xiongnu statecraft and to generate data vital to understanding how inter-regional and intra-regional relationships within the confederacy informed the political structure of the Xiongnu state. By fleshing out regional differences in subsistence, research can also examine herd risk management practices during the Xiongnu Period. This topic is important because herd risk management practices are the predominant method through which subsistence is assured in a mobile pastoral/agro-pastoral society,.

Herd risk management practices are a form of cost-benefit analysis aimed at maintaining livestock health to optimize the production of primary (meat) and secondary (e.g., wool) animal products. Mobile pastoralists/agro-pastoralists implement these practices to ensure that livestock have adequate access to water, pasture/fodder, and shelter through the use of mobility, small-scale agriculture and/or gathering, culling, and through the establishment of semi-permanent/permanent habitation sites located near required resources. For example, modern Buryat herders in the Taravagtai Valley of north central Mongolia mitigate the effect that the harsh climate has on their livestock by moving seasonally between three different permanent habitation sites. To prepare for winter, the herders gather wild grasses for fodder. This feed is stored at winter campsites, which consist of small timber cabins and penning areas and are located in the deep side valleys of the Taravagtai to ensure that herders and livestock are protected from the wind and weather. In turn, access to pasture and fodder in the Taravagtai Valley is divided and regulated along family lines, which creates an informal system of property. For the Xiongnu Period, understanding herd risk management practices will allow research to address fundamental questions about Xiongnu statecraft and the Xiongnu political structure: how did the induction of domestic grains to Mongolia during the Early Iron Age (c. 750–300 BC) (Machicek 2011) affect subsistence and herd management practices? And how was the Xiongnu landscape utilized and organized at a local and regional level, and how did such utilization and organization dictate herder inter-regional and intra-regional mobility?

To examine regional variation in subsistence and herd management practices and how these variations relate to Xiongnu statecraft and the political structure of the Xiongnu, this study focused on the comparison of stable carbon ($\delta^{13}C$ or $^{13}C/^{12}C$) and nitrogen ($\delta^{15}N$ or $^{15}N/^{14}N$) isotope data sampled from domestic cattle (*Bos* sp.), sheep (*Ovis aries*), sheep/goat (*Ovis aries/Capra hircus*), and horse (*Equus caballus*) teeth recovered from Xiongnu Period mortuary sites in two geographically and environmentally discrete areas of Mongolia: the Egiin Gol Valley (EG) and Baga Gazaryn Chuluu (BGC). The nature of the archaeological record of Mongolia during the Xiongnu Period makes stable isotope analysis uniquely positioned to address these questions. As noted, mortuary sites constitute the vast majority of archaeological sites in Mongolia from the Xiongnu Period. While these cemeteries often include faunal skeletons, at present an adequate faunal collection for traditional zooarchaeological analysis centered on species identification and quantity does not exist. And because the animal remains that have been recovered come almost entirely from mortuary sites, they do not represent an accurate picture of household subsistence. In contrast, stable isotope analysis can provide subsistence data from smaller samples and does not require that the animal remains tested come from a household context in order to do so. Although where subsistence and the ritual use of animals differ in terms of the species consumed/sacrificed or their care prior to slaughter, stable isotope analysis of mortuary remains may not adequately answer such questions.

The $\delta^{13}C$ and $\delta^{15}N$ data generated in this study provide a tool for a broad comparison of livestock diet in EG and BGC. In turn, these values form the basis for an analysis of herd risk management practices during the Xiongnu Period. Through a comparison of this study's data against existing research on human diet during the Xiongnu Period (Machicek 2011) and modern sheep and goat (Makarewicz and Tuross 2006) $\delta^{13}C$ data, the extent to which C_4 plants were used for fodder by the Xiongnu and how modern and Xiongnu Period winter herd management practices relate will be assessed. This study provides an initial step in developing the regional subsistence and herd risk management models required to understand the role of mobile pastoralism/agro-pastoralism in Xiongnu statecraft and in the Xiongnu political structure.

Egiin Gol Valley (EG) and Baga Gazaryn Chuluu (BGC)

The Egiin Gol Valley (EG) and Baga Gazaryn Chuluu (BGC) (see Figure 1) provide the ideal contexts for a comparative study of livestock diet based on stable carbon and stable nitrogen isotope analysis because of the distinct ecological variation that exists between the areas. EG is situated within the forest steppe of North-Central Mongolia. Because of the relatively high annual precipitation (340 mm) and the presence of lakes and the Selenge and Egiin Gol river systems (Machicek et al. in prep), this region is more fertile than BGC and even supports some modern agriculture. The elevation of the valley ranges from 840 m and 1250 m, and the peaks are populated by birch, pine, and larch growth and the floors are covered with steppe grasses and small shrubs. The presence of reliable water sources and fertile grazing pasture enables modern mobile pastoral families to undertake short seasonal migrations of only 8 km to 15 km each year. Excavations and surveys in the valley also indicate that during the Xiongnu Period subsistence in the valley was characterized by mobile agro-pastoralism and was probably supplemented with fishing (Machicek 2011) and hunting as well (Honeychurch and Amartuvshin 2007).

