5-2014

The Baker Cave Bison Remains: Bison Diminution and Late Holocene Subsistence on the Snake River Plain, Southern Idaho

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Recommended Citation

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THE BAKER CAVE BISON REMAINS: BISON DIMINUTION AND LATE HOLOCENE SUBSISTENCE ON THE SNAKE RIVER PLAIN, SOUTHERN IDAHO

by

Ryan P. Breslawski

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Anthropology

Approved:

David Byers, Ph.D. Major Professor	Patricia Lambert, Ph.D. Committee Member
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UTAH STATE UNIVERSITY
Logan, Utah

2014

ABSTRACT

The Baker Cave Bison Remains: Bison Diminution and Late Holocene Subsistence on the Snake River Plain, Southern Idaho

by

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Utah State University, 2014

Major Professor: Dr. David Byers
Department: Sociology, Social Work, and Anthropology

The role of bison in the prehistoric subsistence in southern Idaho is not fully understood. Bison remains from Baker Cave, a late Holocene archaeological site dating to cal A.D. 1042-1265, however, provide evidence of pre-contact subsistence strategies in the region. This thesis focuses on the paleoecology of bison and their role in prehistoric subsistence on the Snake River Plain (SRP). The ecological study of bison focuses on the hypothesized trans-Holocene diminution in bison body size in southern Idaho, while a second study focuses on how these animals figured into prehistoric responses to seasonal fat scarcity.

Although bison diminution and its ecological determinants are well understood on the Great Plains, the history of diminution west of the Rocky Mountains is less clear. Bison morphometrics from Baker Cave present the opportunity to assess bison diminution on the Snake River Plain. Bison morphometrics from Baker Cave are indistinguishable not only from other late Holocene bison on the Snake River Plain but also from late Holocene bison from the Great Plains. Further, the Baker Cave bison are smaller than early Holocene bison from the Great Plains and Snake River Plain. These results suggest morphological similarity between Snake River Plain bison and Great Plains bison through the Holocene, pointing to similar bottom up ecological constraints on body size.

Although bison are common components of SRP archaeofaunas, their role in prehistoric subsistence is poorly understood. To shed light on this problem, I hypothesize that the Baker Cave bison assemblage resulted from hunters seeking skeletal fat. I test predictions drawn from this hypothesis with assemblage-level patterns in element representation, impact scar distribution, and fragmentation. These assemblage-level patterns track the skeletal fat utility of elements. These patterns, combined with winter procurement evidenced by fetal remains, support the hypothesis that fat-seeking behavior was a response to winter fat scarcity. A comparison with smaller bison assemblages from southern Idaho suggests that this fat-seeking behavior might have persisted as far back as the middle Holocene, although this requires confirmation from future studies.

(115 pages)

PUBLIC ABSTRACT

The Baker Cave Bison Remains: Bison Diminution and Late Holocene Subsistence on the Snake River Plain, Southern Idaho

Ryan P. Breslawski

This thesis investigates that paleoecology of southern Idaho bison and their role in prehistoric subsistence with two articles. The first article investigates the trajectory of bison diminution in southern Idaho with bison morphometrics from Baker Cave, a late Holocene archaeological site. Results indicate that local bison followed a diminution trend mirroring the diminution trend documented on the Great Plains. This suggests that similar bottom up ecosystem controls acted on bison in both the Great Plains and in southern Idaho through the Holocene.

The second article examines the role of bison in seasonal subsistence strategies. I hypothesize that winter fat scarcity in southern Idaho made prehistoric foragers susceptible to protein poisoning, and therefore, these people employed fat-seeking strategies. I test predictions drawn from this hypothesis with bison remains from Baker Cave. Assemblage level patterns at Baker Cave meet the predictions. Further, fetal bison remains at Baker Cave suggest multiple winter procurement events. These fetal remains, in combination with the assemblage-level patterns, support the hypothesis that this archaeofauna resulted from winter fat seeking behavior. Further, comparisons with other southern Idaho sites containing smaller bison assemblages suggest that this pattern was widespread and may have persisted through the middle and late Holocene. However, further studies are needed to confirm this pattern.

ACKNOWLEDGMENTS

This thesis comprises the lengthiest and most challenging undertaking I have ever attempted, and a number of people and organizations gave me considerable help and guidance along the way. First, Dr. David Byers dedicated a large amount of time over several years to guiding me through this project. As my graduate chair, he continuously challenged me to do the best work that I possibly could, and this played a major role in shaping the final manuscript. The two other members of my supervisory committee, Drs. Patricia Lambert and Kenneth Cannon, also shared many comments and much expertise that significantly improved this project. They all have my sincerest thanks for helping me through this process.

Several organizations and agencies also deserve recognition. The Baker Cave archaeofauna is curated at the Idaho Museum of Natural History, who kindly loaned the assemblage to Utah State University. Baker Cave is located on land now managed by the National Park Service, who facilitated a site visit in 2012. The Midwest Archeological Center also loaned a bison skeleton to Dr. Kenneth Cannon through USU Archeological Services, which aided my specimen identifications. This project was completed with encouragement from the Idaho Bureau of Land Management, Burley Field Office. Dr. L. Suzann Henrikson provided several obscure contract reports with useful background information on the archaeology of southern Idaho. The USU Office of Research and Graduate Studies enabled a poster presentation of this research at the 2014 Society for American Archaeology Meeting through a travel award.

Over the last four years, my fellow graduate students have provided much needed camaraderie, and I hope that I have returned the favor. Thanks especially to Diana

Azevedo, for zooarchaeology discussions in the Aggie Barn bone lab, and to Anastasia Lugo-Mendez, who provided a Spanish abstract translation for one article abstract prior to a journal submission.

Finally, I need to extend my thanks to several people who provided personal support through this project. First, Meagan Roach endured many obscure rants about zooarchaeology and provided some graphic design expertise to various poster and slideshow presentations of this research. My family has also supported my pursuits since long before I started graduate school. My mom and dad, Jackie and Roy, and my sister, Maggie, have provided unconditional encouragement since the day that I told them that I planned to be an archaeologist.

Ryan Breslawski

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CHAPTER 1

INTRODUCTION

In this thesis, I analyze the Baker Cave archaeofauna to shed light on Holocene bison diminution and prehistoric subsistence on the Snake River Plain (SRP). Baker Cave was originally excavated by the Idaho Bureau of Land Management and Boise State University in 1985 to mitigate looting (Plew et al. 1987). However, the Baker Cave archaeofauna was not extensively analyzed in any published study, making it an unrealized source of information on late Holocene bison ecology and human subsistence in the region. I resolve this issue with the first in depth analysis of a bison archaeofauna in Idaho. I present results from this analysis in two articles, each of which fill substantial gaps in our understanding of prehistoric bison ecology and human subsistence in the region. Further, I include the raw data behind these studies in supplementary electronic files included with this manuscript.

Bison are common components of SRP archaeofaunas, although they typically occur in low numbers within these archaeofaunas (Plew 2009). The ecological determinants behind the subsistence behaviors that formed these archaeofaunas are still poorly understood. However, these ecological determinants probably varied on both an intra- and inter-annual basis. Archaeologists have debated the presence of intra-annual subsistence variability (Gould and Plew 1996; Henrikson 1996, 2003; Plew 1990, 2003, 2005), although little of the debate has centered on how these strategies may have tracked seasonal variability in resource quality and abundance.

This lack of knowledge on prehistoric subsistence is partly attributable to the incomplete picture of SRP paleoecology, especially regarding bison. Archaeologists working in the region have noted bison were probably never as numerous on the SRP as on the Great Plains (Butler 1978; Henrikson 2003, 2004, 2005; Plew and Sundell 2000). However, beyond this reasonable observation, SRP bison remain somewhat of a mystery. These animals may have fluctuated in morphology and abundance in accordance with climate mediated changes in forage quality. Such changes had well documented effects on the morphology of Great Plains bison (Hill et al. 2008), although paleoecologists have struggled to document such effects west of the Rocky Mountains (Lyman 2004). A general paucity of bison remains west of the Rocky Mountains is responsible for this problem. Despite this difficulty, archaeologists have explored morphological change in SRP bison through the Holocene (Butler 1971; Butler et al. 1971). However, these brief investigations stagnated over four decades ago.

I revisit the problem of morphological change in SRP bison in Chapter 1. The first article uses recent studies on bison diminution (Hill et al. 2008; Lyman 2004) to construct a hypothesis on morphological change in SRP bison. The first recent study, conducted by Hill et al. (2008), documents a punctuated trend in bison diminution on the Great Plains. They find that declines in bison body mass track climate mediated changes in bison forage quality. Lyman (2004) hypothesizes that a similar trend occurred west of the Rocky Mountains, and he tests this hypothesis with bison remains from eastern Washington. His results also demonstrate diminution, although he cautions that this may be from recurrent Great Plains migrations rather than in situ diminution in eastern Washington. A 2000 year gap in the Middle Holocene makes evaluating these alternative explanations difficult.

I hypothesize that the Baker Cave bison also fit into this diminution trend, and that they were smaller in body size than preceding SRP bison populations. Osteometric differences should reflect size change between these bison populations. I test this prediction by measuring bison metatarsals, humeri, calcanei, tibiae, and radii from Baker Cave. Results demonstrate that these specimens are indistinguishable in size from other late Holocene bison bones, both from the Great Plains and SRP. Further, the Baker Cave specimens are smaller than specimens from the early Holocene Wasden site (Butler et al. 1971). This demonstrates that SRP bison reduced in body size through the Holocene. The Baker Cave specimens are also smaller than early Holocene bison from the Great Plains. The similarity in size between the Baker Cave bison and late Holocene Great Plains bison suggests that these animals were part of one breeding population or that they had similar physical responses to environmental constraints. Therefore, the poor forage quality on the SRP reduced bison population numbers relative to the Great Plains, rather than reducing in body mass relative to the Great Plains bison.

The second article (Chapter 2) also explores bison ecology, but this time through the lens of human subsistence. There was probably intra-annual variability in bison exploitation on the SRP (Henrikson 1996, 2003). However, the ecological determinants driving this variability are unknown (Henrikson 2003; Plew 2005). Studies on hunter-gatherer subsistence and bison ecology elsewhere to provide some clues. For example, Speth and Spielmann (1983) point out that winters frequently impose dietary restrictions on hunter-gatherers in temperate regions. Fat scarcity is an especially severe dietary restriction. Many animals experience fat depletion as forage availability declines (McNab 2002:358-366). This makes meat acquired from these animals especially lean, increasing the risk of protein poisoning. Speth (1983) argues that this may have shaped hunting and processing strategies for large game, especially bison.

In the second article, I apply Speth's (1983) and Speth and Spielmann's (1983) findings to the SRP. Fetal remains from Baker Cave point to a winter occupation, suggesting that hunters procured these animals during a period of winter fat scarcity. I test three predictions drawn from this hypothesis. First, I predict that element frequencies will reflect selective transport of fat rich bones. Second, I predict that impact scars will be distributed across elements according to their fat context. Third, I predict that fat rich bones will be more fragmentary than fat poor bones. Results meet all three predictions, supporting the hypothesis that these bison remains are a product of fat seeking behavior in response to winter fat scarcity.

Is Baker Cave representative of broader subsistence trends in the region? The second article concludes with a discussion of fat and foraging through time on the SRP. This discussion reviews similar bison assemblages on the Great Plains, demonstrating that fat seeking behavior is often indicated by a similar series of assemblage level patterns in bison dominated archaeofaunas. These patterns include skeletal element frequencies, impact scar distributions, and fragmentation patterns that track skeletal fat utility. Data on one of these patterns, the distribution of skeletal elements, are available from several other SRP archaeofaunas containing bison remains. Since SRP archaeofaunas typically contain few bison remains, I aggregate the skeletal element profiles from several archaeological sites across the eastern SRP reported by Henrikson (2003). Despite spanning the middle and late Holocene (going as far back as 6050 cal B.C.), this aggregated profile correlates strongly with not only the Baker Cave skeletal element profile, but also with skeletal fat utility. These results tentatively support a hypothesis for fat seeking behavior that persisted over 8000 years.

References Cited

Butler, B. Robert

1971 The Origin of the Upper Snake Country Buffalo. *Tebiwa* 14(2):1-20.

1978 Bison Hunting in the Desert West Before 1800: The Paleo-Ecological Potential and the Archaeological Reality. *The Plains Anthropologist* 23:106-112.

Butler, B. Robert, Helen Gildersleeve, and John Sommers

1971 The Wasden Site Bison: Sources of Morphological Variation. In *Aboriginal Man and Environments on the Plateau of Northwest North America*, edited by Arnoud H. Stryd and Rachel A. Smith, pp. 126-152. Students' Press, Calgary, Alberta.

Gould, Russell T., and Mark G. Plew

1996 Prehistoric Salmon Fishing in the Northern Great Basin: Ecological Dynamics, Trade-Offs, and Foraging Strategies. In *Prehistoric Hunter-Gatherer Fishing Strategies*, edited by Mark G. Plew, pp. 64-83. Boise State University, Boise.

Henrikson, L. Suzann

1996 *Prehistoric Cold Storage on the Snake River Plain: Archaeological Investigations at Bobcat Cave*. Monographs in Idaho Archaeology and Ethnology No. 1. Idaho State Historical Society, Boise.

2003 Bison Freezers and Hunter-Gatherer Mobility: Archaeological Analysis of Cold Lava Tube Caves on Idaho's Snake River Plain. *Plains Anthropologist* 48:263-285.

2004 Frozen Bison and Fur Trapper's Journals: Building a Prey Choice Model for Idaho's Snake River Plain. *Journal of Archaeological Science* 31:903-916.

2005 Bison Heights: A Late Holocene Bison Kill Site on Idaho's Snake River Plain. *North American Archaeologist* 26:333-355.

Hill, Matthew E., Jr., Matthew G. Hill, and Christopher C. Widga

2008 Late Quaternary *Bison* Diminution on the Great Plains of North America: Evaluating the Role of Human Hunting Versus Climate Change. *Quaternary Science Reviews* 27:1752-1771.

Lyman R. Lee

2004 Late-Quaternary Diminution and Abundance of Prehistoric Bison (*Bison* sp.) in Eastern Washington State, USA. *Quaternary Research* 62:76-85.

McNab, Brian K.

2002 *The Physiological Ecology of Vertebrates*. Cornell University Press, Ithaca.

Plew, Mark G.

1990 Modelling Alternative Subsistence Strategies for the Middle Snake River. *North American Archaeologist* 11:1-15.

2003 Archaeological Evidence of Storage on the Snake River Plain. *North American Archaeologist* 24:271-280.

2005 Comments on Bison Freezers and Hunter-Gatherer Mobility: Archaeological Analysis of Cold Lava Tube Caves on Idaho's Snake River Plain. *Idaho Archaeologist* 28(2):23-26.

2009 Archaic Hunter-Gatherer Diet Breadth and Prey Choice on the Snake River Plain. *Journal of Northwest Anthropology* 43:27-56.

Plew, Mark G., Max G. Pavesic, and Mary A. Davis

1987 *Archaeological Investigations at Baker Caves I and III: A Late Archaic Component on the Eastern Snake River Plain*. Archaeological Reports, No. 5. Boise State University, Boise.

Plew, Mark G., and Taya Sundell

2000 The Archaeological Occurrence of Bison on the Snake River Plain. *North American Archaeologist* 21:119-137.

Speth, John D.

1983 *Bison Kills and Bone Counts: Decision Making by Ancient Hunters*. The University of Chicago Press, Chicago.

Speth, John D., and Katherine A. Spielmann

1983 Energy Source, Protein Metabolism, and Hunter-Gatherer Subsistence Strategies. *Journal of Anthropological Archaeology* 2:1-31.

CHAPTER 2

HOLOCENE BISON DIMINUTION ON THE SNAKE RIVER PLAIN[1]

Introduction

North American bison (*Bison* spp.) declined in body size through the Holocene, a trend well documented by archaeologists and paleontologists working in the Great Plains. Possible factors responsible for diminution include constraints on thermoregulation (Butler et al., 1971), selection for faster maturation rates brought on by anthropogenic exploitation (McDonald, 1981: 258), or the transition from top down (predator limited) to bottom up (forage limited) ecosystem controls (Hill et al., 2008). A strong relationship between climate change and bison diminution, along with a lack of evidence for overhunting, has led some paleoecologists to conclude that human predation was not the prime mover behind shifts in bison morphology (Hill et al., 2008). Instead, climate dependent trends in forage availability and quality appear more likely to have been responsible.

Paleoecologists have documented morphological change in Great Plains bison through a number of biometric studies (Bedord, 1974; Hill, 1996; Hill et al., 2008; Hillerud, 1970; Hughes, 1978). These studies consistently show a pattern of diminution, although the timing of size reduction varies by region and skeletal element (Hill et al., 2008; McDonald, 1981: 259). The trend is also nonlinear. One recent study suggests a slight size increase following the middle Holocene (8000-5000 cal. BP), although late Holocene (5000 cal. BP to present) bison remain far smaller than terminal Pleistocene

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[1] This article is in press in the journal *The Holocene* as “Holocene bison diminution on the Snake River Plain, Idaho, USA”, by Ryan P. Breslawski and David A. Byers. This reprinted version is authorized under the Sage Publications publishing agreement (Appendix).

and early Holocene (12,000-8000 cal. BP) bison (Hill et al., 2008). The general pattern of decreasing body size is not unique to bison, as researchers have documented Holocene diminution across a range of artiodactyl taxa in North America (e.g., Guthrie, 1984; Lyman, 2006, 2009, 2010; Purdue, 1989; Purdue and Reitz, 1993). However, the sheer number of individuals and sites sampled by Hill et al. (2008) make the bison trend by far the best-documented case of artiodactyl diminution on the continent.

The trajectory of bison diminution is far less clear west of the Rocky Mountains, and researchers have yet to demonstrate the same patterns seen in Great Plains populations to the east. Much of this lack of clarity stems from the relative paucity of bison remains found west of the Rocky Mountains. Although bison were present in the western United States through the Holocene, they existed in relatively low numbers compared to the large populations living on the Great Plains. Recent studies collating the Great Basin and eastern Washington bison records demonstrate that regional archaeofaunas rarely contain more than two or three individuals (Grayson, 2006, 2011: 268-278; Lyman, 2004). In contrast, minimum numbers of individuals documented at Great Plains sites can reach the hundreds. Consequently, the small numbers of bison encountered in western archaeological and paleontological contexts complicate statistical evaluations of morphological change.

One region of the American West, the Snake River Plain (SRP), has produced a continuous bison record spanning the Holocene (Butler, 1978; Plew and Sundell, 2000). Although the majority of dated archaeological and paleontological sites contain no more than one individual, a few sites have produced sufficiently large numbers of remains to document bison diminution west of the Rocky Mountains. Investigations at Baker Cave (made up of two chambers designated as 10BN154 and 10BN153; Plew et al. 1987), located on the eastern SRP, produced one such assemblage.

To begin filling the substantial gaps in our understanding of SRP bison, we report on the morphology of those animals found in the Baker Cave archaeofauna. We begin by briefly reviewing research on Holocene bison morphology and fossil bison from the SRP. We then discuss the SRP environment as well as Baker Cave and its associated archaeofauna. We next outline procedures for measuring select bison elements from Baker Cave. Finally, we compare the Baker Cave bison measurements to those of bison from other contexts, both on the SRP and the Great Plains to the east. We do so to assess the trajectory of bison diminution not only on the SRP, but also more broadly within a trans-North American context.

Holocene Bison Diminution

Research on the Great Plains has produced a large and well-documented Holocene bison record. This information has allowed researchers to propose and evaluate ideas about the roles of people and climate in shaping animal populations. In one recent look at Great Plains faunas through the late Quaternary, Hill et al. (2008) assess whether human hunting could account for bison size diminution. They use the timing of human arrival in North American as well as bison mortality profiles to evaluate the human hunting argument. Their results fail to support human predation as a prime mover behind trends in bison morphology. Instead, they find that bison diminution was a punctuated trend apparently unrelated to coincident trends in human demographics. Moreover, shifts in morphology occurred during periods of significant climate change, specifically during the Late Glacial Maximum (18,000-21,000 cal. BP), the Younger Dryas (11,000-13,000 cal. BP), and the middle Holocene (7000-9000 cal. BP). Bison partially rebound in size during the transition from the Middle to the late Holocene (6000-3000 cal. BP), although a sparse record from this period makes the timing of this size increase difficult to establish (see Hill et al., 2008: 1759-1760).

Common explanations for artiodactyl diminution through the Holocene have included thermoregulation (Butler et al., 1971), predator release (Geist, 1989; Matheus, 2001), and forage availability (Geist, 1971, 1989; Guthrie, 1984). Butler et al. (1971) proposed Bergmann's Rule as an explanation for size change in bison after comparing Holocene bison assemblages across North America. However, issues relating to sex determination as well as conflation of latitudinal and temporal variation make their conclusions problematic (Wilson, 1974: 142-145). Hill et al. (2008: 1764) detail further problems with applying Bergmann's Rule to the bison chronocline. These include difficulty in controlling for covariance between temperature and forage availability as well as the lack of a simple linear correlation between body size and temperature through the Quaternary Period. On a more general level, researchers have also demonstrated that models of net primary productivity better explain a number of taxon specific cases (Huston and Wolverton, 2011; Wolverton et al., 2009). In sum, Bergmann's rule is an extremely problematic explanation for changes in bison morphology through the Holocene. For an alternative explanation, Geist (1989) and Matheus (2001) argue that the large body masses of Pleistocene megafauna were a response to predation and interspecific competition. After the extinction of Pleistocene carnivores and other megaherbivores, selection for large body size was relaxed. Unfortunately, the uncertain timing of Pleistocene predator extinctions (Grayson, 1991, 2007; Mead and Meltzer,

1984) complicates this hypothesis. The numerous problems with these hypotheses have left changes in forage quality and availability as the best supported explanation for diminution in Holocene mammals.

