Risk and Climate at High Elevation: A Z-score Model Case Study for Prehistoric Human Occupation of Wyoming's Wind River Range

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RISK AND CLIMATE AT HIGH ELEVATION: A Z-SCORE MODEL CASE STUDY FOR PREHISTORIC HUMAN OCCUPATION OF WYOMING'S WIND RIVER RANGE

by

Ashley K. Losey

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Anthropology

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UTAH STATE UNIVERSITY
Logan, Utah

2013
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ABSTRACT

Risk and Climate at High Elevation: A Z-Score Model Case Study for Prehistoric Human Occupation of Wyoming’s Wind River Range

by

Ashley Losey, Master of Science
Utah State University, 2013

Major Professor: Dr. Christopher Morgan
Department: Sociology, Social Work, and Anthropology

Holocene climate likely influenced prehistoric hunter-gatherer subsistence and mobility as changing climate patterns affected food resources. Of interest here is whether climate-driven resource variability influenced peoples in the central Rocky Mountains. This study employed the z-score model to predict how foragers coped with resource variability. The exercise enabled exploration of the relationship between climate, resources, and foraging strategies at High Rise Village (48FR5891), an alpine residential site in Wyoming’s Wind River Range occupied between 2800–250 cal B.P. The test was applied to occupations dating to the Medieval Warm Period (1150–550 cal B.P.) and the Little Ice Age (550–100 cal B.P.).

Using regional characterizations of temporal variability for these climate periods, a z-score model was employed to develop predictions of how foragers coped with resource variability and predictability during both periods. The model predicted
foraging decisions at High Rise Village that managed the risk of caloric shortfall during the slow-changing Medieval Warm Period and the highly variable Little Ice Age. Predictions for each period were tested against corresponding archaeological expectations for subsistence remains, mobility and technology requirements, and the frequency of site use. Further, this study employed a dendroclimatological study to locally characterize the climate periods and test model assumptions of their contrasting patterns of variability.

The dendroclimatological study corroborates model assumptions and finds that the Medieval Warm Period was a period of multidecadal climatic variability and resource predictability while the Little Ice Age was characterized by short-term variability and resource unpredictability. Poor preservation of subsistence remains hampered the archaeological study. However, as expected, lithic and chronometric data indicate the site was used residentially and relatively frequently during the Medieval Warm Period, and that use decreased during the Little Ice Age. Medieval use of the site appears to be by Uinta Phase (1800–900 cal B.P.) foragers from the adjacent lowlands, and likely related to regional population pressure, as well as resource accessibility and predictability at High Rise Village. A dramatic decrease in site use predates the Little Ice Age and is likely related to regional population decrease and not LIA conditions at High Rise Village.

(174 pages)
PUBLIC ABSTRACT

Risk and Climate at High Elevation: A Z-Score Model Case Study for Prehistoric Human Occupation of Wyoming’s Wind River Range

by

Ashley Losey

Climate was not consistent during the last 2,000 years and different climatic regimes had considerable influence over the lives of the Native American hunter-gatherers who depended on the land for a living. In particular, changing climate affected the availability of plants and animal foods that sustained the people. This study explores how differences in climate between the Medieval Warm Period (1150–550 B.P.) and the Little Ice Age (550–100 B.P.) influenced the Native American inhabitants of High Rise Village, an alpine archaeological site at 3,300 meters above sea level in Wyoming’s Wind River Range.

The research includes two parts: a study of climate during the two periods of occupation, and an archaeological excavation that documents ancient life at High Rise Village. Because climate is a complex phenomenon with localized expression, the climate study focused on a whitebark pine forest at the site. Tree-ring samples from living and dead trees revealed patterns of temperature and precipitation, enabling reconstruction of the local climate during the Medieval Warm Period and Little Ice Age. The archaeological component of the study relied on finds of ancient stone tools, and debris from food preparation and tool making to reconstruct how people used the site.
The climate data indicates local differences in climate between the Medieval Warm Period and the Little Ice Age. These differences translated into changes in food availability and abundance that shaped the way people lived at High Rise Village during these two climatic periods. Specifically, stable, predictable food resources near High Rise Village were repeatedly exploited during the Medieval Warm Period, while the site was used much less frequently during the more variable and difficult Little Ice Age. This research cost approximately $20,000 over three years; funding came primarily from private foundations, with additional funding through research grants from Utah State University.