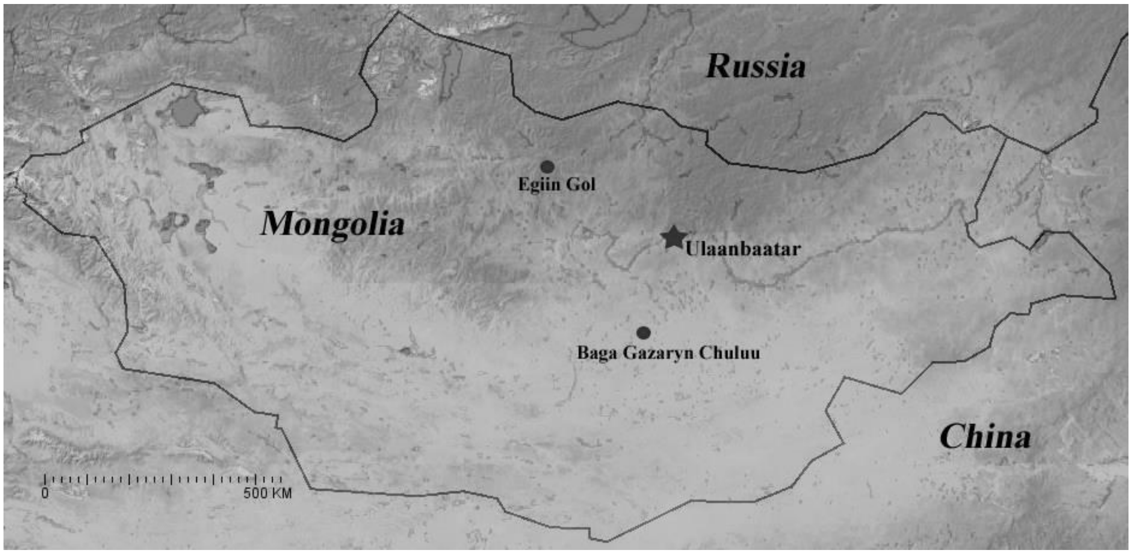

Figure 1. Site Locations: Egiin Gol [EG] and Baga Gazaryn Chuluu [BGC] (Machicek et al. in prep)

In contrast BGC rests in the desert steppe of the North Gobi. The 120 km^2 area is characterized by granite and greywacke outcroppings (Wright et al. 2007, Berkey 1927) and seasons that shift from hot and arid summers to cold and wet winters (Makarewicz and Tuross 2006). BGC receives on average 180 mm of precipitation per year (Machicek 2011) and as such modern pastoralists in the area move more regularly than in EG. On average families change their campsites by 5-10 km every 3-5 weeks during the spring, summer, and fall (Makarewicz and Tuross 2006). While the area is predominantly desert steppe, the elevation range of BGC (1450 m to 1750 m above sea level) creates four different zones of vegetation: desert steppe (1450 a.s.l), valley bottoms (1500-1550 a.s.l.), rocky plateaus (1550-1650 a.s.l.), and alpine peaks (1650-1750 a.s.l.) (ibid.). From the Epi-Paleolithic (10000-3500 years BP) through the Khitan and Mongol Periods (1050-550 years BP), BGC functioned as a place for both occupation and mortuary rituals (Wright et al. 2007). During the Xiongnu Period, occupation in the area fell to the periphery of the rock outcroppings and subsistence centered on mobile pastoralism just as it does today. BGC currently does not support intensive farming and families around BGC use the valleys and rock outcroppings as winter refuge for themselves and their herds. While modern people in BGC generally do not harvest domestic crops, they often gather wild plants for fodder or maintain certain pastures specifically for grazing livestock during the colder months (ibid., Makarewicz 2014).

Isotopic Rationale

While a complete synopsis of the existing literature on stable carbon and stable nitrogen isotope analysis is beyond the scope of this paper (see Katzenberg 2000, Mays 2000, and Ambrose 1990), this section touches on the main points of each technique in order to put this study's data into a better context. Carbon and nitrogen stable isotope analysis represents commonly employed methods in archaeology that evaluate broad dietary trends in humans and animals (e.g., Hammond and O'Connor 2013). For this study, the $\delta^{13}C$ and $\delta^{15}N$ values were acquired from dental collagen and thus reflect the dietary protein intake of each individual sampled (Katzenberg 2000). Although both sets of analysis are presented together and are derived from the same source material, they represent different aspects of an individual's diet.