Hill et al. (2008) see forage quality as playing an important role in bison diminution, although they caution that forage quality alone is probably not the answer. Bison are obligate grazers dependent on grassland forage. Modern studies have shown that more easily digestible, and consequently more nutritious, C_3 grasses tend to dominate in areas characterized by cooler climates, while less nutritious C_4 grasses tend to dominate in warmer environments (Ehleringer, 1978; Epstein et al., 1997; Teeri and Stowe, 1976). Hill et al. (2008) found that the timing of body size reductions tended to occur during warmer periods characterized by expanding dominance of less nutritious, warm weather C_4 grasses. The consumption of more C_4 grasses would have resulted in a lower quality bison diet that would have constrained somatic growth and created a selective pressure emphasizing smaller, less energetically expensive bodies (Hill et al., 2008). If the relationship between forage quality and bison morphology explains the trend in diminution on the Great Plains, then we expect a similar chronocline on the SRP as well.

Geography and Paleoecology of the Snake River Plain

The SRP sits at the southeastern most extent of the Columbia Plateau, where a unique igneous landscape and drainage system characterize the region (Kuntz et al., 1986, 1992; Malde and Powers, 1962; Smith, 2004; Wood and Clemens, 2002). Much like surrounding areas west of the Rocky Mountains, the SRP contains habitat less suitable than that found on the Great Plains (Mack and Thompson, 1982). This is probably due to climate dependent effects on forage availability, including severe inter-annual summer drought and winter snow volume (Williams, 2005).

Although the SRP shares these climatic patterns with much of the northwestern USA, the region's uniquely flat topography provides few obstructions for migrating bison, a factor that likely made the SRP better bison habitat than other areas west of the Rocky Mountains (Van Vuren, 1987). Moreover, the near uniform sagebrush steppe biome across the region provides few ecological obstacles for bison populations, such as habitats fragmented by variability in elevation. While the SRP today lacks the forage communities likely to support large bison populations, these conditions have by no means remained consistent over the Holocene. Instead, climate dependent trends in forage quality and availability mediated the ability of the SRP to support bison populations. These trends likely conditioned local bison diminution in ways similar to those seen on the Great Plains.

Climatic factors such as seasonality, aridity, and temperature condition forage quality and availability. Paleoenvironmental studies suggest that during the Terminal Pleistocene, the SRP was generally wet and cool (Bright, 1966). However, a warming trend began between 10,800 and 10,300 cal. BP, as indicated by pollen cores from Swan Lake, southeastern Idaho (Bright, 1966). This early Holocene warming triggered an expansion of sagebrush and the movement of biotic communities to higher elevations. Warming continued into the Middle Holocene, although records indicate conflicting dates for the timing of maximum aridity. The Swan Lake record suggests a period of maximum aridity between 8400 and 3100 cal. BP (Bright, 1966), although packrat middens from the Idaho National Engineering Laboratory indicate this thermal maximum was reached at about 7000 cal. BP (Bright and Davis, 1982). Pollen from Gray's Lake mirrors the Swan Lake record, suggesting that the swing towards Middle Holocene aridity began around 8200 cal. BP (Beiswenger, 1991). Grass pollen from Scaredy Cat Cave, located in Craters of the Moon National Park, demonstrates that a highly variable climate better characterizes the Middle Holocene, as opposed to a general state of aridity (Wigand, 1997). Finally, most records indicate that an essentially modern climate was established between 3100 and 2000 cal. BP (Beiswenger, 1991; Bright, 1966; Cummings, 2002).

Temporal patterns in SRP climates mirror patterns found in nearby areas of the Great Basin and southwestern Wyoming that document broad climate dependent trends in forage quality and, consequently, artiodactyl reproductive success (Broughton et al., 2008; Byers and Broughton, 2004; Byers and Smith, 2007; Byers et al., 2005). In these instances, trends in artiodactyl abundances mirror trends in effective precipitation, with moister periods characterized by greater abundances of these animals on the landscape. This well documented relationship, in combination with trends in bison morphology identified by Hill et al. (2008), allow us to make several broad predictions about morphological trends in Holocene SRP bison populations. Simply put, we expect early Holocene SRP faunas to contain larger bison, with subsequent size reductions occurring in tandem with increasing Holocene aridity. If the model presented here correctly anticipates the trajectory of SRP bison diminution, then the aridity of the Middle Holocene west of the Rocky Mountains should have selected for smaller individuals and resulted in late Holocene bison possessing smaller mean body sizes.

Bison on the Snake River Plain

Bison remains have been recovered from numerous contexts throughout the SRP. In fact, one recent review of archaeofaunas from southern Idaho documented bison at 56% of the sites in the area (Plew, 2009). Most of these remains are reported as Number of Identified Specimens (NISP), Minimum Number of Individuals (MNI), or simply as presence or absence data. While bison are common components of SRP archaeofaunas, NISP is typically low and MNIs usually indicate no more than one individual (Gruhn, 1961; Henrikson, 1996; Henrikson et al., 2006; Holmer and Ringe, 1986; McDonald, 2006; Murphey and Crutchfield, 1985; Pavesic and Meatte, 1980; Plew, 1981; Rudolph, 1995). Consequently, archaeologists have argued that the SRP did not support bison populations large enough to allow for prehistoric mass kill events like those documented on the Great Plains (Henrikson, 2003, 2004, 2005; see also Daubenmire, 1985; Mack and Thompson, 1982). Unfortunately, these low numbers also make understanding trends in bison morphology difficult.

Regions bordering the northern and eastern SRP have produced a more substantial bison record. For example, the late Holocene (107-757 cal. BP) Rock Springs Site (Arkush, 2002), located in southeastern Idaho, contains an assemblage of 945 specimens representing at least 19 individuals (Walker, 2002). Upland areas north of the SRP also contain evidence for Holocene bison. Swanson (1972) reports at least 128 bison (NISP=1241) at the Birch Creek Rockshelters. Butler (1971) estimates 20-30 bison at the Challis Bison Jump (poor preservation prevented explicit quantification) and at least 11 bison (NISP=364) at Quill Cave. Historic accounts describing large numbers of bison in the uplands support to this archaeofaunal evidence for larger populations in these areas

(Henrikson 2004). Although these sites produced fewer bison than were often documented in Great Plains assemblages, they nonetheless contain far more bison than seen in most SRP archaeological and paleontological faunas.

Exceptions to the pattern of low bison MNI counts include the Wasden Site (Butler, 1968; Butler et al., 1971; Miller and Dort, 1978) and Baker Cave (Miller, 1987; Results section). The Wasden site consists of a cave on the eastern SRP containing a large bison assemblage dating to the early Holocene (8015-8593 cal. BP). Although a complete quantification of bison remains from the Wasden Site remains unpublished, several investigators have provided MNI estimates. Initial investigations of the locality yielded an MNI of 50 based on lower mandibles (Butler, 1968). Butler et al. (1971) raised this minimum estimate to 60 individuals, and Butler (1978) reports at least 66 individuals. Following continued excavations, Miller and Dort (1978) estimate that 150 bison were present at Wasden (however, it is unclear if this is a minimum estimate). Even the smallest minimum bison estimates for Wasden are far larger than MNI estimates from elsewhere on the SRP.

The large number of bison at the Wasden Site is likely why Butler et al. (1971) selected Wasden to examine the change from *B. antiquus* to *B. bison*. They concluded their study by suggesting the next steps for investigating Holocene bison diminution should include establishing age and sex dependent variability in modern bison skeletal elements, comparing archaeological and paleontological metrics for aging and sexing bison with established data and developing standardized criteria for determining age and sex. Great Plains research has mostly fulfilled these goals, although these improved methods have gone unused on the SRP. Baker Cave provides an opportunity to apply these methods to a SRP bison assemblage. For the first time since Butler et al.'s (1971) investigation, enough data are available to evaluate the broad trends in SRP bison diminution.

The Baker Cave Bison

Excavations at Baker Cave

Baker Cave is an eastern SRP site located about 19 km east of Minidoka, Idaho, and roughly 8 km northeast of Lake Walcott (Figure 2-1). The site occupies a lava blister that formed during the extrusion of the Wapi Lava Flow. The setting typifies lava fields found throughout the region today, characterized by a sagebrush-steppe biome dispersed across an uneven basalt terrain. Although at a distance from permanent water today, the geological setting provides opportunities for spring rains to pool in seasonal ponds (Henrikson et al., 2006: 45).

In an effort to mitigate looting, Boise State University, in conjunction with the Idaho Bureau of Land Management, excavated Baker Cave in 1985 (Plew et al., 1987). Investigations took place in two chambers designated Baker I and Baker III. Plew et al. (1987) report a third chamber (Baker II) that lacked cultural materials and sediment depth, which they did not investigate further. Baker I is a low hanging chamber roughly 3 m deep by 7 m wide. A wall constructed of basalt and juniper branches partially blocked the entrance at the time of investigation (Plew et al., 1987: 13). Baker III consists of two interconnected chambers. The first chamber is roughly 60 m by 9 m and contained the majority of cultural deposits. The second chamber is a long tube roughly 6 m wide and 100 m deep. Plew et al. (1987: 13) report little deposition or evidence for human use in

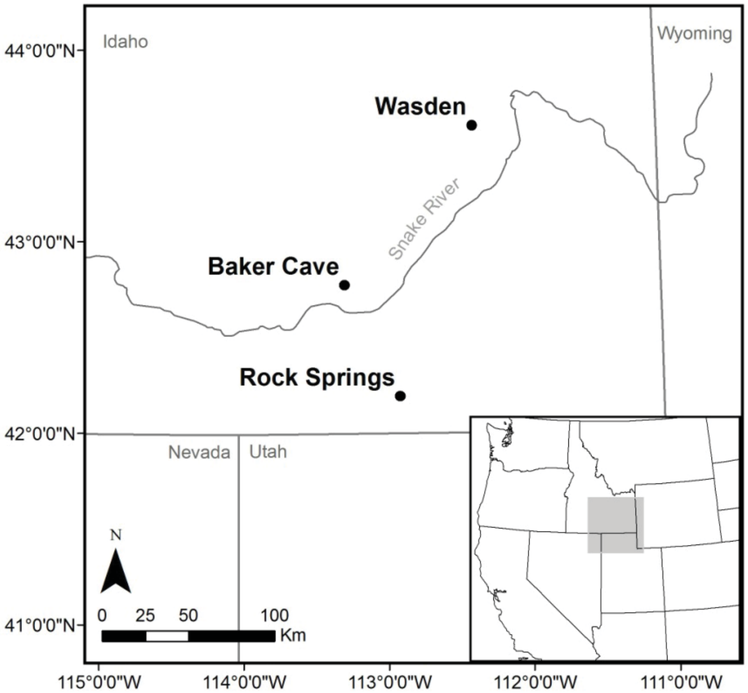

Figure 2-1. Locations of southern Idaho sites that have produced measurable bison specimens.

this chamber. Due to time restrictions, Boise State University focused recovery efforts on Baker I and the first chamber of Baker III.

Plew et al. (1987) designed the excavation to recover the maximum amount of cultural materials. Due to the shallow deposition (~15 cm maximum), they treated all sediments as a single component. Most of the excavation was accomplished with brushes and all sediment was passed through 0.3 cm mesh. They excavated 100% of the undisturbed sediments from Baker I and roughly 70% of Baker III. These efforts resulted in the collection of a large cultural assemblage that included substantial numbers of bison bone.

The Boise State University excavations exposed several archaeological features containing charcoal suitable for radiocarbon dating. The features include an S shaped rock alignment in Baker III as well as three hearths in Baker I and III (Plew et al., 1987: 21). Boise State University collected five radiocarbon dates from the hearths that place occupation of the cave at 685-908 cal. BP (Plew et al., 1987: 22). These dates disagree with two obsidian hydration dates from the cave, which indicate occupation around 1341-1541 BP and 1264-1394 BP (Plew et al., 1987: 17). Plew et al. (1987: 22) suggest that the hearths and obsidian artifacts indicate two different human occupations, although Plew et al.'s course-grained excavation methods failed to document any stratigraphic separation between materials in the cave. Rather, the excavated sediments most likely contain a palimpsest of several hundred years of cultural and natural deposition. Moreover, recent critiques of obsidian hydration dating suggest that a number of environmental factors can bias dates generated by this method (Anovitz et al., 1999). Regardless, while we acknowledge some imprecision in the dating of Baker Cave, the relatively coarse-grained temporal scales researchers have used to examine bison diminution through the Holocene (e.g., the 1000-year bins used by Hill et al. [2008: 1760]) obviate the issue of time averaging over a 350-850 year period.

Bison Remains from Baker Cave

Baker Cave produced a large archaeofauna containing artiodactyls, lagomorphs, rodents, canids, snakes, and birds. Of these specimens, we identified 591 as adult *Bison bison* (MNI=37, based on the distal right tibia). The assemblage also contains 431 fetal bison specimens (MNI=7, based on the right radial diaphysis). Specimens lacking features that distinguish *Bos taurus* from *Bison bison* were classified as large bovid (NISP=179). An additional 3814 specimens fell into the size range of elk (*Cervus canadensis*), moose (*Alces alces*), bison (*Bison bison*), and domestic cattle (*Bos taurus*), but lacked taxonomically diagnostic features. These specimens are mostly comprised of diaphysis fragments. We classify them as large artiodactyl here. The lack of large artiodactyls other than bison suggests that these fragments also represent this taxon.

Taphonomic processes can bias archaeofaunas against certain age and sex classes. A number of factors may affect the representation of less dense bone. This is important to consider for the Baker Cave assemblage since volume mineral density of bison bone significantly, but weakly, predicts the frequencies of element portions in this fauna (r_s=0.282, p=0.005; volume mineral density values from Kreutzer, 1992). A lack of low-density proximal element portions including those of humeri, tibiae, and femora appear to drive this trend. The absence of these skeletal portions is probably due to factors such as carnivore ravaging and weathering. Carnivore damage is present on 7.24% of *Bison bison*, large bovid, and large artiodactyl specimens (NISP=332). *In-situ* chemical weathering probably accounts for some attrition as well. While 72.89% of specimens (NISP=3342) have at least one unweathered surface (no cracking or flaking), 54.86% of specimens (NISP=2515) display at least one surface with evidence for exposure to weathering agents. Of the large artiodactyl specimens, 2.09% (NISP=97) are completely weathered down to fibrous bone or are actively disintegrating.

Despite evidence suggesting that several taphonomic processes have conditioned the collection, a sufficiently large and representative sample of elements has survived for metric analysis. Given this robust, relatively well-preserved bison assemblage, Baker Cave provides a unique opportunity to assess a late Holocene bison population west of the Rocky Mountains. This favorable taphonomic context, in combination with the large adult bison MNI, allows a confident size distribution to be determined from a robust osteometric dataset.

Material and Methods

Adult *Bison bison* specimens were measured to the nearest 0.5 mm using Pittsburgh® Model 47257 6” digital calipers and an osteometric board designed and built in-house. To control for maturational variation, we only included specimens displaying complete fusion. We also only recorded complete dimensions that could be precisely measured. This excluded specimens with carnivore ravaging, rodent gnawing, severe cortical weathering, or other damage along measured points.

We follow Todd’s (1987) protocol for humerus, radius, and tibia measurements; Lewis et al.’s (2005) protocol for metatarsal measurements; and Hill’s (1996) protocol for calcaneus measurements. We measure the greatest length (CL1) and greatest width (CL4) of calcanei. For humeri, we measure the width of the distal articular surface (HM7) and the greatest medial depth of the distal end (HM11). We take measurements on the greatest proximal width (ProxW) and greatest proximal depth (ProxD) of metatarsals. We also measure the greatest proximal articular surface width (RD4) and greatest proximal depth (RD9) of radii. We measure the greatest distal width (TA7) and depth (TA10) of tibiae.

Results

The results presented here derive from 245 measurements taken from 111 specimens of bison bone. These measurements indicate that the Baker Cave bison fauna contains between 70% (based on the calcaneus) and 87.5% (based on the distal tibia) females (Table 2-1). Metrics from the most commonly measured skeletal part, the distal humerus, indicate that 77% of the mature individuals are female. This high frequency of females is not surprising given the presence of numerous fetal remains in context with adult specimens. Although sex ratios varied between metrics, they all suggest a female dominated assemblage.

Calcaneus, humerus, and tibia dimensions all break down into discrete sex distributions (Figures 2-2a, 2-2b, and 2-2c). Radius dimensions plot as one cluster and one outlier, which we interpret as a single male specimen (Figure 2-2d). In contrast, metatarsals group into more ambiguous clusters than the other elements discussed here. Figure 2-2e appears to show two different clusters with one large outlier. This distribution presents the possibility that the outlier is male and the two clusters are female. An alternative interpretation is that each cluster originates from a different sex and the outlier is an exceptionally large male.

To evaluate these alternative interpretations, we consider data on modern bison metatarsals originating from individuals of known sex. Lewis et al. (2005) show that proximal metatarsal width is 57.8 ± 4.4 mm (*s*) in modern males and 50.8 ± 2.8 mm (*s*) in modern females. They also show that proximal metatarsal depth is 54.9 ± 2.8 mm (*s*) in modern males and 48.5 ± 2.3 mm (*s*) in modern females. These data overlap neatly with the Baker Cave metrics. When considering Lewis et al.'s measurements, the two clusters fall within the female group and the outlier falls within the male group. Therefore, we interpret the two clusters as female and the outlier as male. The gap in the female cluster is likely a sampling problem.

We note a potential problem with using modern bison from a different spatial context as a standard for sexing the Baker Cave bison: geographic variability in

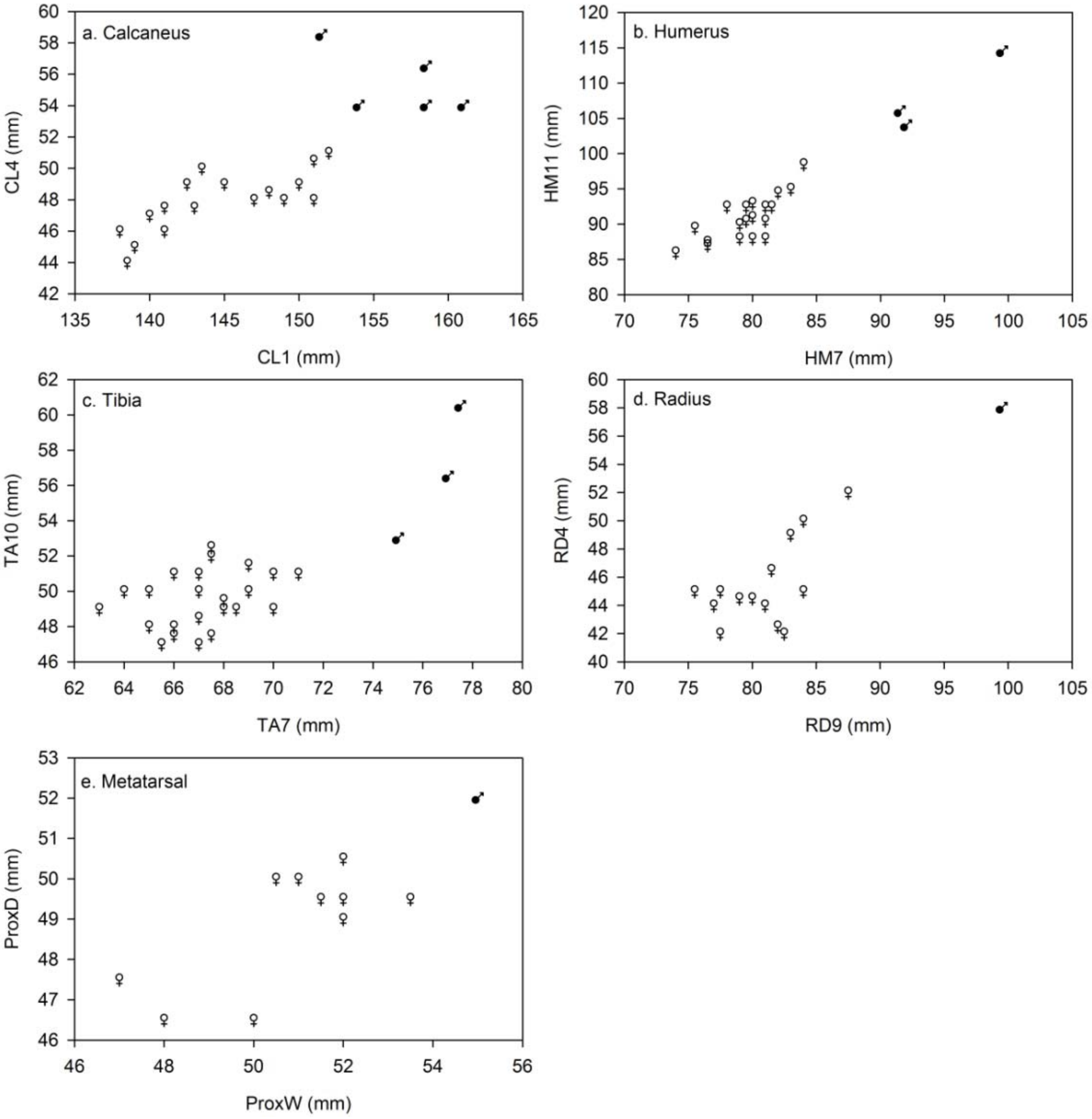

Figure 2-2. Bivariate plots of Baker Cave bison metrics: (a) calcaneus, (b) humerus, (c) tibia, (d) radius, and (e) metatarsal.

Table 2-1. Descriptive statistics for Baker Cave bison specimens.