In most studies concerned with animal diet, $\delta^{13}C$ sampling provides an effective measure of C_3 versus C_4 plant consumption. This distinction is made possible through the distinct photosynthetic pathways of each plant type. C_4 plants, which exist in a range of ecosystems but truly thrive in warm environments with ample sunlight (Christin and Osborne 2014), discriminate against ^{13}C less during CO_2 compensation than C_3 plants (Ambrose 1986). This means that C_4 plants have $\delta^{13}C$ values that range from -9‰ to -14‰ as opposed to C_3 plants that exist within a range from -20‰ to -35‰ (ibid.). Although the two $\delta^{13}C$ value ranges do not overlap, C_3 and C_4 plants grow together often within the same ecotone. Humans and animals often consume both plant types and thus mixed models of C_3 versus C_4 plant consumption are sometimes required when interpreting $\delta^{13}C/\delta^{15}N$ data (e.g., Barton et al. 2009). In addition, a direct relationship does not exist between the $\delta^{13}C$ levels found in the diet of an individual and the $\delta^{13}C$ levels of the individual himself/herself. Humans and animals have on average a 5‰ increase in $\delta^{13}C$ values relative to their diet. However, this number varies as the breadth of an individual's diet increases and only holds steady in instances where the diet of the entire food web remains stable and limited to a few plants and animals (Katzenberg 2000). Parsing out the nature of an individual's diet is also complicated by the relationship between $\delta^{13}C$ values derived from collagen and dietary protein. For the extent to which carbon isotope values represent an individual's plant consumption or the $\delta^{13}C$ values of the animals that they consumed is difficult to determine without data from each trophic level. Or in cases where a new dominant C_3 or C_4 plant is introduced to a human's (e.g., Katzenberg et al. 1995) or herd's diet, a comparison between the $\delta^{13}C$ values of humans and livestock in an area can effectively shed light on plant versus meat consumption.

Stable nitrogen isotope data sampled from collagen reveals several aspects of diet attached to dietary protein intake. The two most common reasons for this method's use in archaeology center on analyzing trophic levels within a food web and determining the extent to which marine versus terrestrial foods are represented in an individual's diet. The use of $\delta^{15}N$ analysis to determine trophic level relies on the fact that an individual's $\delta^{15}N$ value is higher than that of the organisms it consumes (Deniro and Epstein 1981, Hedges and Reynard 2007). These values increase by roughly 3‰ with each trophic level and help to make clear distinctions between predators and prey (Katzenberg 2000). The more immediate contribution of stable nitrogen isotope analysis to this study comes from the propensity of humans and animals in times of water stress to retain a greater quantity of the heavier ^{15}N isotope after expelling urine (Katzenberg 2000, Pate 1994). This allows for the inter-species and inter-regional comparison of livestock water access between EG and BGC.

Methods and Materials

The materials sampled in this study were collected by William Honeychurch of Yale University during the excavation of mortuary sites in BGC and EG and sampled and analyzed at the Cornell University Stable Isotope Laboratory (COIL). Prior to use of the faunal teeth for $\delta^{13}C$ and $\delta^{15}N$ analysis in this study, the team at Yale identified the animals to the species/genus level and selected which teeth were removed from their respective skulls. In total twenty-seven faunal teeth were selected for analysis (26 adult and 1 deciduous), 17 from EG and 10 from BGC. The teeth were identified again to the species/genus level using the comparative collection at Cornell University as well as with the following texts: Payne 1985 and Halstead et al. 2002. Unfortunately in the case of the *Ovis/Capra* teeth sampled from BGC, none of the samples could be identified beyond the subfamily level because of a lack of diagnostic teeth. Although the inability to make such a species-level distinction precluded this study from comparing inter-species $\delta^{13}C/\delta^{15}N$ values between *Ovis aries* and *Capra hircus* from BGC, nevertheless the broad analysis of the differences in the diet of livestock between EG and BGC remains viable.

After identification, the teeth underwent preparation for collagen extraction following the methods of the COIL (adapted from Ambrose 1990 and Lambert and Grupe 1993). Each tooth was manually cleaned and rinsed with DI water to remove any foreign particles. Because the sample set contained a mixture of incisors, premolars, and molars from both maxillary and mandibular sources, bulk sampling was employed to ensure that enough biological material would be available from each tooth for analysis. Using a handheld rotary saw, the root of each tooth was removed. For smaller teeth such as *Ovis* incisors, the entire tooth was selected for analysis. Following this step, each sample was manually cleaned again with DI water and then coarsely ground with a mortar and pestle. Next, 0.5 g of powdered bone from each sample was measured out and combined with 5 ml 0.5 M[a] HCL in a 50 ml centrifuge tube. After reacting for thirty minutes at room temperature, the tubes were centrifuged for five to ten minutes at 2500 rpm and then thoroughly rinsed with deionized H_2O. This process was repeated until the samples reached a pH of 5.6 (neutrality). Once the samples finished their centrifuge cycles, the supernatant was discarded and the tubes were filled with 5 ml of 0.1 M[b] NaOH and left to react for thirty minutes at room temperature. Following reaction, the tubes were again centrifuged for five to ten minutes at 2500 rpm and rinsed with deionized H_2O until they reached neutrality. Then the supernatant was discarded from each tube and replaced with pH 3.0[c] H_2O to 10 ml and left to react for thirty-six to forty-eight hours at eighty degrees Celsius. After the extended reaction period, the tubes were centrifuged once more. The remaining pellets were discarded and the supernatant was kept and freeze-dried. The resulting extracted collagen from each sample was measured out and analyzed using a Carlo Erba NC 2500 (Italy) connected via a Conflo II (Thermo Scientific, Germany) to a Delta V Isotope Ratio Mass Spectrometer (Thermo Scientific, Germany). The standards that describe the instrument's precision are KCRN, CBT and MINK.

Results and Discussion

Carbon ($\delta^{13}C$) Data

The dental collagen sampled from livestock in EG and BGC displayed differences in their $\delta^{13}C$ values (see Figure 2). The stable carbon isotope data from EG ranged from -20.34‰ to -17.26‰ with a mean of -18.55‰ and BGC ranged from -19.99‰ to -15.46‰ with a mean of -16.67‰ (see Table 1). Statistical testing of the $\delta^{13}C$ data (see Table 2) revealed that the differences between the sets of values are significant (Student's *t*-test, $p < 0.0001$). Both sets of data contain values that exist below the range of $\delta^{13}C$ values for C_3 plants (-20‰ to -35‰)—an indication that herds during the Xiongnu Period had mixed C_3/C_4 diets. The higher mean $\delta^{13}C$ value from BGC as compared to EG indicates a greater consumption of C_4 flora by livestock. This result can be explained by the nature of C_4 plants as they have evolved to deal with hot and arid climates (Katzenberg 2000). In turn, such areas contain a relatively higher proportion of C_4 to C_3 plants and for BGC this is true as well (Pyankov et al. 2000).

Table 1. Range and means for $\delta^{13}C$ values by site and taxa.

Site and Taxa	Range (‰)	Mean (‰)
EG	-20.34 to -17.26	-18.55
EG *Bos* sp.	-18.97 to -17.42	-18.28
EG *Ovis aries*	-17.26 to -19.62	-18.54
EG *Equus caballus*	-20.34 to -19.43	-19.89
BGC	-19.99 to -15.46	-16.67
BGC *Bos* sp.	-16.93 to -15.46	-16.19
BGC *Ovis/Capra*	-17.50 to -15.73	-16.47

BGC *Equus caballus*	-19.04	-19.04

Table 2. Significance levels (Student's t-test) between δ^{13}C and δ^{15}N data from Egiin Gol and Baga Gazaryn Chuluu.

Stable Isotope	**p-value**
δ^{13}C	<0.0001
δ^{15}N	<0.0001

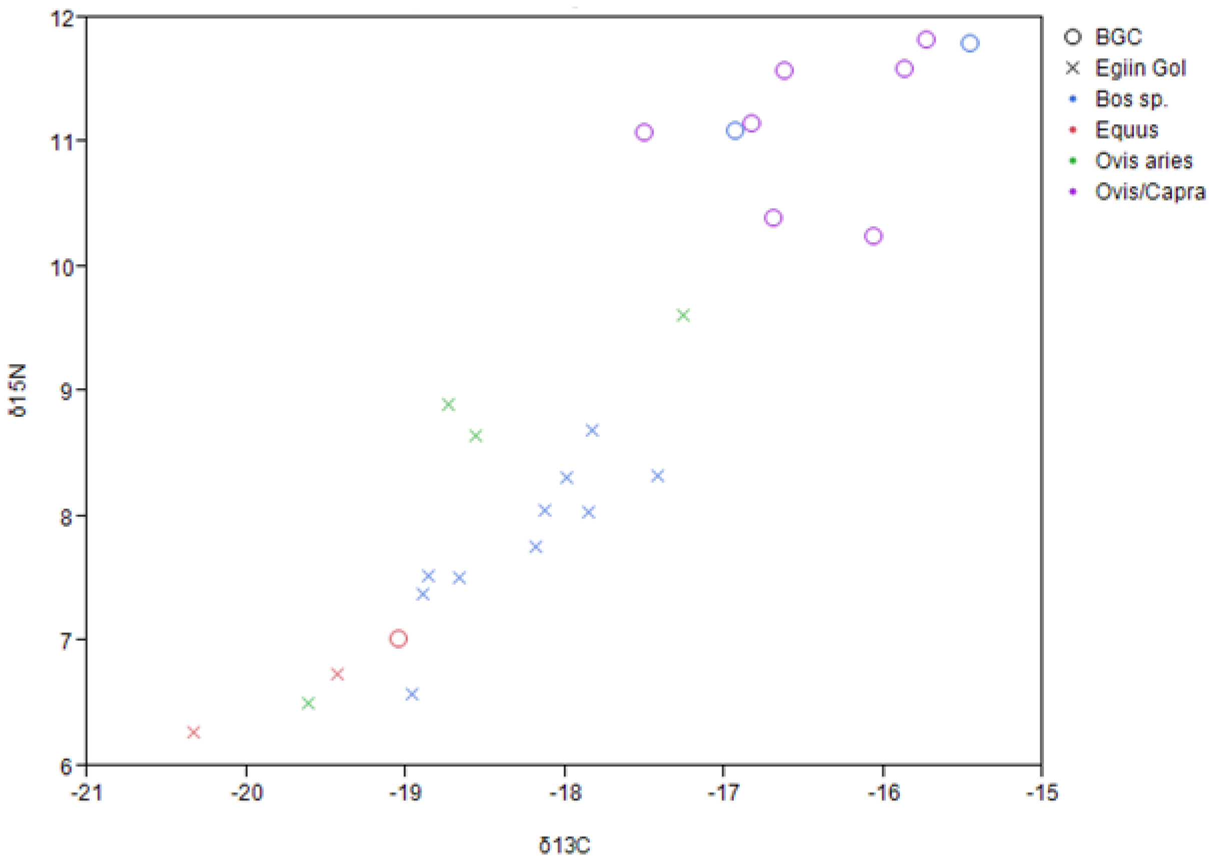

Figure 2. Animal δ^{13}C and δ^{15}N data from Egiin Gol and Baga Gazaryn Chuluu.