	Female				Male			
Measurement	*n*	Range	$\bar{x}$	*s*	*n*	Range	$\bar{x}$	*s*
CL1	17	138.0-151.0	144.3	4.4	5	151.5-161.0	156.7	3.9
CL4	17	44.0-50.5	47.6	1.7	5	54.0-58.5	55.4	2.0
HM7	28	73.0-84.0	79.2	2.7	4	91.5-99.5	93.6	3.9
HM11	20	86.0-98.5	91.1	3.2	3	104.0-114.5	108.2	5.6
ProxW	12	47.0-53.5	51.0	2.2	1	55.0-55.0	55.0	0.0
ProxD	12	46.5-50.5	48.9	1.8	1	52.0-52.0	52.0	0.0
RD4	14	75.5-87.5	80.9	3.3	1	99.5-99.5	99.5	0.0
RD9	14	42.0-52.0	45.4	3.0	1	58.0-58.0	58.0	0.0
TA7	26	63.0-71.0	67.1	1.9	3	75.0-77.5	76.5	1.3
TA10	26	47.0-52.5	49.5	1.5	3	53.0-60.5	56.7	3.8

morphology. Others have identified known latitude controlled differences in bison body size through the Holocene, although these become less pronounced in the late Holocene (Hill et al., 2008: 1760). The modern bison used by Lewis et al. (2005) are primarily northern Great Plains and zoo specimens. Using the latitudinal distinctions defined by Hill et al. (2008: 1760), the northern Great Plains fall within the same range as southern Idaho (although Lewis et al. [2005] do not specify the geographic origin of the zoo specimens). Although this modern sexed sample may not overlap perfectly with the Baker Cave sample, we expect minimal temporal and spatial variation in the size of males and females between the samples. Therefore, it is likely a good standard for identifying male and female metatarsals at Baker Cave.

Discussion

To put the Baker Cave bison in a broader context, we compare the Baker Cave size data to bison metrics from previously reported faunas from the SRP and Great Plains (Table 2-2). Specifically, we compare this dataset to other SRP assemblages, with the

Table 2-2. Descriptive statistics for female bison from archaeological and paleontological contexts.

Metric	Site	Range	x̅	*s*	*n*	Reference
CL1	Baker Cave	138.0-151.0	144.3	4.4	17	Results section
	Glenrock	128.0-155.0	142.3	6.4	108	Hill et al., 2008
	Big Goose Creek	134.0-146.0	142.0	4.1	8	Hill et al., 2008
	Big Bone Lick	129.0-146.0	140.0	4.3	21	Hill et al., 2008
	Mavrakis-Bentzen-Roberts	132.0-154.0	146.1	5.2	37	Hill et al., 2008
	Hawken	140.0-155.0	149.6	5.1	19	Hill et al., 2008
	Mill Iron	156.0-163.0	159.5	3.5	4	Hill, 1996
CL4	Baker Cave	44.0-50.5	47.6	1.7	17	Results section
	Glenrock	42.0-55.0	47.4	2.7	109	Hill et al., 2008
	Big Goose Creek	42.0-49.0	45.8	2.7	8	Hill et al., 2008
	Big Bone Lick	36.0-47.0	41.5	3.1	21	Hill et al., 2008
	Mavrakis-Bentzen-Roberts	44.0-54.0	48.8	2.5	40	Hill et al., 2008
	Hawken	47.0-63.0	51.6	4.7	20	Hill et al., 2008
	Mill Iron	46.0-55.0	51.7	4.9	3	Hill, 1996
HM7	Baker Cave	73.0-84.0	79.2	2.7	28	Results section
	Rock Springs	78.0-79.0	78.7	0.6	3	Walker, 2002
	Logan Creek	76.3-96.4	83.9	6.5	11	Hill et al., 2008
	Spring Creek	75.7-91	82.2	4.6	10	Hill et al., 2008
	Horner	80.0-87.0	83.4	2.3	19	Todd, 1987
HM11	Baker Cave	86.0-98.5	91.1	3.2	20	Results section
	Rock Springs	87.0-91.0	89.3	2.1	3	Walker, 2002
	Logan Creek	91.1-97.5	93.5	3.1	4	Hill et al., 2008
	Spring Creek	86.6-	91.5	3.4	4	Hill et al., 2008

		94.4				
	Horner	85.0-100.0	95.5	3.5	19	Todd, 1987
ProxD	Baker Cave	46.5-52	48.9	1.8	12	Results section
	Wasden[a]	48.0-53.0	50.3	1.6	23	Butler et al., 1971
	Wasden[b]	48.0-61.0	53.2	3.9	36	Butler et al., 1971
RD4	Baker Cave	75.5-87.5	80.9	3.3	14	Results section
	Horner	82.0-89.0	84.9	2.4	18	Todd, 1987
RD9	Baker Cave	42.0-52.0	45.4	3.0	14	Results section
	Horner	45.0-52.0	48.8	2.4	18	Todd, 1987
TA7	Baker Cave	63.0-71.0	67.1	1.9	26	Results section
	Rock Springs	65.0-69.0	67.3	2.1	3	Walker, 2002
	Horner	65.0-75.0	71.1	2.6	21	Todd, 1987
TA10	Baker Cave	47.0-52.5	49.5	1.5	26	Results section
	Rock Springs	47.0-52.0	48.7	2.9	3	Walker, 2002
	Horner	48.0-56.0	52.9	2.2	21	Todd, 1987

Notes: [a] Female specimens identified through a bivariate plot of proximal dimensions.

[b] Female specimens identified through bivariate method specified in Butler et al. (1971).

expectation that on-average the Baker Cave bison will be smaller than early Holocene SRP bison and similar in size to those found in other late Holocene bison assemblages. We also compare the SRP bison data with datasets derived from Great Plains bison to provide insight into continental-scale spatial variability in bison morphology. The data on SRP bison morphology presented here supports a diminution trend similar to the one documented on the Great Plains. Further, comparisons between SRP bison and those from Great Plains assemblages suggest that similar times in both regions contained similarly sized bison, suggesting parallel chronoclines in diminution (see map in Hill et al. [2008: 1756] for Great Plains site locations).

While the lack of bison metrics from SRP assemblages complicates within-region comparisons, data published from two other southern Idaho localities allows for some insights into morphological trends. Butler et al.'s (1971) investigation of SRP bison morphology using the early Holocene Wasden Site generated a large dataset of metatarsal measurements. Unfortunately, Butler et al. did not take the same suite of measurements as those recorded from Baker Cave. Nonetheless, both studies share one metric in common, proximal depth.

We differ from Butler et al. (1971) in our interpretation of the sex distribution within this dataset. Butler et al. (1971: 136) identify 36 females by plotting the width and length of metatarsals. We instead use Lewis et al.'s (2005) protocol for metatarsal measurements to interpret the Wasden sex distribution through clustering in proximal metatarsal width and depth. Doing so results in all three specimens that Butler et al. (1971) identify as male falling within the larger group of specimens that they identify as female (Figure 2-3a). Recognizing this issue, we reclassify the Wasden bison and find 23 females and 16 males (Figure 2-3b).

Figure 2-3 demonstrates the large differences between Butler et al.'s method and the one we use here. We suggest that identifying simple clusters gives a more accurate picture of the Wasden Site sex ratio. One might also interpret these points as three clusters, with the middle cluster that we identify as female here reclassified as male. We do not consider this interpretation since our method provides a more conservative

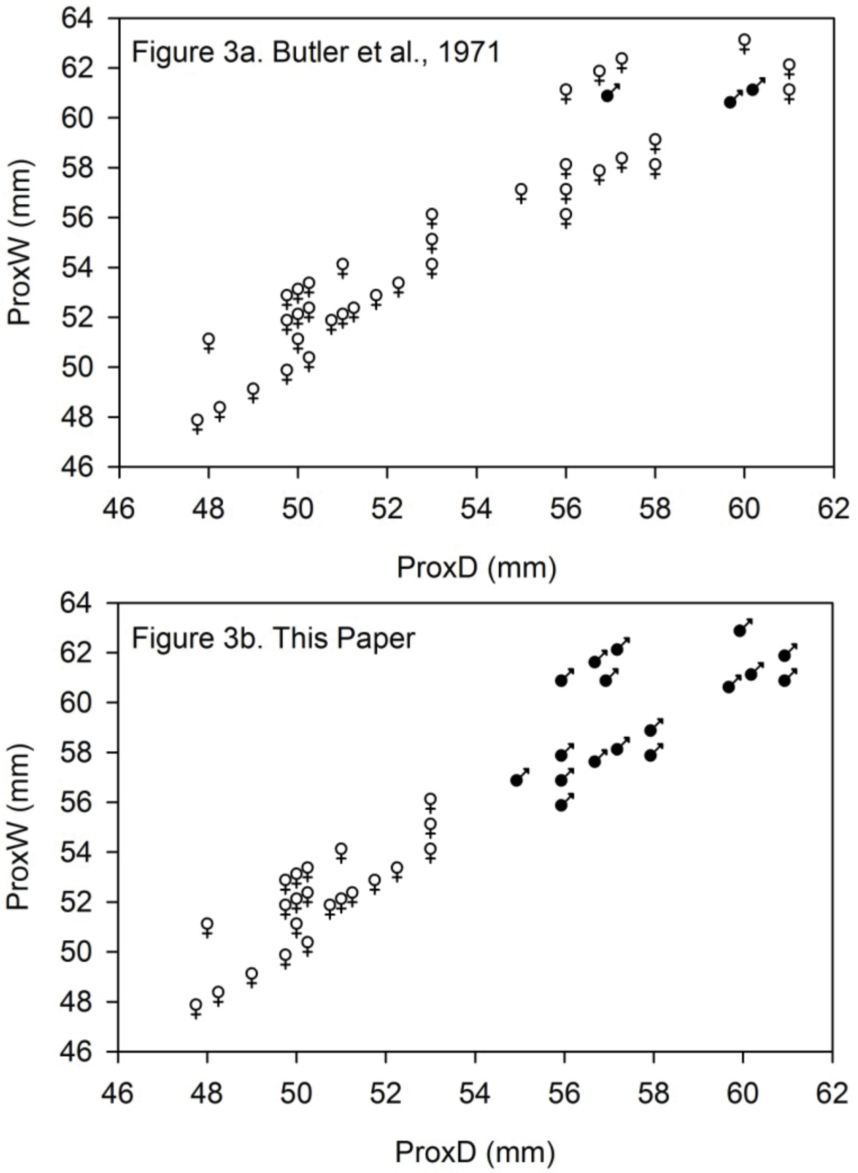

Figure 2-3. Bivariate plots of proximal width and depth of the Wasden Site metatarsals: (a) sex interpreted through Butler et al.'s (1971) method and (b) sex interpreted through simple observation of point clustering (this paper).

measure that already treats only the smallest cluster as female. If this small female cluster contains specimens larger than those at Baker Cave, then reclassifying the middle cluster as female would only increase the mean size difference between the Wasden and Baker Cave metatarsals.

When considering specimens sexed through our simple clustering approach, female Wasden specimens ($\bar{x}$=50.45 mm, *s*=1.50 mm, *n*=23) appear significantly larger than female Baker Cave specimens (*t*=-2.354, *p*=0.029; Figure 2-4). This difference is especially striking when considering that the mean for females derived Butler et al.'s (1971) method results in a proximal depth that is almost 3 mm larger than the mean value that we obtained ($\bar{x}$=53.19 mm, *s*=3.85 mm, *n*=36). Not surprisingly, using Butler et al.'s (1971) numbers also results in a significant size difference with Baker Cave (*t*=-3.696, *p*=0.001). Although additional bison metrics from Wasden would make comparisons between the sites more robust, these data support the hypothesis that SRP bison underwent a dramatic diminution between the early and late Holocene.

Despite a small sample from the Rock Springs site, *t*-tests suggest that bison from this site were similar in size to those from Baker Cave. For example, no inter-site differences are seen in measurements of either humeri (HM7: *t*=0.895, *p*=0.384; HM11: *t*=1.246, *p*=0.287) or tibiae (TA7: *t*=-0.188, *p*=0.865; TA10: *t*=0.492, *p*=0.669). These data, in combination with the Wasden site metrics, suggest two conclusions regarding the Baker Cave bison anticipated by bison studies focused on Great Plains populations. First, early Holocene SRP bison were on-average larger than those dating to the late Holocene. Second, late Holocene bison from different areas of southern Idaho were morphologically similar.

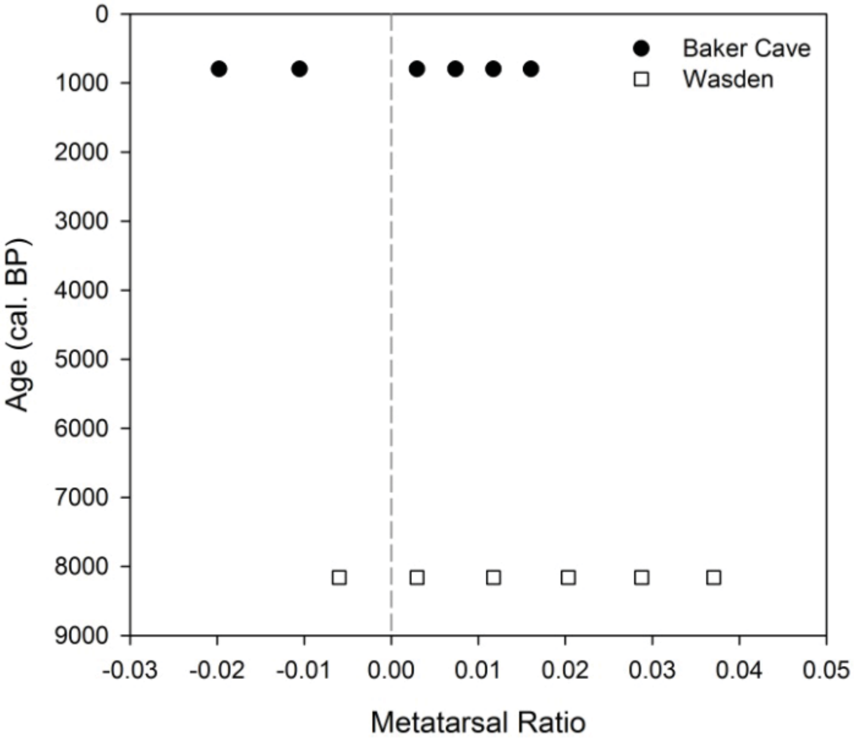

Figure 2-4. Ratio plot comparing female metatarsals from Wasden with those from Baker Cave. Prehistoric values standardized relative to modern female calculated from data in Speth (1983: Appendix). Positive values indicate individuals larger than the modern average and vice versa. Lyman (2004) outlines the specifics of constructing a ratio plot.

The similarity in temporal trends between SRP and Great Plains bison suggests that the two populations experienced similar morphological trajectories. If so, morphological similarity should exist between SRP and Great Plains bison through time as well. To evaluate similarities and differences in bison between the two regions, we next compare the metric data from the three SRP bison records presented here with early, middle, and late Holocene bison data from the Great Plains (Figure 2-5 and Table 2-3). We focus on comparisons of two skeletal elements, calcanei and humeri from female animals, since measurements of these bones were most often reported and females are most common. The early Holocene records we use include the Mill Iron (10,838-11,722 cal. BP) and Horner sites (9255-9511 cal. BP). Great Plains middle Holocene bison are represented by data from the Hawken (7131-7374 cal. BP), Logan Creek-Zone B (6980-7480 cal. BP), and Spring Creek sites (6940-7160 cal. BP). Finally, the Glenrock (221-298 cal. BP), Big Goose Creek (404-600 cal. BP), and Mavrakis-Bentzen-Roberts sites (2536-2684 cal. BP) provide measurements documenting the size of late Holocene bison on the Great Plains.

Comparisons of later late Holocene calcanei (<2000 cal. BP) from both regions suggests that Great Plains and SRP bison were indistinguishable in size during this period (Table 2-3 and Figure 2-5a). Size differences become apparent as recently as 2536-2684 cal. BP at the Mavrakis-Bentzen-Roberts site, where calcaneus breadth is significantly larger than calcanei from more recent assemblages (<2000 cal. BP), including the Baker Cave materials. Middle Holocene bison also appear larger than late Holocene examples, although the strength of the statistical difference depends on the element considered. The Spring Creek and Logan Creek humeri are larger than those at Baker Cave and Rock Springs, although this difference is only statistically significant for HM7 (with the exception of the HM7 comparison between Spring Creek and Baker Cave). The lack of statistical differences between HM11 measurements likely results from the small sample sizes under test, as Spring Creek and Logan Creek only have four cases each for this measurement. Moving earlier into the middle Holocene, the calcanei measurements from Hawken provide an especially strong contrast with those from Baker Cave, suggesting the Hawken bison were larger.

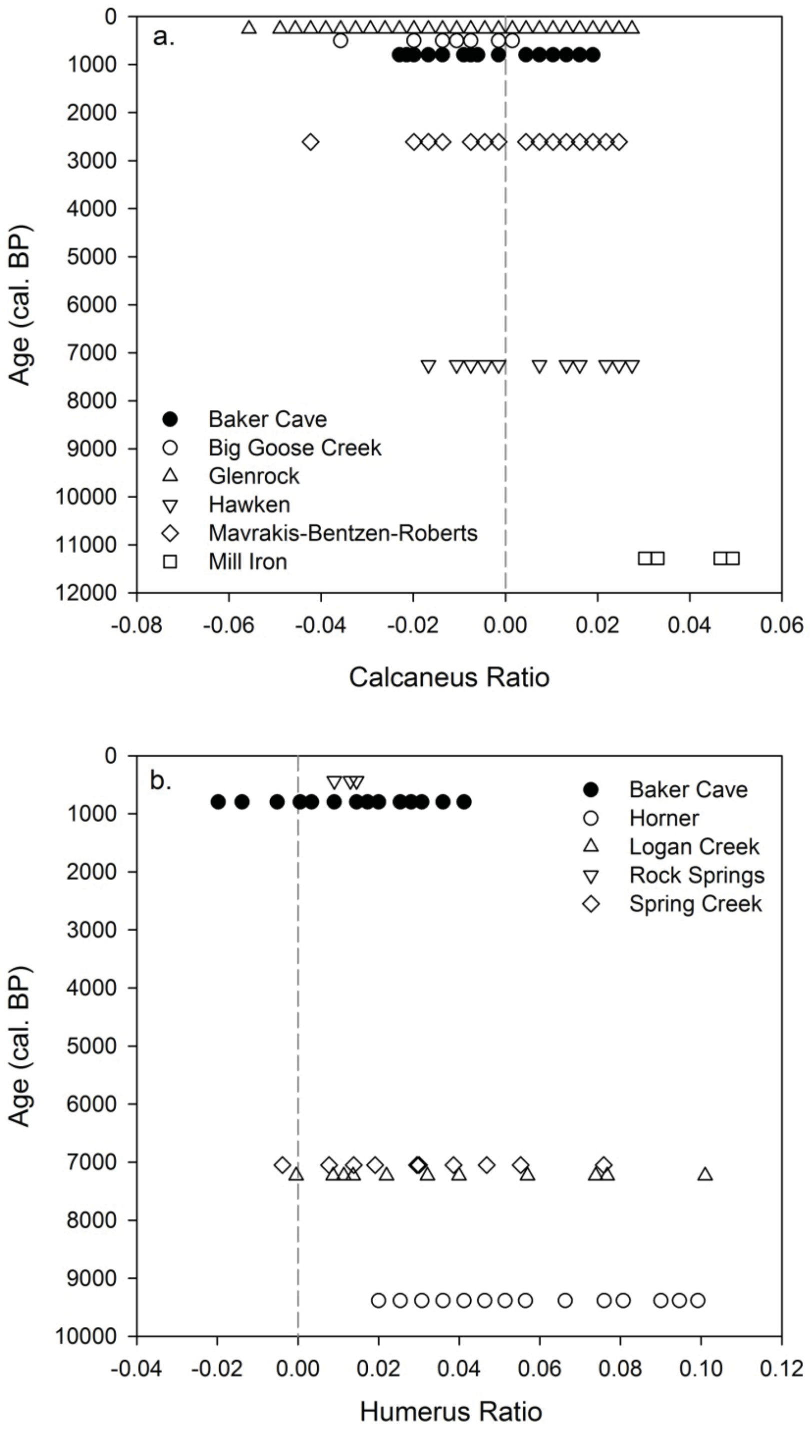

Figure 2-5. Ratio plots comparing Baker Cave females with those from selected SRP and Great Plains sites: (a) calcaneus and (b) humerus metrics. Prehistoric values standardized relative to modern female average presented in Hill et al. (2008). Positive values indicate individuals larger than the modern average and vice versa. Lyman (2004) outlines the specifics of constructing a ratio plot.

Table 2-3. Intersite comparison of calcanei, humeri, and tibiae. Equal variances not assumed. Bold font marks correlations that are significant at the .05 level.