In terms of inter-regional species comparisons for EG and BGC, the dental collagen sampled from EG *Bos* sp. specimens (n=10) represented the largest data set. The δ^{13}C values tightly clustered within a range of -18.97‰ to -17.42‰ and mean of -18.28‰. The BGC derived *Bos* sp. collagen (n=2) values had a smaller range (-16.93‰ to -15.46‰) but a greater mean (-16.19‰). The small range of values for both *Bos* sp. δ^{13}C data sets could indicate that the taxon had narrower grazing diets relative to *Ovis aries* and *Ovis/Capra*, although because δ^{13}C values constitute only dietary protein intake and not a list of consumed flora and because of the small sample size, such a conclusion can only remain a possibility. The *Ovis aries* data from EG (n=4) and *Ovis/Capra* data from BGC (n=7) had the two largest ranges with values from -17.26‰ to -19.62‰ (mean of -18.54‰) and -17.50‰ to -15.73‰ (mean of -16.47‰) respectively. Interestingly, three of the four lowest $\delta^{13}C$ values came from the three *Equus caballus* samples (-20.34‰, -19.43‰, and -19.04‰). Here the data indicate a greater consumption of C_3 plants in both areas by *Equus caballus*, although the reason for the lower δ^{13}C values is beyond the scope of this paper.

Nitrogen ($\delta^{15}N$) Data

Table 3. Range and means for δ^{15}N values by site and taxa.

Site and Taxa	Range (‰)	Mean (‰)
EG	6.28 to 9.63	7.81
EG *Bos* sp.	6.59 to 8.70	7.82
EG *Ovis aries*	6.52 to 9.63	8.43
EG *Equus caballus*	6.28 to 6.75	6.51
BGC	7.01 to 11.83	10.78
BGC *Bos* sp.	11.10 to 11.79	11.45
BGC *Ovis/Capra*	10.25 to 11.83	11.13
BGC *Equus caballus*	7.01	7.01

The δ^{15}N data from EG and BGC also showed significant differences (see Table 3). The δ^{15}N values from EG ranged from 6.28‰ to 9.63‰ with a mean of 7.81‰ and the δ^{15}N values from BGC ranged from 7.01‰ to 11.83‰ with a mean of 10.78‰ (see Table 2). Subjecting the data sets to a Student's *t*-test (see Table 1) revealed that the δ^{15}N values from EG and BGC are significantly different ($p < 0.0001$). The elevated δ^{15}N values found in the BGC samples represent the comparative aridity of the area in relation to EG. The lack of precipitation in BGC would have ensured that livestock herded in the area had less access to water—forcing them to retain a greater quantity of the heavier ^{15}N isotope. The comparative lack of water becomes even more apparent when the single *Equus caballus* sample is removed from the BGC data set. By removing the only $\delta^{15}N$ below 10.00‰ (7.01‰) the BGC $\delta^{15}N$ range of values jumps to 10.25‰ to 11.83‰ and the mean becomes 11.20‰.

In addition to the significant differences that appeared in the inter-regional comparison of $\delta^{15}N$ data in this study, an examination of the $\delta^{15}N$ values from the separate taxa demonstrated variations as well. The *Bos* sp. data from EG had a range of 6.59‰ to 8.70‰ and mean of 7.82‰ and the BGC samples had a range of 11.10‰ to 11.79‰ and mean of 11.45‰. Unlike the $\delta^{13}C$ values though, the *Bos* sp. sampled do not have relatively smaller ranges of $\delta^{15}N$ data than both the *Ovis aries* and *Ovis/Capra* data. The EG and BGC $\delta^{15}N$ values from the *Ovis aries* and *Ovis/Capra* samples range from 6.52‰ to 9.63‰ (mean of 8.43‰) and 10.25‰ to 11.83‰ (mean of 11.13‰) respectively. As noted above, the *Equus caballus* sample from BGC had a noticeably lower $\delta^{15}N$ value than the rest of BGC data. The two *Equus caballus* samples from EG represented two of three lowest $\delta^{15}N$ values from teeth analyzed in the area. This indicates that the *Equus caballus* samples displayed the least amount of water stress relative to the other taxa. This might point to the preferential treatment of the individual *Equus caballus* sampled in this study by their human owners, that these horses have adapted to a semi-arid environment or that the *Equus caballus* sampled from BGC was imported to the area.

Due to the presence of a sheep deciduous fourth premolar (8.91‰) within the EG data set (see Table 4), it is also important to addresses the effect milk consumption and weaning could have had on this $\delta^{15}N$ value. As demonstrated by Makarewicz (2011), milk consumption and weaning in sheep has a measurable effect on the $\delta^{15}N$ values derived from dental collagen as there is an increase in $\delta^{15}N$ values during the period of suckling and a decrease once the livestock has been weaned. In the case of the deciduous premolar from EG, section sampling the tooth and testing the animal's diet over the entirety of the tooth formation would be required to accurately measure the effect milk consumption had on that $\delta^{15}N$ value (8.91‰). This is due to two factors. First, deciduous premolars of sheep begin to form *in utero* (Hillson 1986) and thus, a portion of the stable nitrogen isotopes contained within the dental collagen represent the plant based diet of the mother, instead of the sheep that was sampled. Second, bulk sampling makes it impossible to gauge how long the sheep was allowed to suckle and when it was weaned as only a single data point is generated for each tooth. So unfortunately, the sampling method used does not permit assessment of the effect that milk consumption had on this animal.

Table 4. Animal carbon and nitrogen stable isotope values from Egiin Gol and Baga Gazaryn Chuluu.

	Period	Context ID	Species	%N	δ^{15}Nvs. At. Air	%C	δ^{13}C vs. VPDB	%Collagen Yield	Tooth
EG	Xiongnu	T-12	*Ovis aries*	13.85	6.52	37.75	-19.62	1	M_3
EG	Xiongnu	T-18	*Bos* sp.	14.05	8.06	38.79	-18.14	1	M_3
EG	Xiongnu	T-32	*Bos* sp.	14.06	7.52	38.92	-18.67	2	$M_{1/2}$
EG	Xiongnu	T-37	*Bos* sp.	13.61	8.70	37.31	-17.83	1	I
EG	Xiongnu	T-48	*Bos* sp.	13.44	8.05	37.39	-17.85	1	M^3
EG	Xiongnu	T-59	*Bos* sp.	11.10	8.34	30.07	-17.42	1	$M_{1/2}$
EG	Xiongnu	T-67	*Bos* sp.	9.35	7.38	25.63	-18.90	1	$M^{1/2}$
EG	Xiongnu	T-85	*Bos* sp.	11.77	8.31	31.84	-17.99	7	M_3
EG	Xiongnu	T-87	*Ovis aries*	11.97	8.91	31.83	-18.73	1	dP_4
EG	Xiongnu	T-81	*Ovis aries*	14.07	8.66	38.28	-18.56	1	M_2
EG	Xiongnu	T-88	*Ovis aries*	14.03	9.63	38.38	-17.26	3	M_2
EG	Xiongnu	EX00.4	*Equus caballus*	10.00	6.28	31.95	-20.34	1	$M_{1/2}$
EG	Xiongnu	EX97.1 L9	*Equus caballus*	13.48	6.75	38.85	-19.43	2	I
EG	Xiongnu	EX00.15 L5	*Bos* sp.	11.49	7.76	31.73	-18.18	3	$M_{1/2}$
EG	Xiongnu	EX00.14	*Bos* sp.	14.85	7.54	41.80	-18.87	3	I
EG	Xiongnu	EX99.9 L1	*Bos* sp.	14.92	6.59	41.44	-18.97	3	M_3
BGC	Xiongnu	EX 03.02	*Ovis*/*Capra*	14.35	10.25	39.40	-16.06	2	I
BGC	Xiongnu	EX 08.02	*Ovis*/*Capra*	14.12	11.59	38.46	-15.86	3	I
BGC	Xiongnu	EX 08.02	*Ovis*/*Capra*	9.59	11.58	26.74	-16.63	2	$M^{1/2}$
BGC	Xiongnu	EX 08.03	*Bos* sp.	16.21	11.79	44.00	-15.46	5	$M_{1/2}$
BGC	Xiongnu	EX 08.03	*Ovis*/*Capra*	12.61	11.83	35.20	-15.73	3	$M^{1/2}$
BGC	Xiongnu	EX 08.04	*Bos* sp.	13.58	11.10	36.87	-16.93	3	I
BGC	Xiongnu	EX 08.06	*Ovis*/*Capra*	15.18	11.16	35.81	-16.83	3	I
BGC	Xiongnu	EX 08.06	*Ovis*/*Capra*	12.28	11.08	34.48	-17.50	1	M^3
BGC	Xiongnu	EX 08.13	*Ovis*/*Capra*	15.36	10.40	42.16	-16.69	2	$M^{1/2}$
BGC	Xiongnu	EX 08.19	*Equus caballus*	15.57	7.01	42.80	-19.04	2	$M^{1/2}$

Domestic Plants in the Egiin Gol Valley during the Xiongnu Period

Machicek (2011) demonstrated a slight—although statistically significant—increase in the stable carbon isotope values of humans from the pre-Xiongnu (c. 1000 to 400 BC) to Xiongnu Period in BGC. From this, Machicek posited that the increase in carbon isotope values of humans could be the result of individuals gaining greater access to C_4 agricultural products (such as millet) during the later period. Later, Machicek strengthened this conclusion through the implementation of dental macro-wear analysis (Machicek and Zubova 2012) to analyzing human teeth from Burkhan Tolgoi, a Xiongnu cemetery in north central Mongolia, and Ivolga, a Xiongnu fortified settlement in Transbikalia. Machicek and Zubova demonstrated that the individuals sampled from both sites had tooth wear associated with a mixed plant and animal diet, and that the teeth from Ivolga had heavy wear patterns consistent with the consumption of stone-milled domestic grains.