		Baker Cave		Rock Springs		Glenrock	
Site	Metric	*t*	*p*	*t*	*p*	*t*	*p*
Baker Cave	CL1	0.000	1.000	-	-	1.627	0.115
	CL4	0.000	1.000	-	-	0.518	0.619
	HM7	0.000	1.000	0.895	0.384	-	-
	HM11	0.000	1.000	1.246	0.287	-	-
	TA7	0.000	1.000	-0.188	0.865	-	-
	TA10	0.000	1.000	0.492	0.669	-	-
Rock Springs	HM7	0.895	0.384	0.000	1.000	-	-
	HM11	1.246	0.287	0.000	1.000	-	-
	TA7	-0.188	0.865	0.000	1.000	-	-
	TA10	0.492	0.669	0.000	1.000	-	-
Glenrock	CL1	1.627	0.115	-	-	0.000	1.000
	CL4	0.518	0.619	-	-	0.000	1.000
Big Goose Creek	CL1	1.292	0.216	-	-	0.195	0.849
	CL4	1.846	0.095	-	-	1.688	0.130
Mavrakis-Bentzen-Roberts	CL1	-1.312	0.198	-	-	**-3.615**	**0.001**
	CL4	**-2.030**	**0.049**	-	-	**-3.024**	**0.003**
Spring Creek	HM7	-1.970	0.074	**-2.407**	**0.037**	-	-
	HM11	-0.243	0.820	-1.049	0.343	-	-
Logan Creek	HM7	**-2.323**	**0.040**	**-2.641**	**0.024**	-	-
	HM11	-1.446	0.215	-2.149	0.084	-	-
Hawken	CL1	**-3.352**	**0.002**	-	-	**-5.58**	**<0.000**
	CL4	**-4.435**	**0.002**	-	-	**-3.819**	**0.001**
Horner	HM7	**-5.758**	**<0.000**	**-7.693**	**<0.000**	-	-
	HM11	**-4.174**	**<0.000**	**-4.302**	**0.012**	-	-
	TA7	**-5.934**	**<0.000**	-2.868	0.065	-	-
	TA10	**-6.029**	**<0.000**	-2.444	0.116	-	-
Mill Iron	CL1	**-7.366**	**<0.000**	-	-	**-9.243**	**0.001**
	CL4	-1.397	0.293	-	-	-1.494	0.272

Table 2-3. (Continued)

Big Goose Creek		Mavrakis-Bentzen-Roberts		Spring Creek		Logan Creek	
t	*p*	*t*	*p*	*t*	*p*	*t*	*p*
1.292	0.216	-1.312	0.2	-	-	-	-
1.846	0.095	**-2.030**	**0.05**	-	-	-	-
-	-	-	-	-1.970	0.074	**-2.323**	**0.040**
-	-	-	-	-0.243	0.820	-1.446	0.215
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	**-2.407**	**0.037**	**-2.641**	**0.024**
-	-	-	-	-1.049	0.343	-2.149	0.084
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
0.195	0.849	**-3.615**	**0**	-	-	-	-
1.688	0.130	**-3.024**	**0**	-	-	-	-
0.000	1.000	**-2.464**	**0.029**	-	-	-	-
0.000	1.000	**-2.999**	**0.014**	-	-	-	-
-2.464	**0.029**	0.000	1.000	-	-	-	-
-2.999	**0.014**	0.000	1.000	-	-	-	-
-	-	-	-	0.000	1.000	0.702	0.491
-	-	-	-	0.000	1.000	0.870	0.418
-	-	-	-	0.702	0.491	0.000	1.000
-	-	-	-	0.870	0.418	0.000	1.000
-4.128	**0.001**	**-2.418**	**0.021**	-	-	-	-
-4.099	**<0.000**	**-2.442**	**0.022**	-	-	-	-
-	-	-	-	-0.777	0.453	0.257	0.802
-	-	-	-	-2.125	0.095	-1.158	0.302
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-7.708	**<0.000**	**-6.831**	**0.001**	-	-	-	-
-1.973	0.163	-0.997	0.420	-	-	-	-

Table 2-3. (Continued)

Hawken		Horner		Mill Iron	
t	*p*	*t*	*p*	*t*	*p*
-3.352	**0.002**	-	-	**-7.366**	**<0.000**
-4.435	**0.002**	-	-	-1.397	0.293
-	-	**-5.758**	**<0.000**	-	-
-	-	**-4.174**	**<0.000**	-	-
-	-	**-5.934**	**<0.000**	-	-
-	-	**-6.029**	**<0.000**	-	-
-	-	**-7.693**	**<0.000**	-	-
-	-	**-4.302**	**0.012**	-	-
-	-	-2.868	0.065	-	-
-	-	-2.444	0.116	-	-
-5.58	**<0.000**	-	-	**-9.243**	**0.001**
-3.819	**0.001**	-	-	**-1.494**	0.272
-4.128	**0.001**	-	-	**-7.708**	**<0.000**
-4.099	**<0.000**	-	-	-1.973	0.163
-2.418	**0.021**	-	-	**-6.831**	**0.001**
-2.442	**0.022**	-	-	-0.997	0.420
-	-	-0.777	0.453	-	-
-	-	-2.125	0.095	-	-
-	-	0.257	0.802	-	-
-	-	-1.158	0.302	-	-
0.000	1.000	-	-	**-4.689**	**0.003**
0.000	1.000	-	-	-0.038	0.972
-	-	0.000	1.000	-	-
-	-	0.000	1.000	-	-
-	-	0.000	1.000	-	-
-	-	0.000	1.000	-	-
-4.689	**0.003**	-	-	0.000	1.000
-0.038	0.972	-	-	0.000	1.000

These data suggest that southern Idaho bison followed a diminution trend similar to the one identified on the Great Plains. This agreement between regions suggests that the bottom up ecosystem controls acting on Great Plains bison morphology likely also conditioned diminution in southern Idaho. Further, late Holocene bison in both regions are morphologically indistinguishable, pointing to a lack of geographic variability on each side of the Rocky Mountains. This is interesting since the low quality of SRP forage might potentially limit somatic growth relative to the Great Plains. Instead, it appears that the two regions' environments differentially conditioned population numbers, rather than morphology, across the Holocene. The morphological similarity between the bison from the two regions may be due to gene flow or parallel trends in growing season length (or both). If both southern Idaho and the northern Great Plains had similar forage growth seasons, then bison may have experienced similar somatic responses to the intra-annual length of forage availability (Guthrie, 1984).

Conclusions

Punctuated changes in bison morphology occur along-side climatic events on the Great Plains, suggesting that diminution results from climate dependent trends in forage quality and availability (Hill et al., 2008). Similar climatic trends characterize western North America (Broughton et al., 2008; Byers and Broughton, 2004; Byers and Smith, 2007; Byers et al., 2005), including the SRP. Therefore, we expected to see a similar pattern of bison diminution on the SRP. To test this hypothesis, we measured specimens from Baker Cave, a late Holocene SRP site, and compared those specimens to bison from other geographic and temporal contexts. Bison from the Wasden Site, located on the eastern SRP, suggest that early Holocene individuals were larger than those from the late

Holocene. In contrast, our study demonstrates that late Holocene bison from multiple SRP contexts shared similar morphologies. These comparisons also hold when the Baker Cave bison are compared with late Holocene assemblages from the Great Plains (Glenrock and Big Goose Creek). However, Great Plains bison from as recently as 2500 cal. BP were larger than the Baker Cave animals. Moreover, measurements taken on specimens from the Hawken, Spring Creek, and Logan Creek sites all demonstrate that middle Holocene Great Plains bison were larger than the late Holocene individuals from Baker Cave. These differences become even greater when the Baker Cave materials are compared to early Holocene Great Plains bison recovered from the Horner and Mill Iron sites.

Our study confirms that SRP and Great Plains bison experienced similar trends in morphological change across the Holocene. However, some questions remain open. It is still unknown if morphological similarity with Great Plains populations extends back through the middle and early Holocene. Additionally, it is unknown if the pattern of SRP diminution follows the punctuated pattern documented on the Great Plains. Resolving these problems will require further metric studies of SRP bison. Several large bison assemblages remain unanalyzed and temporal gaps in the record could be further filled with smaller assemblages from across the region. Finally, paleoecologists should collect more data from as of yet uninvestigated localities across the SRP. Completing these steps would create a dataset that allows for a detailed look at Holocene bison diminution west of the Rocky Mountains. Currently, such a dataset does not exist in western North America. We hope to address these gaps in knowledge in the near future.

References

Anovitz LM, Elam JM, Riciputi LR et al. (1999) The failure of obsidian hydration dating: Sources, implications, and new directions. *Journal of Archaeological Science* 25: 735-752.

Arkush BS (2002) *Archaeology of the Rock Springs Site: A Multi-Component Bison Kill and Processing Camp in Curlew Valley, Southeastern Idaho*. Boise State University Monographs in Archaeology no. 1. Boise: Boise State University.

Bedord JN (1974) Morphological variation in bison metacarpals and metatarsals. In: Frison GC (ed.) *The Casper Site: A Hell Gap Bison Kill on the High Plains*. New York: Academic Press, pp. 199-240.

Beiswenger JM (1991) Late Quaternary vegetational history of Grays Lake, Idaho. *Ecological Monographs* 61(2): 165-182.

Bright RC (1966) Pollen and seed stratigraphy of Swan Lake, southeastern Idaho. *Tebiwa* 9(2): 1-47.

Bright RC and Davis OK (1982) Quaternary paleoecology of the Idaho National Engineering Laboratory, Snake River Plain, Idaho. *American Midland Naturalist* 108(1): 21-33.

Broughton JM, Byers DA, Bryson RA et al. (2008) Did climatic seasonality control late Quaternary artiodactyl densities in western North America? *Quaternary Science Reviews* 27(19-20): 1916-1937.

Butler BR (1968) An introduction to archaeological investigations in the Pioneer Basin locality of eastern Idaho. *Tebiwa* 11(1): 1-30.

Butler BR (1971) A bison jump in the upper Salmon River Valley of eastern Idaho.

Tebiwa 14(1): 4-32.

Butler BR (1978) Bison hunting in the Desert West before 1800: The paleo-ecological potential and the archaeological reality. *Plains Anthropologist* 23(82): 106-112.

Butler BR, Gildersleeve H and Sommers J (1971) The Wasden Site bison: Sources of morphological variation. In: Arnoud HS and Smith RA (eds) *Aboriginal Man and Environments on the Plateau of Northwest America*. Calgary: Students' Press, pp. 126-152.

Byers DA and Broughton JM (2004) Holocene environmental change, artiodactyl abundances, and human hunting strategies in the Great Basin. *American Antiquity* 69(2): 235-255.

Byers DA and Smith CS (2007) Ecosystem controls and the archaeofaunal record: An example from the Wyoming Basin, USA. *The Holocene* 17(8): 1171-1183.

Byers DA, Smith CS and Broughton JM (2005) Holocene artiodactyl population histories and large game hunting in the Wyoming Basin, USA. *Journal of Archaeological Science* 32(1): 125-142.

Cummings LS (2002) *Stratigraphic Pollen Analysis at Tomcat Cave, Idaho*. Report for the Idaho Bureau of Land Management, Burley Field Office. Report no. 02-01. Golden, CO: Paleo Research Institute.

Daubenmire R (1985) The western limits of the range of the American bison. *Ecology* 66(2): 622-624.

Ehleringer JR (1978) Implications of quantum yield differences on the distributions of C_3 and C_4 grasses. *Oecologia* 31(3): 255-267.

Epstein HE, Lauenroth WK, Burke IC et al. (1997) Productivity patterns of C_3 and C_4

functional types in the U.S. Great Plains. *Ecology* 78(3): 722-731.

Geist V (1971) The relation of social evolution and dispersal in ungulates during the Pleistocene, with emphasis on the Old World deer and the genus *Bison*. *Quaternary Research* 1(3): 283-315.

Geist V (1989) Environmentally guided phenotype plasticity in mammals and some of its consequences to theoretical and applied biology. In: Burton MN (ed.) *Alternative Life-History Styles of Animals*. Dordecht: Kluwer Academic Publishers, pp. 153-176.

Grayson DK (1991) Late Pleistocene mammalian extinctions in North America: taxonomy, chronology, and explanations. *Journal of World Prehistory* 5(3): 193-231.

Grayson DK (2006) Holocene bison in the Great Basin, western USA. The Holocene 16(6): 913-925.

Grayson DK (2007) Deciphering North American Pleistocene extinctions. *Journal of Anthropological Research* 63(2): 185-213.

Grayson DK (2011) *The Great Basin: A Natural Prehistory*. Berkeley, CA: University of California Press.

Gruhn R (1961) *The Archaeology of Wilson Butte Cave*. Occasional Papers of the Idaho State College Museum no. 6. Pocatello, ID: Idaho State University.

Guthrie RD (1984) Alaskan megabucks, megabulls, and megarams: the issue of Pleistocene gigantism. In Genoways HH and Dawson MR (eds.) *Contributions in Quaternary Vertebrate Paleontology: A Volume in Memorial to John E. Guilday*. Pittsburgh, PA: Carnegie Museum of Natural History, pp. 482-510.

Henrikson LS (1996) *Prehistoric Cold Storage on the Snake River Plain: Archaeological Investigations at Bobcat Cave*. Monographs in Idaho Archaeology and Ethnology no.

1. Boise, ID: Idaho State Historical Society.

Henrikson LS (2003) Bison freezers and hunter-gatherer mobility: archaeological analysis of cold lava tube caves on Idaho's Snake River Plain. *Plains Anthropologist* 48(187): 263-285.

Henrikson LS (2004) Frozen bison and fur trapper's journals: building a prey choice model for Idaho's Snake River Plain. *Journal of Archaeological Science* 31(7): 903-916.

Henrikson LS (2005) Bison Heights: a late Holocene bison kill site on Idaho's Snake River Plain. *North American Archaeologist* 26(4): 333-355.

Henrikson LS, McAlister KW and Long MM (2006) *Craters of the Moon National Monument and Preserve Archaeological Overview*. Report for the USDI National Park Service and USDI Bureau of Land Management. Report no. 2006-022. Eugene, OR: University of Oregon Museum of Natural and Cultural History.

Hill ME Jr, Hill MG, and Widga CC (2008) Late Quaternary bison diminution on the Great Plains of North America: evaluating the role of human hunting versus climate change. *Quaternary Science Reviews* 27(17-18): 1752-1771.

Hill MG (1996) Appendix 3: size comparison of the Mill Iron Site calcanei. In: Frison GC (ed.) *The Mill Iron Site*. Albuquerque, NM: University of New Mexico Press, pp. 231-238.

Hillerud JM (1970) *Subfossil High Plains Bison*. PhD Dissertation, University of Nebraska, Lincoln.

Holmer RN and Ringe BL (1986) Excavations at Wahmuza. In: Holmer RN (ed.) *Shoshone-Bannock Culture History*. Swanson/Crabtree Anthropological Research

Laboratory Reports of Investigations 85-16. Pocatello, ID: Idaho State University Press, pp. 39-198.

Hughes SS (1978) Bison diminution on the Great Plains. *Wyoming Contributions to Anthropology* 1: 18-47.

Huston MA and Wolverton S (2011) Regulation of animal size by eNPP, Bergmann's rule, and related phenomena. *Ecological Monographs* 81(3): 349-405.

Kreutzer LA (1992) Bison and deer bone mineral densities: comparison and implications for the interpretation of archaeological faunas. *Journal of Archaeological Science* 19(3): 271-294.

Kuntz MA, Covington HR and Schorr LJ (1992) An overview of basaltic volcanism of the eastern Snake River Plain, Idaho. In: Link PK, Kuntz MA and Platt LB (eds.) *Regional Geology of Eastern Idaho and Western Wyoming*. Boulder, CO: The Geological Society of America, pp. 227-268.

Kuntz MA, Spiker EC, Rubin M et al. (1986) Radiocarbon studies of latest Pleistocene and Holocene lava flows of the Snake River Plain, Idaho: Data, lessons, and interpretations. *Quaternary Research* 25(2): 163-176.

Lewis PJ, Buchanan B and Johnson E (2005) Sexing bison metapodials using principal component analysis. *Plains Anthropologist* 50(194): 159-172.

Lyman RL (2004) Late-Quaternary diminution and abundance of prehistoric bison (*Bison* sp.) in eastern Washington State, USA. *Quaternary Research* 62(1): 76-85.

Lyman RL (2006) Archaeological evidence of anthropogenically induced twentieth-century diminution of North American wapiti (*Cervus elaphus*). *American Midland Naturalist* 156: 88-98.

Lyman RL (2009) The Holocene history of bighorn sheep (*Ovis canadensis*) in eastern Washington state, northwestern USA. *The Holocene* 19(1): 143-150.

Lyman RL (2010) Taphonomy, pathology, and paleoecology of the terminal Pleistocene Marmes Rockshelter (45FR50) “big elk” (*Cervus elaphus*), southeastern Washington State, USA. *Canadian Journal of Earth Sciences* 47: 1367-1382.

McDonald JN (1981) *North American Bison: Their Identification and Classification*. Berkeley, CA: University of California Press.

McDonald N (2006) Appendix IV: analysis of faunal remains, 2003, 10-CN-6. In: Plew MG, Plager S, Jacobs TD et al. (eds.) *Archaeological Excavations at 10-CN-6, Middle Snake River, Idaho*. Boise State University Monographs in Archaeology no. 3. Boise, ID: Boise State University Printing and Graphics Services, pp. 95-102.

Mack RN and Thompson JN (1982) Evolution in steppe with few large, hooved animals. *The American Naturalist* 119(6): 757-773.

Malde HE and Powers HA (1962) Upper Cenozoic stratigraphy of western Snake River Plain, Idaho. *Geological Society of America Bulletin* 73(10): 1197-1220.

Matheus PE (2001) Pleistocene predators and people in eastern Beringia: Did short-faced bears really keep humans out of North America. In: Gerlach SG and Murray MS (eds.) *People and Wildlife in Northern North America: Essays in Honor of R. Dale Guthrie*. BAR International Series 944. Oxford, England: Archaeopress, pp. 79-101.

Mead JI and Meltzer DJ (1984) North American late Quaternary extinctions and the radiocarbon record. In: Martin PS and Klein RG (eds) *Quaternary Extinctions: a Prehistoric Revolution*. Tucson, AZ: The University of Arizona Press, pp. 440-450.

Miller SJ (1987) The fauna of Baker Caves. In: Plew MG, Pavesic MG and Davis MA (eds.) *Archaeological Investigations at Baker Caves I and III: A Late Archaic Component on the Eastern Snake River Plain*. Archaeological Reports no. 5. Boise, ID: Boise State University, pp. 25-42.

Miller SJ and Dort W Jr (1978) Early man at Owl Cave: current investigations at the Wasden Site, eastern Snake River Plain, Idaho. In: Bryan AL (ed.) *Early Man in America: From a Circum-Pacific Perspective*. Edmonton: University of Alberta, pp. 129-139.

Murphey KA and Crutchfield MJ (1985) *Archaeological Test Excavations at the Crutchfield Site: Hagerman Valley, Idaho*. University of Idaho Anthropological Papers no. 86. Moscow, ID: University of Idaho.

Pavesic MG and Meatte DS (1980) *Archaeological Test Excavations at the National Fish Hatchery Locality, Hagerman Valley, Idaho*. Boise State University Archaeological Reports no. 8. Boise, ID: Boise State University.

Plew MG (1981) *Archaeological Test Excavations at Four Sites in the Western Snake River Canyon near Bliss, Idaho*. Archaeological Reports no. 5. Boise, ID: Idaho Archaeological Consultants.

Plew MG (2009) Archaic hunter-gatherer diet breadth and prey choice on the Snake River Plain. *Journal of Northwest Anthropology* 43(1): 27-56.

Plew MG, Pavesic MG and Davis MA (1987) *Archaeological Investigations at Baker Caves I and III: a Late Archaic Component on the Eastern Snake River Plain*. Archaeological Reports no. 5. Boise, ID: Boise State University.

Plew MG and Sundell T (2000) The archaeological occurrence of bison on the Snake River Plain. *North American Archaeologist* 21(2): 119-137.

Purdue JR (1989) Changes during the Holocene in the size of white-tailed deer (*Odocoileus virginianus*) from central Illinois. *Quaternary Research* 32: 307-316.

Purdue JR and Reitz EJ (1993) Decrease in the body size of white-tailed deer (*Odocoileus virginianus*) during the late Holocene in South Carolina and Georgia. In: Martin RA and Barnosky AD (eds.) *Morphological Change in Mammals of North America*. New York, NY: Cambridge University Press, pp. 281-298.

Rudolph T (1995) *The Hetrick Site: 11,000 Years of Prehistory in the Weiser River Valley, Idaho*. Report for the Idaho Department of Transportation. Report no. 0685. McLean, VA: Science Applications International Corporation.

Smith RP (2004) Geologic setting of the Snake River Plain aquifer and vadose zone. *Vadose Zone Journal* 3(1): 47-58.

Speth JD (1983) *Bison Kills and Bone Counts: Decision Making by Ancient Hunters*. Chicago, IL: University of Chicago Press.

Swanson EH Jr (1972) *Birch Creek: Human Ecology in the Cool Desert of the Northern Rocky Mountains 9,000 B.C. - AD 1850*. Pocatello, ID: Idaho State University Press.

Teeri JA and Stowe LG (1976) The distribution of C_4 grasses in North America. Oecologia 23(1): 1-12.

Todd LC (1987) Appendix 1: bison bone measurements. In: Frison GC and Todd LC (eds) *The Horner Site: The Type Site of the Cody Cultural Complex*. New York, NY: Academic Press, pp. 371-404.

Van Vuren D (1987) Bison west of the Rocky Mountains: An alternative explanation. *Northwest Science* 61(2): 65-69.

Walker DN (2002) Appendix A: faunal remains from archaeological excavations at the

Rock Springs Site, southeast Idaho. In: Arkush BS (ed.) *Archaeology of the Rock Springs Site: a Multi-Component Bison Kill and Processing Camp in Curlew Valley, Southeastern Idaho*. Boise State University Monographs in Archaeology no. 1. Boise, ID: Boise State University, pp. 99-166.

Wigand P (1997) *Pollen and macrofossil analysis of site 10MA143*. Report for the Idaho Bureau of Land Management, Burley Field Office. Reno, NV: Desert Research Institute.

Williams HA (2005) *Spatial Precipitation Variability, Snowfall, and Historical Bison Occurrence in the Northwest United States*. MA Thesis, Georgia State University, Atlanta.

Wilson M (1974) The Casper local fauna and its fossil bison. In: Frison GC (ed.) *The Casper Site: a Hell Gap Bison Kill on the High Plains*. New York, NY: Academic Press, pp. 125-172.