While these conclusions require further analysis, they do raise the question of how domestic C_4 grains affected the diet of livestock during the Xiongnu Period. For the context of this paper the question is best answered by focusing on the livestock sampled from EG due to fact that subsistence in the area during the Xiongnu Period likely consisted of pastoralism and agriculture. And in turn, Xiongnu mortuary sites in Northern Mongolia have produced domestic grains. In particular, the site of Noin Ula (Korolyuk and Polosmak 2010) contained plant remains from a millet genus (*Panicum* L. or *Setaria*) of which several species are used as fodder crops in Central Asia and China. Unfortunately for this study a pre-Xiongnu faunal carbon and nitrogen stable isotope data set from EG was not available for direct comparison. But through an examination of what extensive foddering of herds with C_4 grains would look like isotopically, a relative measure of the extent to which C_4 plants made up a portion of animal diet in EG during the Xiongnu Period is possible.

On average C_4 plant $\delta^{13}C$ values range from -9‰ to -14‰ and specifically in Inner Asia, common millet (*Panicum miliaceum*) has a $\delta^{13}C$ value on average of -13.1 ± 0.54‰ and foxtail millet has a $\delta^{13}C$ value on average of -12.5 ± 0.40‰ (Yang et al. 2011). The livestock sampled from EG produced a mean value significantly less than the range given above (-18.55‰) and as discussed, humans and animals have on average a 5‰ increase in $\delta^{13}C$ values relative to their diet. This indicates that the mean $\delta^{13}C$ value from EG comes from animals that likely had mixed C_3 and C_4 plant diets and primarily consumed C_3 plants. These data demonstrate that if domestic C_4 plants were adopted as fodder or animal feed during the Xiongnu Period in EG, then the grains made it only sparingly into the livestock's diets.

Comparison against Existing Modern Animal $\delta^{13}C$ and $\delta^{15}N$ Data from Mongolia

Makarewicz and Tuross (2006) collected the modern animal $\delta^{13}C$ and $\delta^{15}N$ data discussed in this section (see Table 5). The authors' research demonstrated the viability of using stable carbon and nitrogen isotope analysis to detect foddering in livestock through the direct comparison of $\delta^{13}C/\delta^{15}N$ values derived from dental collagen sampled from domestic and wild sheep and goat populations (mandibular M1 and M3 teeth) that grazed throughout BGC. In addition, the dietary data generated from each taxon was compared against baseline $\delta^{13}C/\delta^{15}N$ values that Makarewicz and Tuross created using plant samples collected during the summer from four vegetation zones of BGC. In all, Makarewicz and Tuross demonstrated that while all four taxa freely graze the different vegetation zones of BGC, the *Ovis aries* and *Capra hircus* had greater access to naturally growing C_4 plants due to the collection and use of summer grasses as fodder by local herders during the winter months. In turn, this risk management practice was detected isotopically through the comparatively elevated $\delta^{13}C/\delta^{15}N$ values in the *Ovis aries* and *Capra hircus* teeth.

The utility of the data Makarewicz and Tuross (2006) presented for comparison against the animal isotopic data generated in this study comes from two points: the text provided a set of dental collagen derived $\delta^{13}C$ values from foddered and non-foddered sheep and goat populations around BGC and the authors' suggestion for an expanded definition of foddering that centered on food "that would be unavailable to animals without human intervention" (862). Although both points allowed for a comparison and discussion of modern and Xiongnu Period animal diet around BGC, this process has some limitations that need to be addressed before the comparison is presented. First, Makarewicz and Tuross included only range and mean $\delta^{13}C/\delta^{15}N$ values for each taxon and this voided the possibility of using Student's t-test to check for statistically significant differences between the data sets. Second, the authors separated out all of the taxa sampled in their study to the species level. As noted, the BGC *Ovis/Capra* teeth sampled in this study were only identified to subfamily. While this precluded the direct comparison of *Ovis aries* and *Capra hircus* carbon stable isotopic values from each study, the incongruence in level of identification did not prevent a general examination of wild versus livestock diet as the differences between the *Ovis aries* and *Capra hircus* $\delta^{13}C/\delta^{15}N$ values from the modern data set proved statistically insignificant (866). Third, a $\delta^{13}C/\delta^{15}N$ data set for *Ovis ammon* and *Capra sibirica* (wild sheep and goat) from BGC does not exist for the Xiongnu Period and thus was not available for comparative analysis. Lastly, the environment of BGC during the Xiongnu Period likely differed from its current conditions as the climate of Mongolia is drier (Fukumoto et al. 2012) and warmer (D'Arrigo et al. 2001) today than it was during the Xiongnu Period. While precise paleoclimate data on floral composition and the relative abundance of C_3 and C_4 plants around BGC during the Xiongnu Period does not exist, warmer and drier conditions generally indicate greater relative C_4 plant growth (Christin and Osborne 2014) and thus the current climate of BGC is more likely to support C_4 plant growth than during the Xiongnu Period.

The range of $\delta^{13}C$ values for the *Ovis aries* and *Capra hircus* samples from Makarewicz and Tuross 2006 were -16.1‰ to -18.6‰ (mean of -17.5+/-0.8‰) and -16.4‰ to -19.8‰ (mean of -18.2+/-1.3‰) respectively. In contrast, the *Ovis/Capra* samples from this study had a range of -17.50‰ to -15.73‰ and mean value of -16.47‰. This indicates that on average the Xiongnu Period *Ovis/Capra* sampled from BGC had diets heavier in C_4 plants than those sampled in Makarewicz and Tuross (2006). While this does not provide direct evidence that Xiongnu families around BGC foddered their sheep and goats, it does strongly suggest that the $\delta^{13}C$ values of the *Ovis*/*Capra* samples could not exist without past human intervention because as the wild sheep and goat ranges indicate, natural access to C4 plants for sheep and goats during the winter produces $\delta^{13}C$ values significantly lower than that of modern and Xiongnu Domestic sheep and goats. Thus whether families occupying BGC gathered wild plants for fodder or maintained certain pasture areas for winter grazing (both of which they practice today, as Makarewicz 2014 notes), the $\delta^{13}C$ values derived from the Xiongnu Period *Ovis*/*Capra* remains prove that Xiongnu occupying BGC likely employed foddering to ensure sheep and goat health throughout the winter.

Table 5. Range and means for $\delta^{13}C$ and $\delta^{15}N$ values from modern domestic and wild *Ovis* and *Capra* species in Baga Gazaryn Chuluu (adapted from Makarewicz and Tuross 2006).

Taxa	n	Mean δ13C (‰)	Range δ13C (‰)	Mean δ15N (‰)	Range δ15N (‰)
O. aries (all teeth)	25	-17.5+/-0.8	-16.1 to -18.6	11.2+/-1.1	8.6 to 12.9
O. ammon (all teeth)	17	-19.2+/-0.8	-17.2 to -20.4	8.8+/-1.3	5.5 to 10.5
C. hircus (all teeth)	9	-18.2+/-1.3	-16.4 to -19.8	9.8+/-1.2	7.9 to 11.1
C. sibirica (all teeth)	7	-19.5+/-0.7	-18.0 to -19.9	8.1+/-1.0	7.1 to 9.8

Conclusions

Subsistence practices during the Xiongnu Period varied across the confederacy based on environmental, regional, and cultural factors. This study examined part of this variation using stable isotope analysis to determine how animal diet differed between EG and BGC and how the diet of livestock from both regions was the outcome of environmental factors and human risk management practices. The results demonstrated that during the Xiongnu Period, herders managing livestock near BGC had to cope with the aridity of area during the summer and relied on C_4 plants during the winter to support their sheep and goats. In contrast, the livestock that grazed EG experienced less water stress and did not have their diet significantly augmented by the domestic C_4 grains (*Panicum* L) that have been discovered at mortuary sites in Northern Mongolia.

The data from EG indicates that during the process of Xiongnu statecraft, domestic grains did not play a significant role in herd risk management practices. Instead, these products provided an additional source of nutrition for some herders and during the Xiongnu Period, domestic grains were utilized both for subsistence and as elite mortuary offerings. This could indicate that the primary role domestic grains played in Xiongnu statecraft was that the diversification of subsistence practices during the Early Iron Age increased the health and longevity of herders by providing an additional buffer against livestock die-off. And in turn, that such a buffer provided an additional catalyst for Xiongnu statecraft. It is also likely that during the Xiongnu Period, the introduction of domestic grains provided a new source from which wealth and political power could be derived as they functioned as an item of both subsistence and prestige.

The $\delta^{13}C$ and $\delta^{15}N$ values from BGC point to herd risk management practices similar to those practiced today. The uniform use of wild grasses as a fodder crop at BGC could indicate that in spite of the adoption of a centralized political structure and increased social hierarchy, the Xiongnu Confederacy did not maintain control of resources or herd risk management practices at the local level. If such control were present, the data might have a larger range of sheep and goat $\delta^{13}C$ values due to differential access to fodder grasses based on social hierarchy. While differences in access to resources certainly existed among herders in the Xiongnu Confederacy, at the local level, herder and herd mobility was likely regulated mainly along family lines similar to those found among the modern Buryat herders in the Taravagtai Valley.

While these conclusions require further analysis, with continued isotopic study of human and animal diet and mobility during the Xiongnu Period the analysis can be refined and eventually the scope can be expanded. In addition, by combining stable isotope analysis with better zooarcheological and botanical data and implementing new forms of analysis such as plant microfossil analysis derived from dental calculus (see Henry and Piperno 2008), we can more fully assess regional differences in subsistence and herd risk management practices and how they relate to Xiongnu statecraft and the Xiongnu political structure.

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