Wolverton S, Huston MA, Kennedy JH et al. (2009) Conformation to Bergmann's rule in white-tailed deer can be explained by food availability. *American Midland Naturalist* 162(2): 403-417.

Wood SH and Clemens DM (2002) Geological and tectonic history of the western Snake River Plain. In: Bonnichsen B, White CM and Curry M (eds.) *Tectonic and Magnetic Evolution of the Snake River Plain Volcanic Province*. Idaho Geological Survey Bulletin no. 230. Moscow, ID: Idaho Geological Survey, pp. 69-103.

CHAPTER 3

SKELETAL FAT, CARCASS USE, AND THE LATE HOLOCENE BISON REMAINS FROM BAKER CAVE[2]

Introduction

Despite an archaeofaunal record spanning the Holocene (Plew 2009), few published studies have attempted to place the zooarchaeology of Snake River Plain (SRP) bison (*Bison bison*) within a behavioral context and the motivations behind the subsistence decisions made by people hunting these animals remain largely unexplored (but see Henrikson 2004). In this paper, we begin to fill this gap in knowledge with a study of the bison remains from Baker Cave (comprised of two chambers designated as 10BN154 and 10BN153; Plew et al. 1987), a Late Holocene bison processing site. Baker Cave sits in large, unvegetated and difficult to traverse lava field almost a half km from the edge of the flow and the nearest bison forage. This location suggests that carcass portions were transported a considerable distance across rugged terrain for processing and consumption. Baker Cave also represents a rare occurrence on the SRP, a site producing an extensive and well-preserved collection of bison remains. Importantly, this large sample of prey animals allows us to explore the motivations behind the use of bison by prehistoric SRP foragers.

Within this context, we ask the simple question, why transport a bone? One can easily strip meat from an element such as a humerus or femur to increase transport utility (Metcalfe and Barlow 1992; Metcalfe and Jones 1988). For example, ethnoarchaeological

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[2] This article is in review for the journal *American Antiquity*. It is titled "Skeletal Fat, Carcass Use, and the Late Holocene Bison Remains from Baker Cave, Southern Idaho," by Ryan P. Breslawski and David A. Byers.

accounts of Hadza field butchery demonstrate that hunters often strip meat from bones with ease (Bunn et al. 1988; O'Connell et al. 1988, 1992). This is especially true for larger animals, where bones impose even greater transport costs (O'Connell et al. 1990; O'Connell and Marshall 1989). If butchers can easily field dress a carcass, removing low utility portions, why would they choose to move large, heavy bison bones across a rugged lava flow to Baker Cave?

We suggest that this transport decision stems from the relationship between bison nutritional status and season of acquisition. Archaeologists working on the SRP tend to agree that the seasonal scheduling of resources played some role in subsistence decisions, especially as it relates to the presence or absence of storage (Gould and Plew 1996; Henrikson 1996, 2003; Plew 1990, 2003, 2005). However, the relationship between season and subsistence patterns still begs clarification, having moved little beyond the reasonable observation that the storage of animal products may represent a seasonal subsistence adaptation on the SRP. Lacking is an understanding of the relationship between seasonally-mediated trends in prey nutritional status and the butchery decisions made by prehistoric foragers living in southern Idaho.

The season of procurement can have profound implications for prey nutritional quality. Warren A. Ferris, a nineteenth century fur trapper traveling through northern Utah's Bear River Valley, observed that local bison had "reduced to mere skeletons" during the winter (Phillips 1940:43). His account reflects a pattern of winter fat depletion experienced by bison across North America (Speth 1983; Speth and Spielmann 1983). Prehistoric bison in southern Idaho likely experienced this seasonal fat depletion along with other southern Idaho artiodactyls (e.g., see Trout and Thiessen's [1968:188-200] study of mule deer [*Odocoileus hemionus*] in Owyhee County). This is part of a well-documented trend in seasonal fat depletion observed in many animals occupying temperate environments (McNab 2002:358-366).

The relationship between season and known trends in prey nutritional quality suggests that prehistoric hunter-gatherers faced winter fat scarcity on the SRP. Lean meat often dominates winter diets, leading to elevated metabolisms and fatty acid deficiencies (Speth and Spielmann 1983). In these situations, fat and carbohydrates become essential nutrients. Without them, people dependent on lean meat from rabbits, rodents, and artiodactyls risk exposure to protein poisoning. Despite theoretical expectations that hunter-gatherers living in southern Idaho faced winter fat scarcity through the Holocene, archaeologists have yet to demonstrate that people organized subsistence around this problem. Did winter fat scarcity condition bison transport and processing decisions on the SRP?

To answer this question, we use several datasets derived from the Baker Cave bison remains. Since abundant fetal bison remains provide evidence for winter procurement, a time when bison suffer from fat depletion, we suggest that winter fat scarcity motivated the transport and processing decisions that produced the skeletal element frequencies and bone modifications at Baker Cave. Within this context, we test the hypothesis that the within-bone fat utility (marrow and grease) of skeletal elements conditioned carcass transport and processing decisions. Consequently, hunters should have transported fat-rich bones to Baker Cave in higher frequencies than fat-poor bones. The intra-carcass distribution of processing signatures, including impact scars and fragmentation, should also reflect a focus on fat extraction. Our results show that this is indeed the case, carcass parts were transported and processed in accordance with their skeletal fat utility.

Prehistoric Bison on the Snake River Plain

The SRP sits west of the Rocky Mountains and adjacent to the northern Great Plains. It forms the southeastern most extent of the Columbia Plateau, directly north of the Great Basin. Southern Idaho contains most of the SRP, although the western-most portion crosses into eastern Oregon. The Snake River drainage system and a unique igneous landscape distinguish the SRP from surrounding regions (Kuntz et al. 1992; Malde and Powers 1962; Smith 2004; Wood and Clemens 2002). Like much of the northwestern United States, climatic patterns limit the region's carrying capacity for bison (Daubenmire 1985; Mack and Thompson 1982; Williams 2005). While bison may not have been numerous, they were probably an important part of the local diet (Henrikson 2004).

Bison are common components of SRP archaeofaunas (Butler 1978; Plew and Sundell 2000). Figure 3-1 plots the locations of archaeological sites in the region that have produced bison remains. Well-known localities containing records of bison exploitation include the Wasden Site (Butler 1968; Butler et al. 1971; Miller 1983; Miller and Dort 1978:137) and Wilson Butte Cave (Gruhn 1961:172-182). Archaeologists have also recovered bison remains from Wahmuza (Holmer and Ringe 1986:161-171), 10GG1 (Plew 1981:154), the Medbury Site (Plew and Willson 2002), Alpha Cave (Henrikson et al. 2006:79-94), the Roasting Rock Site (Henrikson et al. 2006:97-110), Crutchfield (Murphey and Crutchfield 1985), Bobcat Cave (Henrikson 1996), Scaredy Cat Cave (Henrikson 2003), Tomcat Cave (Henrikson 2004), Poison Creek (Neudorfer 1976:90-

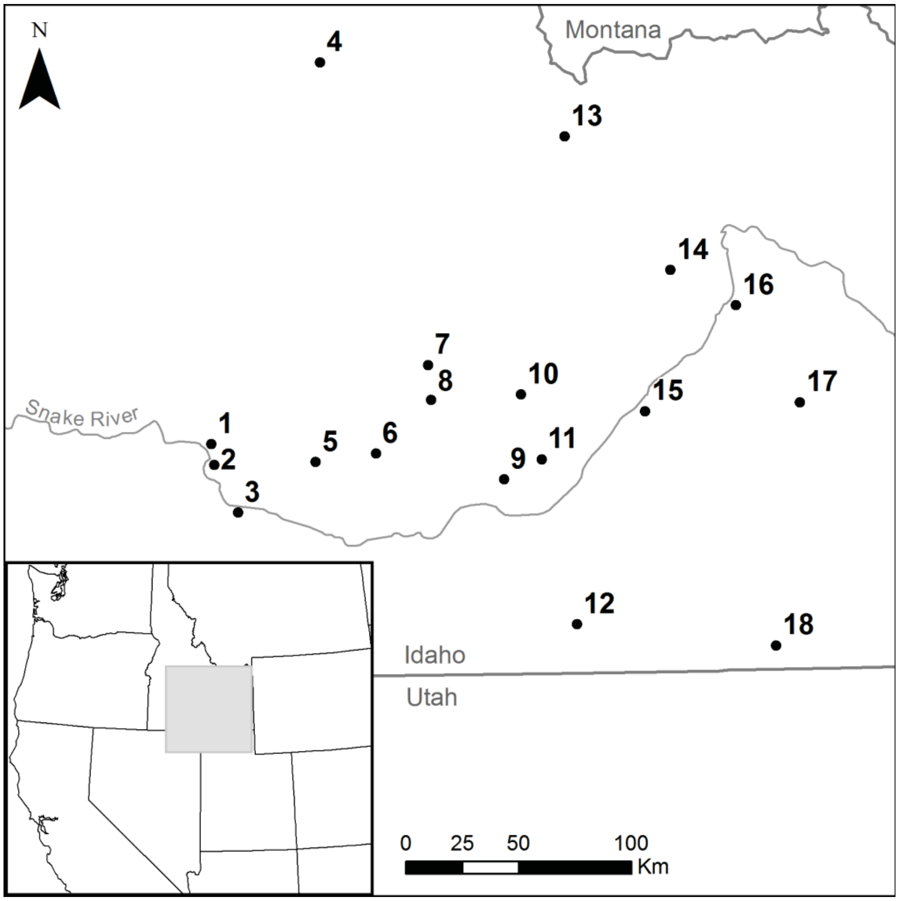

Figure 3-1. Locations of sites discussed in the text: (1) The Medbury Site, (2) Crutchfield, (3) 10GG1, (4) The Challis Bison Jump and Quill Cave, (5) Wilson Butte Cave, (6) Tomcat Cave, (7) The Roasting Rock Site, (8) Bobcat Cave, (9) Baker Cave, (10) Scaredy Cat Cave, (11) Alpha Cave, (12) The Rock Springs Site, (13) The Birch Creek Rockshelters, (14) The Wasden Site, (15) Wahmuza, (16) 10BV93, (17) Poison Creek, and (18) Weston Canyon Rockshelter.

91), 10BV93 (Gough 1990), and Baker Cave (Miller 1987). Although bison are frequent components of SRP sites, they usually occur in low numbers. SRP sites containing bison remains typically have fewer than 100 specimens, and these rarely represent more than one or two individuals. There are exceptions to this pattern (e.g., Butler [1968] reports at least 50 individual bison at the Wasden Site), but they are extremely rare in the archaeological record thus far.

Henrikson (2004) suggests that these animals were a preferred resource, but hunters encountered them too infrequently to produce abundant bison dominated archaeofaunas. SRP assemblages likely resulted from infrequent small-scale hunting encounters with these animals. Consequently, the large mass kills common on the Great Plains are rare or absent on the SRP (Butler 1978; Henrikson 2003, 2004, 2005; Plew and Sundell 2000). Sites located in more mesic, higher quality forage environments bordering the SRP have produced larger bison assemblages. These sites occur in the upland areas of southeastern Idaho, and they include the Rock Springs Site (Walker 2002), Weston Canyon Rockshelter (Miller 1972, 1999), the Challis Bison Jump and Quill Cave (Butler 1971), as well as the Birch Creek Rockshelters (Swanson 1972). However, these faunas represent a departure from taxonomic patterns on the lowland SRP.

Baker Cave

Baker Cave is located in the southwestern portion of the Wapi Lava Flow, a landform dated to 382-242 cal B.C. (Kuntz et al. 1986). The site sits about 19 km east of Minidoka, Idaho, and roughly 8 km northeast of Lake Walcott, a dammed portion of the Snake River (Figure 3-1). Although at a distance from permanent water today, basalt landscape features provide opportunities for spring rains to pool in seasonal ponds (Henrikson et al. 2006:45). The sagebrush-steppe communities that typify most of the SRP also characterize land surrounding the Wapi Lava Flow, while the immediate site vicinity is generally barren of vegetation (Plew et al. 1987:10).

Boise State University, in conjunction with the Idaho Bureau of Land Management (BLM), excavated Baker Cave in 1985 to mitigate looting. Excavations took place in two chambers designated Baker I and Baker III. Plew et al. (1987) report a third chamber (Baker II) that lacked cultural materials and sediment. Baker I is a low hanging chamber roughly 3 m deep and 7 m wide. A basalt boulder and juniper branch wall partially blocked the Baker I entrance during the initial investigation (Plew et al. 1987:13). Baker III consists of two connected chambers. The first chamber is 60 m by 9 m and contained the majority of cultural deposits, while the second chamber is roughly 6 m by 100 m and contained little evidence for human activity (Plew et al. 1987:13). Boise State University and the BLM focused recovery efforts on Baker I and the first chamber of Baker III. They treated all sediments as a single component due to the minimal deposition (15 cm maximum). Most of these sediments were removed with brushes and passed through .3 cm mesh. They excavated all undisturbed sediments from Baker I and about 70 percent of Baker III.

Boise State University exposed several cultural features and sampled charcoal for radiocarbon dating. The features include three hearths in Baker I and III and an S shaped rock alignment in Baker III (Plew et al. 1987:21). The hearths contained floral and faunal materials. The hearths also produced five radiocarbon dates that suggest human activity at cal A.D. 1042-1265 (Plew et al. 1987:22). Two obsidian hydration dates suggest a slightly different period of human activity spanning A.D. 459-659 and A.D. 606-736 (Plew et al. 1987:17). Plew et al. (1987) argue that the differences between results from each dating method indicate two separate occupations. However, they do not explore other explanations for these results. Regardless of the differences in dates, the age of the Wapi Lava Flow restricts the depositional history of Baker Cave to the most recent 2400 years.

The Baker Cave Archaeofauna: Natural and Cultural Formation Processes

We identified 18,860 specimens to 25 taxa (Table 3-1). Identifications were aided by a faunal reference collection housed at Utah State University and published guides (Broughton and Miller 2010; Brown and Gustafson 1979; Olsen 1964). Of these specimens, 15.24 percent were identified to genus (NISP = 2875), 1.73 percent to family (NISP = 327), 20.58 percent to order (NISP = 3882), 24.84 percent to class (NISP = 4685), and 37.60 percent to unidentified vertebrate (NISP = 7091).

We identified 591 specimens as *Bison* and an additional 179 specimens as "large bovid". The "large bovid" taxon includes specimens that we could not positively identify as *Bos* or *Bison* with the criteria outlined by Balkwill and Cumbaa (1992). Distal right tibia represent a minimum of 37 individual bison. We identified another 3814 specimens as "large artiodactyl." These specimens fall within the size range of elk (*Cervus canadensis*), moose (*Alces alces*), domestic cow (*Bos taurus*), and bison (*Bison bison*). Given a complete lack of any specimens identified to a large genera besides *B. bison*, we treat all specimens identified to "large bovid" or "large artiodactyl" as bison for the remainder of the paper.

In this section, we evaluate the processes that shaped this bison assemblage. We begin by describing the depositional history and demographics of the Baker Cave bison. We follow this with a discussion of the non-human taphonomic processes that acted on the Baker Cave archaeofauna. Finally, we investigate the role of fat seeking human behavior in shaping element frequencies, impact scar distributions, and fragmentation at the site.

Table 3-1. Specimen Counts for Taxa Identified at Baker Cave.

Taxon	NISP
Bison bison	
adult	591
fetal	481
Large bovid	179
Large artiodactyl	3814
Odocoileus sp.	2
Antilocapra americana	1
Medium artiodactyl	12
Medium size mammal	176
Lepus sp.	945
Sylvilagus sp.	840
cf. *Brachylagus idahoensis*	13
Leporidae	125
Canis cf. *latrans*	5
Canis sp.	9
Small carnivore	6
Sciuridae	6
Rodentia	47
Small mammal	456
Unspecified mammal	4045
Aves	8
Colubridae	4
Unspecified small vertebrate	54
Unidentified vertebrate	7037
Margaritifera sp.	1
Unionoida	3
Total	18860

Bison Sex Ratios, Fetal Remains, and the Baker Cave Depositional History

Based on skeletal morphometrics (refer to Chapter 2), adult females dominate the Baker Cave bison assemblage. Distal humeri comprise the largest sample of completely fused elements with sufficient preservation for morphometric analysis (MNE = 11 left and 12 right). These specimens represent at least 10 adult females and three adult males (Chapter 2). Analyses of several other skeletal elements likewise document a female dominated assemblage. Moreover, Baker Cave also contains a large assemblage of fetal bison remains (NISP = 431, MNI = 7) that is consistent with a female skewed sex distribution.

Fetal bison size varies predictably with gestation length (Gogan et al. 2005), allowing for archaeological insight into the timing of prey acquisition and depositional history (e.g., McKee 1985; Wilson 1974). We investigated the depositional history of Baker Cave with a metric analysis of fetal bison humeri. We measured the minimum depth and minimum width of fetal humerus diaphyses at the mid-shaft. These metrics form two clusters and one outlier (Table 3-2; Figure 3-2), suggesting at least two depositional events. We refer to the cluster of larger specimens as Cluster 1 and the cluster of smaller specimens as Cluster 2.

To understand Baker Cave's depositional history, we compare Clusters 1 and 2 to fetal bison humeri from other contexts. Frison et al. (1978:44) report a seven-month old fetal bison humerus diaphysis that measured a minimum of 13.5 mm deep and 13.0 mm wide. Frison et al. (1978:44) also report a neonatal bison humerus with a minimum diaphysis depth of 19.3 mm and a minimum diaphysis width of 17.10 mm. If these measurements represent a reasonable proxy for the broader trend in bison fetal development, an assumption made with all due caution given the comparative sample, then Baker Cave Cluster 1 humeri fall between these two sizes, suggesting that these fetuses are more than seven months old, but not full term. Assuming that conception occurred between mid-July and late August (Kirkpatrick et al. 1993), Cluster 1 is

Table 3-2. Fetal Humerus Metrics from Baker Cave.

ID	Side	Least depth of diaphysis (mm)	Least width of diaphysis (mm)
6122	R	8.9	7.9
631	R	11.0	11.0
5515	R	11.7	11.5
5944	L	11.9	10.8
3723	R	12.7	12.4
5494	R	15.8	14.9
492	R	16.8	15.3
3724	L	17.1	15.1

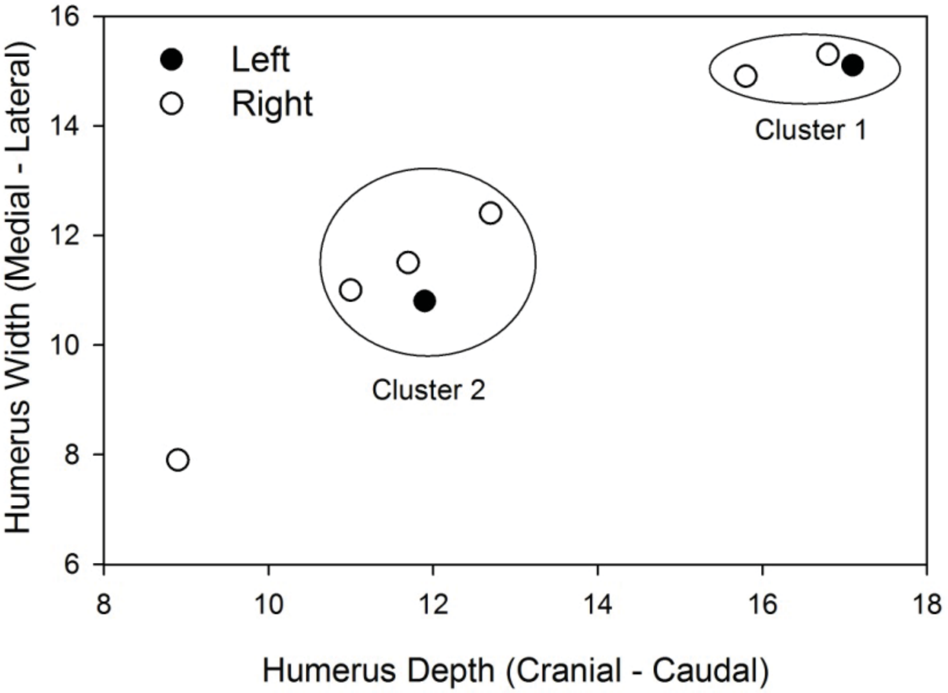

Figure 3-2. Bivariate plot of the least depth and least width of fetal humerus diaphyses. Open points represent left elements and closed points represent right elements.

probably the result of a kill between mid-March and late April. Frison et al. (1978:44) also detail humerus metrics from three to six month old fetuses at Big Goose Creek, a Great Plains site (minimum diaphysis depth = 5.2-12.7 mm; minimum diaphysis width = 4.9-12.7 mm). Cluster 2 humeri overlap with the largest Big Goose Creek specimens, suggesting that they are about six months old. Assuming the same onset dates for pregnancy as we did for Cluster 1, Cluster 2 is probably the result of a mid-January to late February kill. The outlying humerus is likely an out of season fetus or the result of a mid-November to late January kill.

While it would be ideal to support this fetal evidence for season of death with molar eruption and wear pattern data, the dental sample at Baker Cave is frustratingly small. There are four left and two right mandibles with few articulated teeth, none of which contain complete dental rows. Fortunately, these fetal remains do provide some evidence for repeated subsistence activities in the mid- to late winter (and potentially the early spring), which falls within the seasonal period of fat depletion in bison. These animals may have been procured in as few as two organized events, or in several more small scale hunting events as archaeologists have argued was typical for the region (Butler 1978; Henrikson 2003, 2004, 2005; Plew and Sundell 2000).

Non-Human Taphonomic Processes at Baker Cave

We observed several different non-human modifications to the Baker Cave bison remains. Canid ravaging was the most common. In addition to the presence of canid remains (NISP = 14), tooth furrows, tooth punctures, pitting, and crenulated margins characterize 7.24 percent (NISP = 332) of the bison specimens. Along with carnivores, rodents, weathering, and fire also played a small role in shaping the assemblage. One percent (NISP = 46) of the bison remains display rodent gnawing, mostly on flat bones such as innominates and scapulae. A slight majority of the bison specimens display some physical deterioration in the form of cracking or flaking (NISP = 2515, 54.86 percent). A small portion of these specimens is weathered completely down to fibrous bone or is actively disintegrating (NISP = 97, .02 percent). This may be a result of freeze/thaw cycles or dessication (Miller 1987). Finally, 22.4 percent of the bison remains display burning (NISP = 1020, 22.40 percent) and only .65 percent (NISP = 30) are calcined.

We used bone density data presented by Kreutzer (1992) to understand the effects of density mediated attrition on assemblage level patterns at Baker Cave. First, we converted observed scan site frequencies to %Survivorship values based on their anatomical distribution in a bison (*sensu* Lyman 1994:251). These values correlate weakly, but significantly, with volume mineral density ($r_s = .282$, $p = .005$). We also evaluated the influence of density-mediated attrition on %MAU. To do so, we first averaged volume mineral densities across each element (e.g., for the femur, we average density values for scan sites FE1 through FE7). We then compared these averaged density values to %MAU, which produced a weakly positive yet insignificant correlation (Figure 3-3a; $r_s = .352$, $p = .092$). The absence of some spongy grease rich portions, such as proximal humeri and both femoral ends, appears to drive this relationship. This observation is not surprising since canids frequently target these skeletal portions (Binford 1981:71-72, 74-75; Blumenschine and Marean 1993; Haynes 1980, 1983).

Transport Decisions and Skeletal Element Utility

We evaluate the transport decisions that conditioned the Baker Cave bison remains by comparing skeletal element frequencies (in this case, %MAU, as defined by

Binford 1978:69-72) with Emerson's (1990:837-845) utility models for bison. Since carnivores likely deleted the ends of some long bones at Baker Cave, we evaluate human behavior at the scale of whole elements rather than element portions (*sensu* Metcalfe and Jones 1988). Consequently, we do not rely on epiphyses alone for long bone frequencies, reducing the effects of density-mediated attrition on interpretations of the Baker Cave skeletal profile (Marean and Frey 1997). Doing so requires some modification of Emerson's (1990) utility values. In this case, we average the values for long bone proximal and distal halves and use these new values as estimates for the utility of complete long bones.

The Baker Cave %MAU values demonstrate that elements are not represented in proportion to their numbers in a complete bison (Table 3-3). To investigate how transport decisions might have conditioned element representation, we compare %MAU against models of intra-carcass nutritional variability[1]. We begin by comparing %MAU with the general caloric utility of elements to see if carcass portions were transported based on combined protein and fat utility. In this case, %MAU and generalized utility do not correlate (Figure 3-3b; $r_s = .132$, $p = .538$), suggesting that generalized caloric utility did not condition %MAU. To further unpack this problem, we next compare %MAU with protein utility (Figure 3-3c). Protein utility also fails to predict %MAU ($r_s = -.062$, $p = .785$), suggesting that some other aspect of intra-carcass utility conditioned transport decisions. Skeletal fat content, however, strongly predicts %MAU (Figure 3-3d; $r_s = .775$, $p < .001$), suggesting that within-bone nutrients conditioned the transport of skeletal parts to Baker Cave. Comparisons of %MAU with bone grease (Figure 3-3e; $r_s = .740$, p

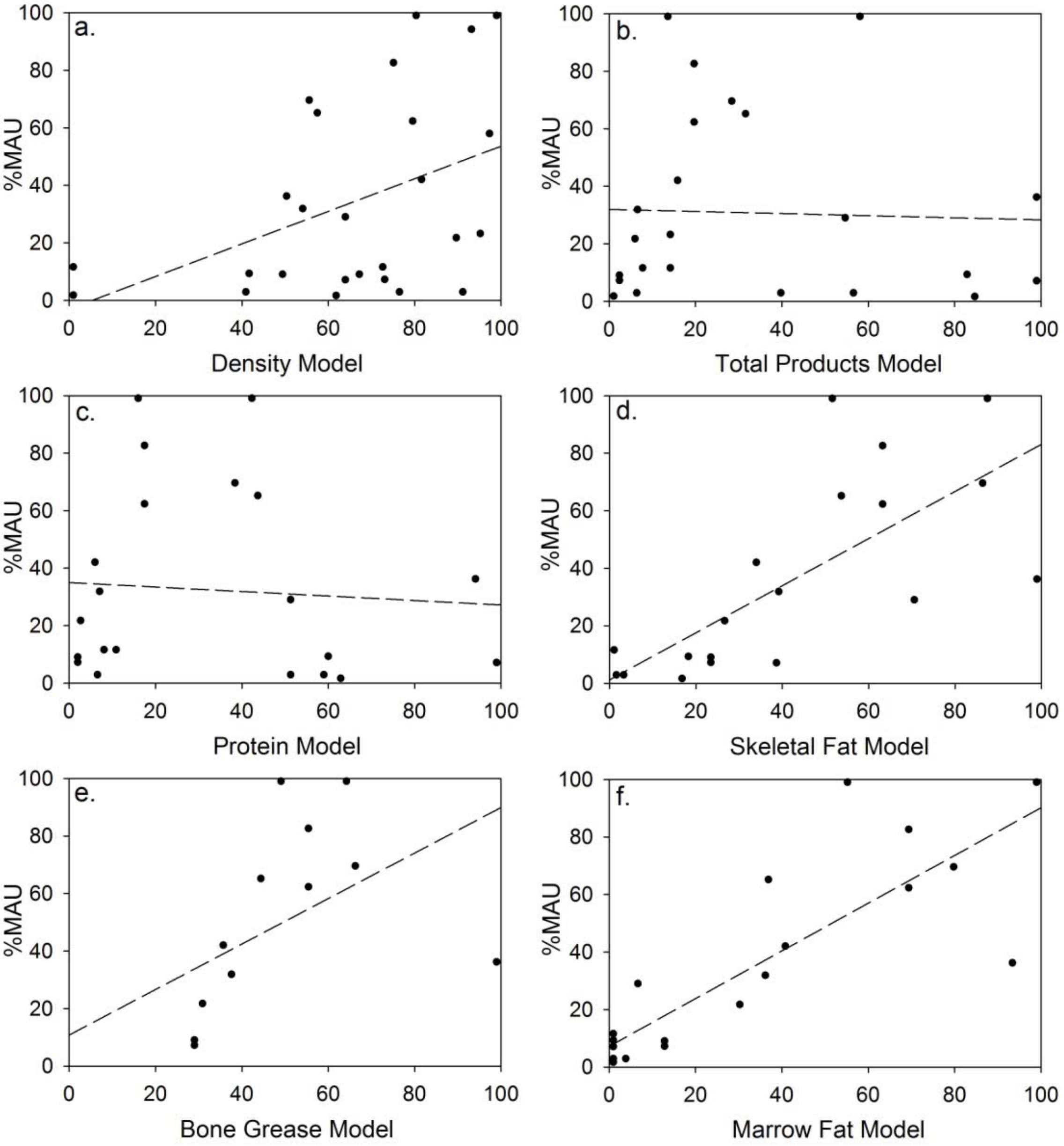

Figure 3-3. The relationship between Baker Cave %MAU and (a) bone density (Kreutzer 1992), as well as Emerson's (1990) (b) Total Products Model, (c) Protein Model, (d) Skeletal Fat Model, (e) Bone Grease Model, and (f) Marrow Fat Model.

Table 3-3. Baker Cave Bison Skeletal Profile with Skeletal Fat Utility, Bone Density, and %IPE Values.

	NISP				MNE						Skel.	Impact scars		
Element	Axial	L	R	U	Axial	L	R	U	%MAU	Density	Fat	*n*	*n*/MNE	%IPE
Cranium	83				4				11.59			1	0.25	12.50
Mandible		21	25	12		6	10	1	23.19	0.62		11	0.65	32.35
Hyoid		4	5			4	3		3.50			0	0.00	0.00
Atlas vert	1				1				2.90	0.59	1.60	0	0.00	0.00
Axis vert	6				4				11.59	0.47	1.10	0	0.00	0.00
Cerv vert	29				5				2.90	0.50	3.30	1	0.20	10.00
Thoracic vert	34				8				1.66	0.40	16.80	1	0.13	6.25
Lumbar vert	72				16				9.28	0.27	18.30	3	0.19	9.38
Rib		84	90	358		26	26	25	7.14	0.41	38.70	36	0.47	23.38
Sacrum	2				1				2.90	0.27		0	0.00	0.00
Caudal vert	3				3				1.74			0	0.00	0.00
Scapula		63	73	67		18	27	3	65.22	0.37	53.70	24	0.50	25.00
Humerus		60	75	23		22	26	2	69.57	0.36	86.40	78	1.56	92.86
Radius		85	62	8		30	27		82.61	0.49	63.25	34	0.60	35.51
Ulna		34	39	1		22	21	1	62.32	0.52	63.25	9	0.20	12.18
Ulnar carpal		12	8			10	8		26.1			0	0.00	0.00
Intermediate carpal		12	11			11	11		31.88	0.35	39.20	0	0.00	0.00
Radial carpal		10	7			9	7		23.2			0	0.00	0.00
2nd & 3rd carpal		8	2			7	2		13.0			0	0.00	0.00
Fourth carpal		7	2			7	2		13.0			0	0.00	0.00
Accessory carpal		6	1			6	1		10.1			0	0.00	0.00
Metacarpal		7	11	5		5	7	3	21.74	0.58	26.70	7	0.47	27.78
Innominate		18	25	4		9	11	1	28.99	0.41	70.60	7	0.33	16.67
Femur		38	33	43		12	6	7	36.23	0.33	100.00	42	1.68	100.00
Patella		6	7			6	7		18.8			0	0.00	0.00
Tibia		87	93	21		31	37	1	98.55	0.52	87.55	76	1.10	65.56
Astragalus		38	37			33	36		100.00	0.65	51.60	0	0.00	0.00
Calcaneus		39	41			31	34		94.20	0.60		4	0.06	3.08
Lateral malleolus		11	15			11	15		37.7			0	0.00	0.00
Central & 4th tarsal		14	28			14	26		57.97	0.63		0	0.00	0.00
2nd & 3rd tarsal		12	19			12	19		44.93			0	0.00	0.00
Metatarsal		22	27	12		11	18	2	42.03	0.53	34.00	24	0.77	46.08
Proximal sesamoid				62				62	11.23			0	0.00	0.00
Distal sesamoid				41				41	14.86			0	0.00	0.00
1st Phalanx				23				20	7.25	0.47	23.50	0	0.00	0.00
2nd Phalanx				28				25	9.07	0.44	23.50	0	0.00	0.00
3rd Phalanx				25				24	9.07	0.32	23.50	0	0.00	0.00

Note: Utility model data is from Emerson (1990) and bone density data is from Kreutzer (1992).

= .004) and marrow fat utility (Figure 3-3f; $r_s = .855$, $p < .001$) result in similarly positive and significant relationships.

Bone grease and marrow fat utility, as components of skeletal fat utility, are strongly correlated ($r_s = .967$, $p < .001$). This makes bone grease and marrow fat difficult to distinguish as independent variables driving transport decisions. Regardless, it is clear that skeletal fat likely conditioned the differential transport of elements to Baker Cave. Consequently, we consider skeletal fat utility in the following analyses of processing intensity.

Processing Decisions and Skeletal Fat Utility

If skeletal fat differentially motivated transport decisions, then the Baker Cave bison bones should display modifications consistent with the extraction of this nutrient. We test this expectation by generating three datasets designed to measure processing intensity relative to skeletal fat value: Impacts per Element (%IPE), %Complete, and NISP/MNE. To calculate %IPE, we first recorded impact scars on bison specimens. These were identified as (1) conchoidal flake scars on the medullary walls of long bones and/or (2) depressions associated with radiating cracks. We normalized impact scar frequencies for each element by dividing the total number of impact scars recorded for each element by that bone's MNE (Impacts/MNE). We then scaled each Impacts/MNE value to the highest Impacts/MNE value in the assemblage, and then multiplied these values by 100. This calculation results in a variable normalized to the same scale as %MAU (0-100 percent).

Our study recorded 358 impact scars distributed over 2397 specimens (Table 3-3), and we use these data to calculate %IPE for the Baker Cave bison remains. If skeletal fat conditioned the decision to transport a specific element, then we expect to see differential investment in processing effort as well. Fat-rich bones should display higher levels of processing intensity and, therefore, elements with higher skeletal fat values should display higher %IPE values. Our analysis suggests that this is indeed the case. A comparison of %IPE with skeletal fat utility produces a positive and significant relationship (Figure 3-4a; $r_s = .701$, $p = .001$). We repeat the comparison with a smaller dataset consisting of only the marrow rich long bones to further test the strength of the relationship. This comparison also produces a positive and significant correlation between %IPE and skeletal fat utility (Figure 3-4b; $r_s = .916$, $p < .001$), further underscoring the relationship between skeletal fat utility and processing intensity.

We complement %IPE with %Complete, a second measure designed to capture processing intensity. To calculate %Complete, we first measured the maximum length of all the long bone specimens identified to element. These include humeri, radii, metacarpals, femora, tibiae, metatarsals, and phalanges 1-3. We then calculated the mean maximum length for each element in the Baker Cave assemblage, including complete and fragmentary specimens (Table 3-4). Next, we calculated the mean length of complete long bones as measured from modern bison (Lewis et al. 2005; Todd 1983). Since we could not locate data on the mean length of complete modern bison phalanges, we used complete phalanges from Baker Cave to calculate these values. Finally, we divided the mean lengths of the Baker Cave long bone specimens by the mean lengths of the complete long bones. Multiplying these values by 100 generates %Complete values for each element. This calculation results in a value that captures the on-average level of completeness relative to a whole element and provides a rough measure of fragmentation between elements, with higher values indicating less fragmentation.

If skeletal fat value mediated processing decisions, then fat-rich bones should display relatively high levels of fragmentation as measured by low %Complete values. To test this expectation, we compare %Complete with skeletal fat utility. As expected, the two measures correlate negatively and significantly, indicating that elements with higher skeletal fat utility also display more fragmentation ($r_s = -.892$, $p = .001$). Visual inspection of the relationship between %Complete and skeletal fat value suggests that high levels of phalanx completeness may drive this negative correlation (Figure 3-4c). However, as shown in Figure 3-4d, even when we exclude phalanges from analysis, a linear relationship remains ($r_s = -.721$, $p = .068$; the small sample size of seven elements is likely driving the lower significance value for this correlation).

We support the %Complete analysis with another measure of long bone fragmentation, NISP/MNE. NISP/MNE values increase with the amount of fragmentation, since more specimens should represent individual elements as they are subjected to increasing processing intensity (Lyman 1994:336-338). Skeletal fat utility does not predict NISP/MNE values across the entire bison carcass, probably because the axial skeleton is not generally processed for within bone nutrients (Figure 3-4e; $r_s = -.238$, $p = .313$). However, much like %Complete, skeletal fat utility strongly predicts the distribution of NISP/MNE across long bones (Figure 3-4f; $r_s = .954$, $p < .001$).

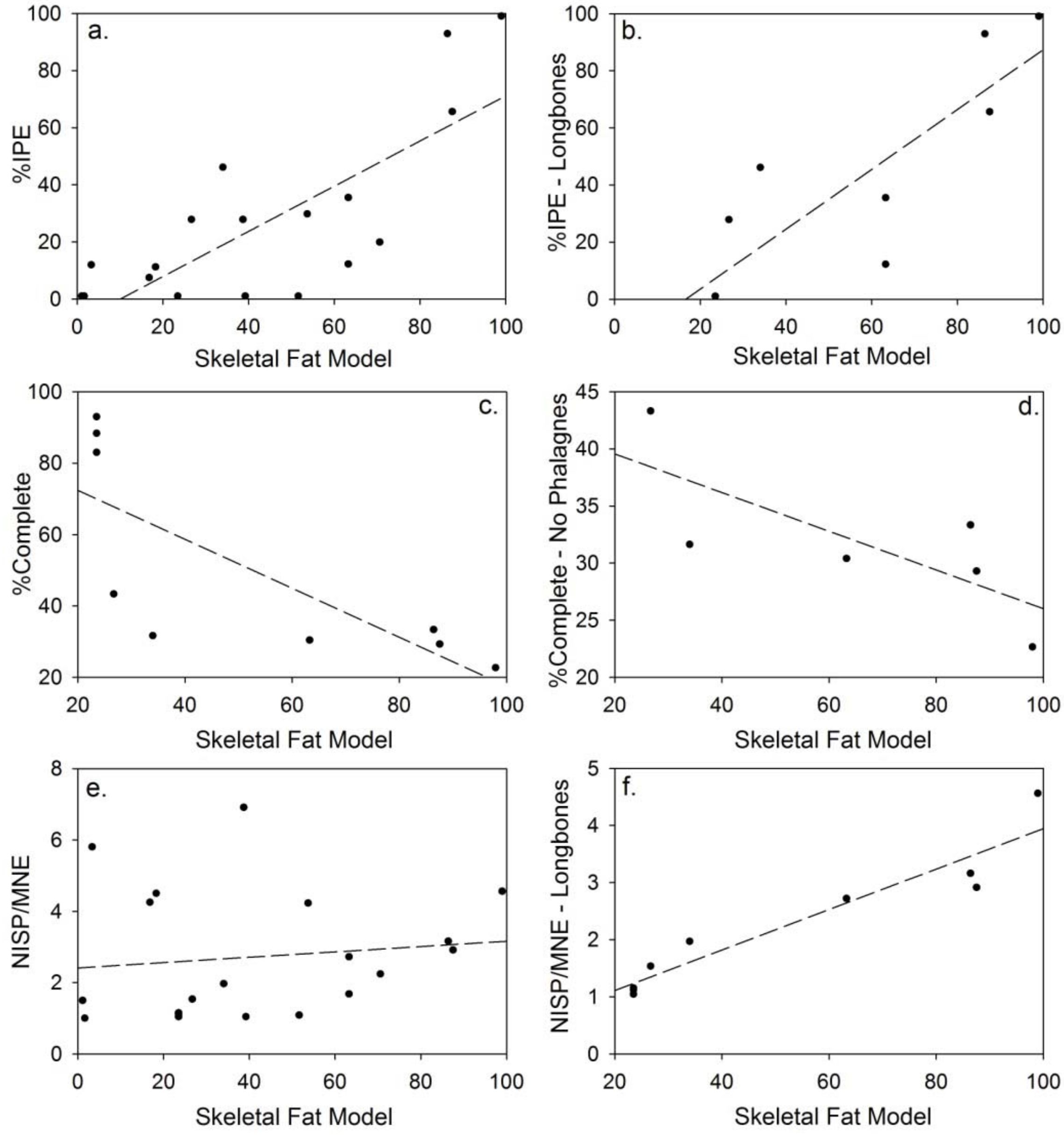

Figure 3-4. The relationship between Emerson's (1990) Skeletal Fat Model and (a) %IPE, (b) %IPE for long bones only, (c) %Complete for long bones, (d) %Complete for long bones minus phalanges, (e) NISP/MNE, and (f.) NISP/MNE for long bones only.

Table 3-4. Bison Long Bone Fragmentation at Baker Cave.

	Average Maximum Dimension (mm)					Skeletal Fat Utility
Element	Baker Cave	Complete	%Complete	NISP/MNE	%IPE	
Humerus	100.44	301.35	33.33	3.16	92.86	86.40
Radius	115.54	380.19	30.39	2.72	35.51	63.25
Metacarpal	90.39	208.70	43.31	1.53	27.78	26.70
Femur	88.71	391.80	22.64	4.56	100.00	100.00
Tibia	111.31	380.19	29.28	2.91	65.56	87.55
Metatarsal	80.63	254.93	31.63	1.97	46.08	34.00
Phalanx 1	60.86	73.34	82.98	1.15	0.00	23.50
Phalanx 2	46.32	49.83	92.96	1.12	0.00	23.50
Phalanx 3	57.24	64.80	88.34	1.04	0.00	23.50

Note: We calculated average values for complete humeri, radii, femora, and tibiae with data from Todd (1983). We calculated average values for complete metapodials with data from Lewis et al. (2005). We calculated average values for complete phalanges from complete Baker Cave specimens.

In sum, our results suggest that skeletal fat was a prime motivator behind both the transport of skeletal parts to Baker Cave and the way those elements were processed once there. Assemblage-level patterns in element representation, impact scar distribution, and fragmentation support this conclusion. Further, taphonomic processes do not appear to bias our results in a meaningful way. Combining this evidence for transport, processing, and seasonality, our analysis of the Baker Cave archaeofauna supports the hypothesis that fat seeking behavior was a response to winter fat scarcity.

Regional Trends in Transport and Processing Decisions

To provide a broader context for the transport and processing decisions at Baker Cave, we compare this bison assemblage to other archaeofaunas from the Great Plains and southern Idaho. The Great Plains' well-documented record of bison exploitation makes this region ideal for putting assemblage level patterns at Baker Cave into a broader behavioral context. We do not intend to exhaustively review Great Plains bison assemblages (see Kornfeld et al. 2010), but rather, with a four site sample, to demonstrate some regularity in assemblage level patterns resulting from similar subsistence behaviors.

Fat Utility and Great Plains Bison Assemblages

We compare Baker Cave to two other bison processing sites and two bison kill sites from the Great Plains. The processing sites include the Locality II Agate Basin component at Hell Gap (southeastern Wyoming; Byers 2001, 2002, 2009) and Spring Creek (southwestern Nebraska; Widga 2004). We selected these processing sites because the authors report data on fragmentation and impact scar distributions, allowing for the quantification of similarities with Baker Cave. The kill sites include Garnsey (southern New Mexico; Speth 1983) and the Waugh Site (northwestern Oklahoma; Hill and Hofman 1997). Garnsey is a late Holocene spring kill (Speth 1983). If skeletal fat utility in part conditioned the transport of elements away from Garnsey, then the resulting skeletal element profile should represent bison parts discarded in the field and, consequently, fail to correlate with the one from Baker Cave. Waugh represents an early Holocene kill that may have occurred during the fall rut (Hill and Hofman 1997). Hill and Hofman (1997) argue that element transport was unselective at Waugh. If so then the Waugh skeletal element profile should contrast with the one from Baker Cave as well. %MAU values from the Great Plains processing sites compare favorably to %MAU at Baker Cave. In this instance, Baker Cave correlates significantly and positively with %MAU at both Hell Gap ($r_s = .605$, $p < .001$) and Spring Creek ($r_s = .714$, $p < .001$). In contrast to the processing sites, we found no relationship between Baker Cave %MAU and %MAUs from either of the two kill sites (Garnsey: $r_s = .206$, $p = .214$; the Waugh

Site: $r_s = -.011$, $p = .948$), suggesting that similarities between Baker Cave and the processing sites are due to similarities in transport decisions. Do these similarities carry over into processing behavior as well?

Data from Hell Gap provide one opportunity to compare processing intensity at Baker Cave with that from another site. Byers (2001:81) provides %IPE (impacts/element in his paper) values for humeri, radii, metacarpals, femora, tibiae and metatarsals, allowing for comparisons with the patterns seen at Baker Cave. At Hell Gap, %IPE correlates with skeletal fat utility (Figure 3-5a; $r_s = .771$, $p = .072$), although, statistical significance is weak in this case. Moreover, %IPE distributions for the Baker Cave and Hell Gap assemblages display a strong and significant relationship ($r_s = .943$, $p = .005$). We also consider fragmentation at Hell Gap by calculating NISP/MNE values for that assemblage's long bones. Much like Baker Cave, skeletal fat utility predicts fragmentation at Hell Gap (Figure 3-5b; $r_s = .917$, $p < .001$). These impact scar and fragmentation patterns demonstrate that the patterns observed at Baker Cave are not unique. Unsurprisingly, Byers (2002) also argues that human modifications to the Hell Gap bison bones represent fat-seeking behaviors.

Spring Creek provides an additional example of how fat seeking behaviors can condition a faunal assemblage. We arrayed %MAU as reported by Widga (2004) against skeletal fat utility, and this comparison produced a positive and significant correlation ($r_s = .662$, $p = .007$). Widga (2004) also details impact scar distributions across elements. Like Baker Cave and Hell Gap, we use these impact scar distributions to construct %IPE values for Spring Creek long bones (Widga [2004] does not mention impact scars on phalanges, but he *does* detail cutmarks. We interpret this as a complete lack of impact

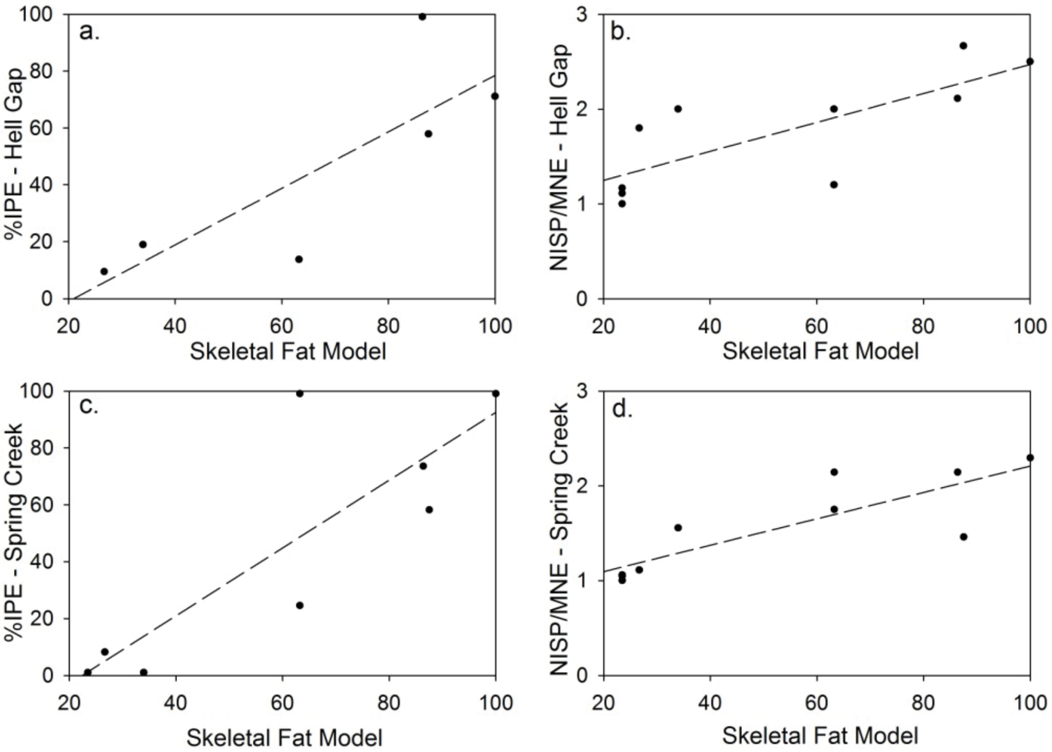

Figure 3-5. The relationship between Emerson's (1990) Skeletal Fat Model and (a) %IPE at Hell Gap (Byers 2001), (b) NISP/MNE at Hell Gap (Byers 2001), (c) %IPE at Spring Creek (Widga 2004), and (d) NISP/MNE at Spring Creek (Widga 2004).

scars on phalanges). Once again, skeletal fat utility predicts the distribution of %IPE (Figure 3-5c; $r_s = .838$, $p = .002$). NISP/MNE values also demonstrate that skeletal fat utility predicts fragmentation levels across long bones at Spring Creek (Figure 3-5d; $r_s = .855$, $p = .002$). Widga (2004) interprets Spring Creek as a secondary processing area where butchers extracted marrow and removed meat for transport elsewhere. This resembles "snack sites" reported in ethnoarchaeological studies of Hadza butchery (Bunn et al. 1988; O'Connell et al. 1988, 1992), where hunters consumed meat and marrow at or near kill sites before transporting meat back to a central consumption area.

Baker Cave, along with the Hell Gap and Spring Creek sites, demonstrates that impact scar distributions and fragmentation patterns that track fat utility often accompany evidence for fat-seeking transport behavior. The processing decisions responsible for these patterns relate directly to within-bone nutrients and suggest that skeletal element profiles at consumption sites should primarily be understood in these terms (Brink 1997; Madrigal and Holt 2002; Marshall and Pilgrim 1991). Processing and transport behaviors centered on meat acquisition frequently treat bone as a low utility item to be discarded in the field. Therefore, understanding the contexts that make skeletal nutrients valuable is important for predicting when hunters transport bone back to consumption sites.

Fat Utility and Snake River Plain Bison Assemblages

Does Baker Cave reflect a general pattern of fat seeking behavior on the SRP? This question is difficult to answer since the region has produced few large bison assemblages and, to date, Baker Cave is the only large SRP bison assemblage to be analyzed in depth. Smaller collections of bison remains from lava caves across the eastern SRP allow us to explore the issue, albeit within a different archaeological context. Henrikson (2003) describes bison remains from three SRP lava caves: Bobcat Cave, Scaredy Cat Cave, and Tomcat Cave. Henrikson (2003) notes that these bison remains were cached in chambers that retain ice year round and they may have functioned as cold storage facilities. She suggests that these contexts represent a solution to fluctuating resource abundances that was employed by SRP foragers across much of the Holocene (Henrikson 2003:283), although it is unknown what type of resource insecurity drove this storage strategy.

These sites provide an opportunity to investigate the importance of skeletal fat to SRP foragers more broadly. Much like the patterns documented at Baker Cave, aspects of the cold storage assemblages point to a fat seeking strategy. For example, long bones from these storage features often display green breaks suggestive of marrow and grease extraction (Henrikson 2003). Additionally, the relationship between skeletal element frequencies and skeletal fat utility at these caves hints at an emphasis on this nutrient. While several of these cold storage contexts are known, none has produced a large number of remains. However, if these sites represent a subsistence strategy spanning the middle and late Holocene, as Henrikson (2003) suggests, then aggregating their skeletal element profiles should reveal the general behavioral patterns behind them. Doing so produces a skeletal element profile that correlates positively and significantly with %MAU at Baker Cave ($r_s = .567$, $p = .027$). Moreover, like Baker Cave, the aggregated cold storage cave %MAU also displays a positive and significant correlation with skeletal fat utility ($r_s = .726$, $p = .017$)[2].

Several cautionary notes are in order for this exploration of fat insecurity and bison storage. These three sites span the middle Holocene and originate from different spatial contexts. If they represent a general pattern of fat seeking behavior, it would have had to persist through the middle and late Holocene (beginning at least as early as 6000 cal B.C.). Additionally, these faunas appear to result from small-scale hunting events rather than large time-averaged accumulations. Small synchronic assemblages such as these often reflect situational constraints on transport and processing (Lupo 2001), making them generally poor examples of broad trends in subsistence behavior. Therefore, we cannot be sure that this aggregated skeletal profile represents a region-wide trend. However, the strong similarity between the aggregated skeletal profile and Baker Cave, and the strong relationship between the aggregated skeletal profile and skeletal fat utility, suggests that these assemblages reflect a similar generalized response to similar constraints. Although these caves lack data on procurement season, considering the strong similarities in skeletal part representation with Baker Cave and accompanying evidence for marrow extraction, we suspect that winter fat insecurity conditioned this storage strategy.

Confirming a pattern of fat seeking behavior that persisted through the middle and late Holocene, and understanding how it might have varied, will require SRP archaeologists to study bison dominated archaeofaunas from other contexts. This is especially true in light of theoretical expectations that processing intensity should vary with resource abundance (Burger et al. 2005), which has been demonstrated in the neighboring Wyoming Basin (Smith et al. 2008). Considering well-documented fluctuations in artiodactyl abundances through the Holocene in western North America (Broughton et al. 2008; Byers and Broughton 2004; Byers and Smith 2007; Byers et al. 2005), processing intensity likely varied with bison encounter rates on the SRP. Processed bison phalanges from the eastern SRP site 10BV93 (Miller 1990), dated to 2934-2752 cal B.C. (Gough 1990), hint at more intensive processing earlier in the late Holocene. Documenting this variability will require similar studies with large archaeofaunas from sites such as Wasden (Butler 1968, 1978) and the Birch Creek Rockshelters (Swanson 1972). Additional work on smaller bison assemblages will also shed light on these patterns, as is suggested by Henrikson's (1996, 2003) work on faunal storage features.

Conclusions

When does transporting bone from a large carcass become a benefit rather than a burden? We approached this question with bison remains from Baker Cave, a late

Holocene processing site on the SRP. We hypothesized that winter fat scarcity raised the value of marrow and grease rich bone. Since fetal bison morphometrics suggest winter/early spring kills, we predicted that bison bones were transported to Baker Cave, and processed there in proportion to their fat utility. We tested this hypothesis with element frequencies, impact scar distributions, and fragmentation patterns. Our results suggest that hunters transported and processed these bones in accordance with their fat utility. Taken as a whole, this assemblage supports the hypothesis that hunters transported and processed the Baker Cave bison remains in response to winter fat scarcity. This not only underscores previous arguments for the importance of considering skeletal nutrients in zooarchaeology (Brink 1997; Madrigal and Holt 2002; Marshall and Pilgrim 1991), but also provides new insights into the seasonal determinants of subsistence behavior on the SRP.

At this point, we do not know how long this fat seeking adaptation existed on the SRP or if it varied through time. Cold storage caves located throughout the region suggest that as a generalized strategy, fat seeking behavior may have persisted for at least 8000 years. However, the current sample is too small to confirm a long-term subsistence strategy. Theoretical expectations (Burger et al. 2005) and records from neighboring regions (Smith et al. 2008) further suggest that this behavior may have varied with the abundance of bison on the landscape. We aim to describe and explain this variability in future studies.

References Cited

Balkwill, Darlene M., and Stephen L. Cumbaa

1992 *A Guide to the Identification of Postcranial Bones of Bos taurus and Bison bison*. Syllogeus No. 71. Canadian Museum of Nature, Ottawa, Ontario.

Binford, Lewis R.

1978 *Nunamiut Ethnoarchaeology*. Academic Press, New York.

1981 *Bones: Ancient Men and Modern Myths*. Academic Press, New York.

Blumenschine, Robert J., and Curtis W. Marean

1993 A Carnivore's View of Archaeological Bone Assemblages. In *From Bones to Behavior*, edited by Jean Hudson, pp. 273-300. Center for Archaeological Investigations, Southern Illinois University, Carbondale.

Brink, Jack W.

1997 Fat Content in Leg Bones of *Bison bison*, and Applications to Archaeology. *Journal of Archaeological Science* 24:259-274.

Broughton, Jack M., David A. Byers, Reid A. Bryson, William Eckerle, and David B. Madsen

2008 Did Climatic Seasonality Control late Quaternary Artiodactyl Densities in Western North America? *Quaternary Science Reviews* 27:1916-1937.

Broughton, Jack M., and Shawn D. Miller

2010 *Zooarchaeology: Laboratory Manual*. Unpublished manuscript. Department of Anthropology, University of Utah, Salt Lake City.

Brown, Christopher L., and Carl E. Gustafson

1979 *A Key to Postcranial Skeletal Remains of Cattle/Bison, Elk, and Horse*. Reports of Investigations No. 57. Department of Anthropology, Washington State University, Pullman.

Bunn, Henry T., Laurence E. Bartram, and Ellen M. Kroll

1988 Variability in Bone Assemblage Formation from Hadza Hunting, Scavenging, and Carcass Processing. *Journal of Anthropological Archaeology* 7:412-457.

Burger, Oskar, Marcus J. Hamilton, and Robert Walker

2005 The Prey as Patch Model: Optimal Handling of Resources with Diminishing Returns. *Journal of Archaeological Science* 32:1147-1158.

Butler, B. Robert

1968 An Introduction to Archaeological Investigations in the Pioneer Basin Locality of Eastern Idaho. *Tebiwa* 11(1):1-30.

1971 A Bison Jump in the Upper Salmon River Valley of Eastern Idaho. *Tebiwa* 14(1):4-32.

1978 Bison Hunting in the Desert West Before 1800: The Paleo-Ecological Potential and the Archaeological Reality. *The Plains Anthropologist* 23:106-112.

Butler, B. Robert, Helen Gildersleeve, and John Sommers

1971 The Wasden Site Bison: Sources of Morphological Variation. In *Aboriginal Man and Environments on the Plateau of Northwest North America*, edited by Arnoud H. Stryd and Rachel A. Smith, pp. 126-152. Students' Press, Calgary, Alberta.

Byers, David A.

2001 The Hell Gap Site Locality II Agate Basin Faunal Assemblage: a Study of Paleoindian Faunal Resource Exploitation. Unpublished Master's thesis, Department of Anthropology, University of Wyoming, Laramie.

2002 Paleoindian Fat-Seeking Behavior: Evidence from the Hell Gap Site, Locality II Agate Basin Faunal Assemblage. *Plains Anthropologist* 47:359-377.

2009 The Agate Basin Faunal Remains at Locality II. In *Hell Gap: A Stratified Paleoindian Campsite at the Edge of the Rockies*, edited by Mary L. Larson, Marcel Kornfeld, and George C. Frison, pp. 135-156. University of Utah Press, Salt Lake City.

Byers, David A., and Jack M. Broughton

2004 Holocene Environmental Change, Artiodactyl Abundances, and Human Hunting Strategies in the Great Basin. *American Antiquity* 69:235-255.

Byers, David A., and Craig S. Smith

2007 Ecosystem Controls and the Archaeofaunal Record: An Example from the Wyoming Basin, USA. *The Holocene* 17:1171-1183.

Byers, David A., Craig S. Smith, and Jack M. Broughton

2005 Holocene Artiodactyl Population Histories and Large Game Hunting in the Wyoming Basin, USA. *Journal of Archaeological Science* 32:125-142.

Daubenmire, Rexford

1985 The Western Limits of the Range of the American Bison. *Ecology* 66:622-624.

Emerson, Alice M.

1990 Archaeological Implications of Variability in the Economic Anatomy of *Bison bison*. Unpublished Ph.D. dissertation, Department of Anthropology, Washington State University, Pullman.

Frison, George C., Michael Wilson, and Danny N. Walker

1978 *The Big Goose Creek Site: Bison Procurement and Faunal Analysis*. Occasional Papers on Wyoming Archaeology No. 1. Department of Anthropology, University of Wyoming, Laramie.

Gogan, Peter J., Kevin M. Podruzny, Edward M. Olexa, Helga I. Pac, and Kevin L. Frey

2005 Yellowstone Fetal Development and Phenology of Parturition. *Journal of Wildlife Management* 69:1716-1730.

Gough, Stan (editor)

1990 *Cultural Resource Investigations of the Bonneville Power Administration's Goshen-Drummond No. 1 Transmission Line, Southeastern Idaho*. Reports in Archaeology and History No. 100-68. Eastern Washington University, Cheney.

Gould, Russell T., and Mark G. Plew

1996 Prehistoric Salmon Fishing in the Northern Great Basin: Ecological Dynamics, Trade-Offs, and Foraging Strategies. In *Prehistoric Hunter-Gatherer Fishing Strategies*, edited by Mark G. Plew, pp. 64-83. Boise State University, Boise.

Gruhn, Ruth

1961 *The Archaeology of Wilson Butte Cave*. Occasional Papers of the Idaho State College Museum No. 6. Idaho State University, Pocatello.

Haynes, Gary

1980 Evidence of Carnivore Gnawing on Pleistocene and Recent Mammalian Bones. *Paleobiology* 6:341-351.

1983 A Guide for Differentiating Mammalian Carnivore Taxa Responsible for Gnaw Damage to Herbivore Limb Bones. *Paleobiology* 9:164-172.

Henrikson, L. Suzann

1996 *Prehistoric Cold Storage on the Snake River Plain: Archaeological Investigations at Bobcat Cave*. Monographs in Idaho Archaeology and Ethnology No. 1. Idaho State Historical Society, Boise.

2003 Bison Freezers and Hunter-Gatherer Mobility: Archaeological Analysis of Cold Lava Tube Caves on Idaho's Snake River Plain. *Plains Anthropologist* 48:263-285.

2004 Frozen Bison and Fur Trapper's Journals: Building a Prey Choice Model for Idaho's Snake River Plain. *Journal of Archaeological Science* 31:903-916.

2005 Bison Heights: A Late Holocene Bison Kill Site on Idaho's Snake River Plain. *North American Archaeologist* 26:333-355.

Henrikson, L. Suzann, Kaylon W. McAlister, and Montana M. Long

2006 *Craters of the Moon National Monument and Preserve Archaeological Overview*. Report No. 2006-022. Museum of Natural History and Cultural History, University of Oregon, Eugene.

Hill, Matthew E., Jr., and Jack L. Hofman

1997 The Waugh Site: A Folsom-Age Bison Bonebed in Northwestern Oklahoma. *Plains Anthropologist* 42:63-83.

Holmer, Richard N., and Brenda L. Ringe

1986 Excavations at Wahmuza. In *Shoshone-Bannock Culture History*, pp. 39-198, edited by Richard N. Holmer. Reports of Investigations 85-16. Swanson/Crabtree Anthropological Research Laboratory, Idaho State University, Pocatello.

Kirkpatrick, Jay F., Diane F. Gudermuth, R. L. Flagan, J. C. McCarthy, and Bill L. Lasley

1993 Remote Monitoring of Ovulation and Pregnancy of Yellowstone Bison. *The Journal of Wildlife Management* 57:407-412.

Kornfeld, Marcel, George C. Frison, and Mary L. Larson

2010 *Prehistoric Hunter-Gatherers of the High Plains and Rockies*. Left Coast Press, Walnut Creek, California.

Kreutzer, Lee A.

1992 Bison and Deer Bone Mineral Densities: Comparisons and Implications for the Interpretation of Archaeological Faunas. *Journal of Archaeological Science* 19:271-294.

Kuntz, Mel A., Harry R. Covington, and Linda J. Schorr

1992 An Overview of Basaltic Volcanism of the Eastern Snake River Plain, Idaho. In *Regional Geology of Eastern Idaho and Western Wyoming*, edited by Paul K. Link, Mel A. Kuntz, and Lucian I. Platt, pp. 227-269. Memoir 179. Geological Society of America, Boulder.

Kuntz, Mel A., Elliott C. Spiker, Meyer Rubin, Duane E. Champion, and Richard Lefebvre

1986 Radiocarbon Studies of Latest Pleistocene and Holocene Lava Flows of the Snake River Plain, Idaho: Data, Lessons, and Interpretations. *Quaternary Research* 25:163-176.

Lewis, Patrick J., Briggs Buchanan, and Eileen Johnson

2005 Sexing Bison Metapodials Using Principal Component Analysis. *Plains Anthropologist* 50:159-172.

Lupo, Karen D

2001 Archaeological Skeletal element profiles and Differential Transport: An Ethnoarchaeological Example from Hadza Bone Assemblages. *Journal of Anthropological archaeology* 20:361-378.

Lyman, R. Lee

1994 *Vertebrate Taphonomy*. Cambridge University Press, Cambridge, United Kingdom.

Mack, Richard N., and John N. Thompson

1982 Evolution in Steppe with Few Large, Hooved Mammals. *The American Naturalist* 119:757-773.

Madrigal, T. Cregg, and Julie Z. Holt

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

Malde, Harold E., and Howard A. Powers

1962 Upper Cenozoic Stratigraphy of Western Snake River Plain, Idaho. *Geological Society of America Bulletin* 73:1197-1220.

Marean, Curtis W., and Carol J. Frey

1997 Animal Bones from Caves to Cities: Reverse Utility Curves as Methodological Artifacts. *American Antiquity* 62:698-711.

Marshall, Fiona, and Tom Pilgram

1991 Meat versus Within-Bone Nutrients: Another Look at the Meaning of Body Part Representation in Archaeological Sites. *Journal of Archaeological Science* 18:149-163.

McKee, Dave F.

1985 The Utilization of Bison Fetal Bones and Mandibles in a Study of Seasonality at the River Bend Site (48NA202). *Wyoming Archaeologist* 28:29-38.

McNab, Brian K.

2002 *The Physiological Ecology of Vertebrates*. Cornell University Press, Ithaca.

Metcalfe, Duncan, and K. Renee Barlow

1992 A Model for Exploring the Optimal Trade-off between Field Processing and Transport. *American Anthropologist* 94:340-356.

Metcalfe, Duncan, and Kevin T. Jones

1988 A Reconsideration of Animal Body-Part Utility Indices. *American Antiquity* 53:486-504.

Miller, Susanne J.

1972 Weston Canyon Rockshelter: Big-Game Hunting in Southeastern Idaho. Unpublished Master's thesis, Department of Anthropology, Idaho State University, Pocatello.

1983 Osteo-Archaeology of the Mammoth-Bison Assemblage at Owl Cave, the Wasden Site, Idaho. In *Proceedings of the Fifteenth Annual Conferences of the*

Archaeological Association of the University of Calgary: Carnivores, Human Scavengers, and Predators: A Question of Bone Technology, edited by Genevieve L. LeMoine and A. Scott MacEachem, pp. 39-53. University of Calgary Archaeological Association, Calgary, Alberta.

1987 The Fauna of Baker Caves. In *Archaeological Investigations at Baker Caves I and III: a Late Archaic Component on the Eastern Snake River Plain*, edited by Mark G. Plew, Max G. Pavesic, and Mary A. Davis, pp. 25-42. Archaeological Reports, No. 5. Boise State University, Boise.

1990 Faunal Analysis. In *Cultural Resource Investigations of the Bonneville Power Administration's Goshen-Drummond No. 1 Transmission Line, Southeastern Idaho*, edited by Stan Gough, pp. 67-73. Reports in Archaeology and History, No. 100-68. Eastern Washington University, Cheney.

1999 Weston Canyon Rockshelter Faunal Analysis. *Tebiwa* 27(1):47-59.

Miller, Susanne J., and Wakefield Dort, Jr.

1978 Early Man at Owl Cave: Current Investigations at the Wasden Site, Eastern Snake River Plain, Idaho. In *Early Man in America: From a Circum-Pacific Perspective*, edited by Alan L. Bryan, pp. 129-139. University of Alberta, Edmonton.

Murphey, Kelly A., and M. J. Crutchfield

1985 *Archaeological Test Excavations at the Crutchfield Site: Hagerman Valley, Idaho*. Anthropological Papers No. 86. University of Idaho, Moscow.

Neudorfer, Giovanni M.

1976 *Poison Creek (10-BM-50): A Study in Methodology and Site Structure in Southeastern Idaho*. Archaeological Reports No. 3. Idaho State University Museum of Natural History, Pocatello.

O'Connell, James F., and Brendan Marshall

1989 Analysis of Kangaroo Body Part Transport Among the Alyawara of Central Australia. *Journal of Archaeological Science* 16:393-405.

O'Connell, James F., Kristen Hawkes, and Nicholas G. Blurton Jones

1988 Hadza Hunting, Butchering, and Bone Transport and Their Archaeological Implications. *Journal of Anthropological Research* 44:113-161.

1990 Reanalysis of Large Mammal Body Part Transport among the Hadza. *Journal of Archaeological Science* 17:301-316.

1992 Patterns in the Distribution, Site Structure and Assemblage Composition of Hadza Kill-Butchering Sites. *Journal of Archaeological Science* 19:319-345.

Olsen, Stanley J.

1964 *Mammal Remains from Archaeological Sites*. Papers of the Peabody Museum of Archaeology and Ethnology Volume 56, No. 1. Peabody Museum, Cambridge, MA.

Phillips, Paul C.

1940 *Life in the Rocky Mountains, by W. A. Ferris*. Old West Publishing Company, Denver.

Plew, Mark G.

1981 *Archaeological Test Excavations at Four Prehistoric Sites in the Western Snake River Canyon near Bliss, Idaho*. Idaho Archaeological Consultants Project Reports No. 5. Report on file at Albertsons Library, Boise State University, Boise.

1990 Modelling Alternative Subsistence Strategies for the Middle Snake River. *North American Archaeologist* 11:1-15.

2003 Archaeological Evidence of Storage on the Snake River Plain. *North American Archaeologist* 24:271-280.

2005 Comments on Bison Freezers and Hunter-Gatherer Mobility: Archaeological Analysis of Cold Lava Tube Caves on Idaho's Snake River Plain. *Idaho Archaeologist* 28(2):23-26.

2009 Archaic Hunter-Gatherer Diet Breadth and Prey Choice on the Snake River Plain. *Journal of Northwest Anthropology* 43(1):27-56.

Plew, Mark G., Max G. Pavesic, and Mary A. Davis

1987 *Archaeological Investigations at Baker Caves I and III: A Late Archaic Component on the Eastern Snake River Plain*. Archaeological Reports, No. 5. Boise State University, Boise.

Plew, Mark G., and Taya Sundell

2000 The Archaeological Occurrence of Bison on the Snake River Plain. *North American Archaeologist* 21:119-137.

Plew, Mark G., and Christopher A. Willson

2002 Archaeological Test Excavations at the Medbury Site (10-EL-1367), Southwest Idaho. *Idaho Archaeologist* 28(2):15-22.

Smith, Craig S., David A. Byers, and Cynthia D. Craven

2008 Bison Exploitation in the Wyoming Basin at the Middle/Late Holocene Transition: A View from the Graham Ranch Site. *Plains Anthropologist* 53:313-332.

Smith, Richard P.

2004 Geologic Setting of the Snake River Plain Aquifer and Vadose Zone. *Vadose Zone* 3:47-58.

Speth, John D.

1983 *Bison Kills and Bone Counts: Decision Making by Ancient Hunters*. The University of Chicago Press, Chicago.

Speth, John D., and Katherine A. Spielmann

1983 Energy Source, Protein Metabolism, and Hunter-Gatherer Subsistence Strategies. *Journal of Anthropological Archaeology* 2:1-31.

Swanson, Earl H., Jr.

1972 *Birch Creek: Human Ecology in the Cool Desert of the Northern Rocky Mountains 9,000 BC - AD 1850*. Idaho State University, Pocatello.

Todd, Lawrence C.

1983 The Horner Site: Taphonomy of an Early Holocene Bison Bonebed. Unpublished Ph.D. dissertation, Department of Anthropology, University of New Mexico, Albuquerque.

Trout, Lester E., and Jerold L. Thiessen

1968 Food Habits and Condition of Mule Deer in Owyhee County. *Western Proceedings of the Forty-Eighth Annual Conference*: 188-200. Western Association of State Game and Fish Commissioners, Cheyenne.

Walker, Danny N.

2002 Appendix A: Faunal Remains from Archaeological Excavations at the Rock Springs Site, Southeast Idaho. In *Archaeology of the Rock Springs Site: A Multi-*

Component Bison Kill and Processing Camp in Curlew Valley, Southeastern Idaho, edited by Brooke S. Arkush, pp. 99-166. Monographs in Archaeology No. 1. Boise State University, Boise.

Widga, Christopher C.

2004 Early Archaic Subsistence in the Central Plains: The Spring Creek (25FT31) Fauna. *Plains Anthropologist* 49:25-58.

Williams, Heather A.

2005 Spatial Precipitation Variability, Snowfall, and Historical Bison Occurrence in the Northwest United States. Unpublished Master's thesis, Department of Anthropology, Georgia State University, Atlanta.

Wilson, Michael C.

1974 The Casper Local Fauna and its Fossil Bison. In *The Casper Site: a Hell Gap Bison Kill on the High Plains*, edited by George C. Frison, pp. 125-172. Academic Press, New York.

Wood, Spencer H., and Drew M. Clemens

2002 Geological and Tectonic History of the Western Snake River Plain. In *Tectonic and Magnetic Evolution of the Snake River Plain Volcanic Province*, edited by Bill Bonnichsen, Craig M. White and Michael Curry, pp. 69-103. Bulletin No. 230. Idaho Geological Survey, Moscow.

Notes

1. We use Emerson's (1990) bison nutritional models to understand transport and processing behaviors. For general utility, we compare our results with the Total Products Model. For protein utility, we compare our results with the Protein Model. We use the

Skeletal Fat Model to understand skeletal fat utility. Finally, we use the Bone Grease Model and the Marrow Fat Model to understand bone grease and marrow fat utility.

2. Henrikson (2003) reports MNE and MAU values for metapodials generally, but not metacarpals or metatarsals. To make this element class comparable to the Skeletal Fat Model, we averaged the utility values of metacarpals and metatarsals.

CHAPTER 4

DISCUSSION AND CONCLUSIONS

These morphometric and zooarchaeological analyses shed light on late Holocene bison ecology and human subsistence on the Snake River Plain (SRP). Additionally, they point to new gaps that future research must fill. In this chapter, I discuss how these studies answer previous questions concerning paleoecology and archaeology on the SRP, as well as how each study raises new questions in these areas. I begin with a discussion of bison diminution, and I follow this with a discussion of prehistoric subsistence in southern Idaho.

The first article (Chapter 2) comprises one of very few studies examining bison diminution west of the Rocky Mountains. Therefore, it is a critical contribution to the documentation of this process. Prior investigations include Butler's (1971; Butler et al. 1971) examination of the Wasden bison and Lyman's (2004) review of bison remains in eastern Washington. Only the latter study evaluates bison diminution with modern methods, while the morphometric profile of the Wasden bison is less clear in the context of recent studies on bison diminution. Lyman's study documents a pattern of diminution similar to that recorded on the Great Plains by Hill et al. (2008), although there are large temporal gaps in the eastern Washington Record. Lyman (2004) points out that the eastern Washington pattern could have resulted from either in situ diminution west of the Rocky Mountains or from repeated migrations from a changing Great Plains bison population. He notes that if the second scenario is responsible for the eastern Washington pattern, southern Idaho might have served as a migration route between each region.

This study corroborates the diminution trend documented on the Great Plains and eastern Washington. Since these animals were present in both southern Idaho and eastern Washington during the same periods, it is plausible that the eastern Washington bison were migrants traveling across southern Idaho. However, unlike eastern Washington, bison do appear to have occupied southern Idaho through the entire Holocene (Plew 2009). Therefore, in situ diminution is testable in southern Idaho, unlike in eastern Washington. However, confirming continuous diminution will require additional morphometric analyses of existing bison assemblages from the region. If paleoecologists document a continuous record of bison diminution in southern Idaho, then morphological trends in bison west of the Rocky Mountains may have occurred independently of diminution in Great Plains bison. Alternatively, diminution west of the Rocky Mountains may have resulted from a mixture of both Great Plains migrations *and* in situ diminution. Future research on bison diminution west of the Rocky Mountains must evaluate these alternative hypotheses.

This thesis also contributes significantly to knowledge of the prehistoric use of bison in southern Idaho. Prior to the second study (Chapter 3), little was known of bison exploitation in the region. Archaeologists typically agree that these animals were too infrequently encountered for regular large scale communal hunts (Butler 1978; Plew and Sundell 2000), although they were probably a preferred resource (Henrikson 2003, 2004, 2005). Recent studies also demonstrate that people periodically stored these animals over the last 7000 years (Henrikson 1996, 2003). Henrikson (2003) notes that this storage strategy was probably a response to resource insecurity, although the type of resource insecurity driving this subsistence behavior is unknown. This phenomenon was probably conditioned by the seasonal availability of resources, although evidence for the season of procurement and storage is lacking thus far (Henrikson 2003; Plew 2005).

To better understand prehistoric bison procurement in southern Idaho, I conducted a comprehensive analysis of the Baker Cave bison remains. This analysis tested predictions drawn from the hypothesis that hunters processed these animals in response to winter fat scarcity (which is a problem for many foragers living in temperate climates [Speth and Spielmann 1983]). The analysis demonstrated that bison body parts were transported back to Baker Cave, and processed at Baker Cave, in proportion to their skeletal fat utility. Although Baker Cave does not appear to have been a cold storage feature like those documented by Henrikson (1996, 2003), it does contain evidence for a response to resource insecurity. Importantly, it contains evidence for a specific type of resource insecurity tied to seasonal fluctuations in resource quality.

The comparison between Baker Cave and the cold storage features suggests that all of these sites represent a generalized subsistence strategy for resolving winter fat scarcity. However, it should be cautioned that these cold storage features currently lack evidence for winter procurement. This generalized strategy is currently supported by one line of evidence, element frequencies. This hypothesized fat seeking strategy requires further lines of supporting evidence. This evidence could take the form of impact scar distributions and fragmentation patterns that indicate fat seeking processing decisions. It could also take the form of data that indicate winter procurement, such as fetal bison remains or patterns in bison molar eruption and wear. Until these data are available, this hypothesis will remain tentative.

Finally, the second article (Chapter 3) further supports an argument made by zooarchaeologists interested in big game hunting: bones at secondary processing and consumption sites should be understood primarily in terms of their skeletal nutritional value, rather than the the nutritional value of meat attached to them (Brink 1997; Madrigal and Holt 2002; Marshall and Pilgram 1991). The Baker Cave bison remains were clearly utilized independently of the meat attached to them. Since experienced butchers can easily strip the meat from many bones (Bunn et al. 1988; O'Connell et al. 1988, 1992), it is unclear if bones at consumption areas can reveal anything about protein considerations. More often than not, these bones probably indicate situations where marrow and grease were highly valued resources. When within bone nutrients were not in demand, zooarchaeologists should not necessarily expect large game exploitation to be represented by bone material at consumption areas. This study provides an example of when archaeologists should expect to encounter these situations.

References Cited

Brink, Jack W.

1997 Fat Content in Leg Bones of *Bison bison*, and Applications to Archaeology. *Journal of Archaeological Science* 24:259-274.

Bunn, Henry T., Laurence E. Bartram, and Ellen M. Kroll

1988 Variability in Bone Assemblage Formation from Hadza Hunting, Scavenging, and Carcass Processing. *Journal of Anthropological Archaeology* 7:412-457.

Butler, B. Robert

1971 The Origin of the Upper Snake Country Buffalo. *Tebiwa* 14(2):1-20.

1978 Bison Hunting in the Desert West Before 1800: The Paleo-Ecological Potential and the Archaeological Reality. *The Plains Anthropologist* 23:106-112.

Butler, B. Robert, Helen Gildersleeve, and John Sommers

1971 The Wasden Site Bison: Sources of Morphological Variation. In *Aboriginal Man and Environments on the Plateau of Northwest North America*, edited by Arnoud H. Stryd and Rachel A. Smith, pp. 126-152. Students' Press, Calgary, Alberta.

Henrikson, L. Suzann

1996 *Prehistoric Cold Storage on the Snake River Plain: Archaeological Investigations at Bobcat Cave*. Monographs in Idaho Archaeology and Ethnology No. 1. Idaho State Historical Society, Boise.

2003 Bison Freezers and Hunter-Gatherer Mobility: Archaeological Analysis of Cold Lava Tube Caves on Idaho's Snake River Plain. *Plains Anthropologist* 48:263-285.

2004 Frozen Bison and Fur Trapper's Journals: Building a Prey Choice Model for Idaho's Snake River Plain. *Journal of Archaeological Science* 31:903-916.

2005 Bison Heights: A Late Holocene Bison Kill Site on Idaho's Snake River Plain. *North American Archaeologist* 26:333-355.

Hill, Matthew E., Jr., Matthew G. Hill, and Christopher C. Widga

2008 Late Quaternary *Bison* Diminution on the Great Plains of North America: Evaluating the Role of Human Hunting versus Climate Change. *Quaternary Science Reviews* 27:1752-1771.

Lyman R. Lee

2004 Late-Quaternary Diminution and Abundance of Prehistoric Bison (*Bison* sp.) in Eastern Washington State, USA. *Quaternary Research* 62:76-85.

Madrigal, T. Cregg, and Julie Z. Holt

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

Marshall, Fiona, and Tom Pilgram

1991 Meat versus Within-Bone Nutrients: Another Look at the Meaning of Body Part Representation in Archaeological Sites. *Journal of Archaeological Science* 18:149-163.

O'Connell, James F., Kristen Hawkes, and Nicholas G. Blurton Jones

1988 Hadza Hunting, Butchering, and Bone Transport and Their Archaeological Implications. *Journal of Anthropological Research* 44:113-161.

1992 Patterns in the Distribution, Site Structure and Assemblage Composition of Hadza Kill-Butchering Sites. *Journal of Archaeological Science* 19:319-345.

Plew, Mark G.

2005 Comments on Bison Freezers and Hunter-Gatherer Mobility: Archaeological Analysis of Cold Lava Tube Caves on Idaho's Snake River Plain. *Idaho Archaeologist* 28(2):23-26.

2009 Archaic Hunter-Gatherer Diet Breadth and Prey Choice on the Snake River Plain. *Journal of Northwest Anthropology* 43(1):27-56.

Plew, Mark G., and Taya Sundell

2000 The Archaeological Occurrence of Bison on the Snake River Plain. *North American Archaeologist* 21:119-137.

Speth, John D., and Katherine A. Spielmann

1983 Energy Source, Protein Metabolism, and Hunter-Gatherer Subsistence Strategies. *Journal of Anthropological Archaeology* 2:1-31.

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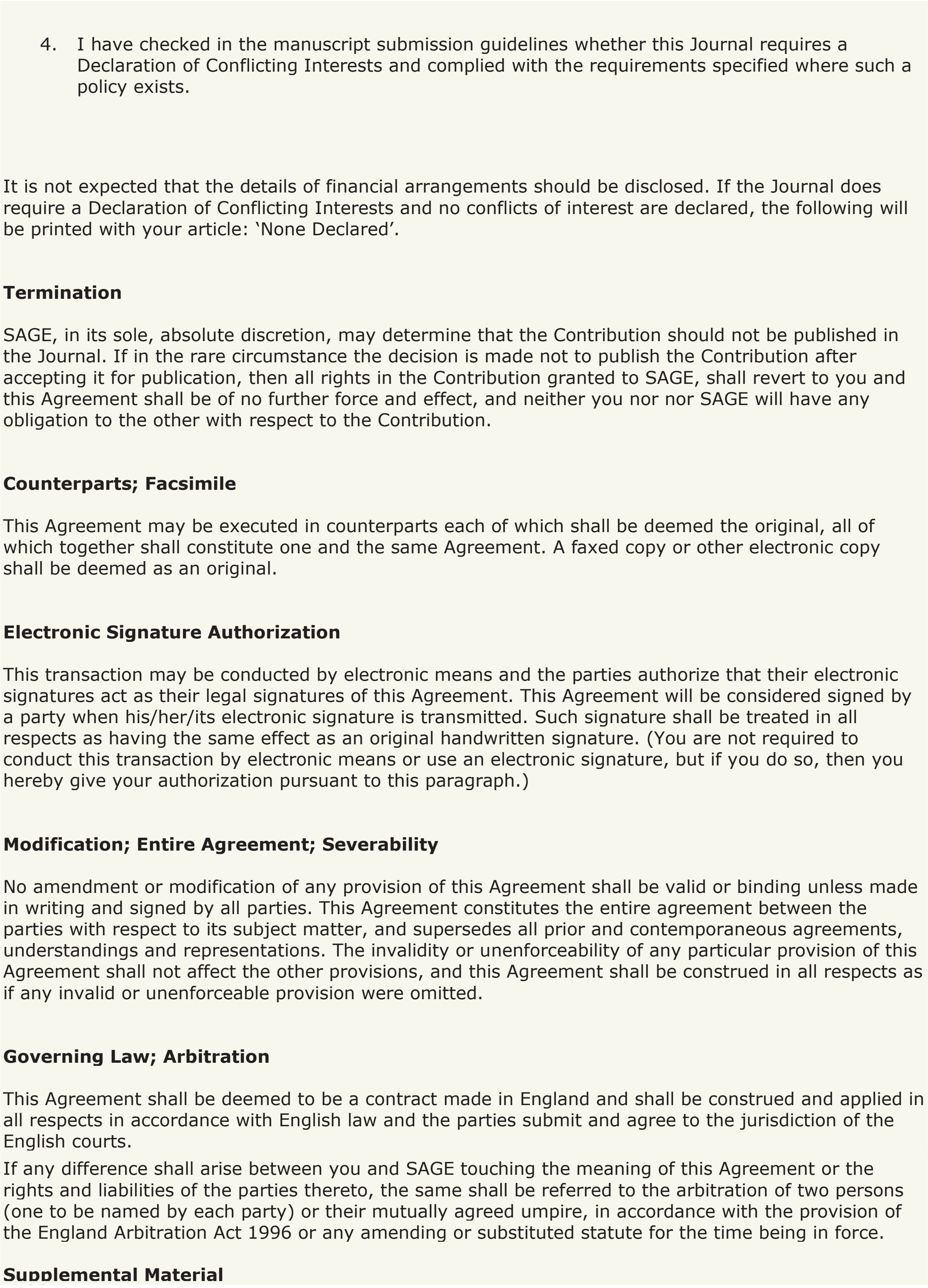

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