Resource managers, policy makers, and the public cannot make informed decisions about modern climate change when referencing only modern climate data and written history. Study of ancient climate expands the scale of time to provide a more complete picture of the range of climatic variability. Archaeological study identifies Native American lifeways that may differ markedly from those that occurred during the Historic period. These broader contexts enable policy makers and land managers to make more informed decisions.
ACKNOWLEDGMENTS

First and foremost, my committee provided invaluable support and enthusiasm throughout this process, which I appreciate more than I can say. Thank you Chris Morgan for all your patience and encouragement and for generally keeping me facing in the right direction. And, thank you Steve Simms and Ken Cannon for all your ideas, help, and guidance. Further, my dendroclimatological study would not have been possible without the generosity and encouragement from Justin DeRose at the Utah State University (USU) Dendro Lab.

I must also thank the faculty and staff of the USU Anthropology Program for the opportunity to be a part of this graduate program and the support of the last three years. And, many thanks to Richard Adams, Bryon Schroeder, and Matt Stirn, all formerly at the University of Wyoming, for answering many early questions about High Rise Village and sharing in the enthusiasm for mountain archaeology.

Further thanks are deserved for my fellow students, graduate and undergraduate alike, for much help and camaraderie. In particular, thank you Dallin Webb, Dayna Reale, Luke Trout, and Chris Davies for your invaluable volunteer work during our 2011 field season. Thank you Britt McNamara, Dayna Reale, Liz Seymour, and Jessica Dougherty for help floating and with the collection. Thank you Martin Welker and Rebecca Esplin for many companionable hours in the arch lab. And, thank you Liz Goss, for good conversation, music, and snacks during many late evenings in the Dendro Lab.
Several grants made this work possible and recognition is in order for the National Geographic Society / Waitt Grants Program, Brigham Young University’s Charles Redd Center for Western Studies, and USU’s College of Humanities and Social Sciences, Graduate Student Senate, and Anthropology Program.

Finally, I would like to thank my partner Avery for all of his patience and support and many late cups of tea and early cups of coffee. And, thank you to Mom and James for their encouragement and support across long distances.

Ashley Losey
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CHAPTER 1

INTRODUCTION

Dynamic late Holocene climate (Dunbar 2000) and affiliated ecological changes likely influenced the subsistence and mobility patterns of peoples living in the Rocky Mountains of North America. As climate transitioned between different regimes, spatial and temporal patterns of precipitation and temperature changed across the region. In response, ecological communities changed composition, species shifted distributions, and populations alternately changed, struggled, and thrived (e.g., Lyford et al. 2003; Plager and Holmer 2004; Whitlock 1993). For hunter-gatherers in the region, food resources, and perhaps foraging strategies, varied depending on climate patterns.

Two principal late Holocene patterns are the Medieval Warm Period (MWP; 1150–550 B.P.) and the Little Ice Age (LIA; 550–100 B.P.) (Bradley et al. 2001; Bradley and Jones 1992; Grove 2003; Hughes and Diaz 1994a; Lamb 1990; Mann 2002a, b). In the broadest sense, this transition was from a warm and dry regime to a cool, often wetter one (Mann 2002a, b). However, both periods had often intricate and varied expression driven by the interaction of local and regional factors with hemispheric climate processes (Dunbar 2000). Further, the MWP and LIA also differed in the scale of temporal variability: the MWP was characterized by multidecadal patterns while the LIA was a period of more frequent change, often at a decadal or interannual scale (Gray et al. 2003; Gray et al. 2004; Herweijer et al. 2007; Wang et al. 2010).
Modern wildlife studies indicate that the MWP and LIA likely had distinct effects on plant and animal resources in the Rocky Mountains. Under warm, more consistent MWP conditions (Gray et al. 2004; Herweijer et al. 2007; Perkins 2001), alpine resource populations were likely healthy and stable (Inouye et al. 2000; Tomback and Linhart 1990), and consequently predictable for hunter-gatherers. In contrast, resources were likely considerably less predictable during the LIA as populations navigated frequent and inconsistent changes in the environment (Brunstein 1996; Inouye et al. 2000; Tomback and Linhart 1990). Of interest here is whether these divergent patterns of climate-driven environmental variability influenced subsistence and settlement patterns in the region.

To investigate these influences requires an approach that accounts for how foragers respond to environmental variability. Risk-sensitive foraging theory offers a series of models that predict how foragers cope with different types of resource variability (Baksh and Johnson 1990; Halstead and O’Shea 2004; Kacelnik and Bateson 2000; Winterhalder 1986; Winterhalder et al. 1999). As conceptualized within a subset of this body of theory, risk can be quantified as the probability of falling below a caloric threshold, below which there are negative consequences for the forager (Winterhalder 1986). Given several foraging options, each with some degree of variability, the risk-sensitive forager will favor those options most likely to avoid falling below the threshold (Winterhalder 1986).

Of the risk-sensitive foraging models, the z-score model offers a relatively simple means to predict risk-sensitive foraging in a variable environment (Stephens and
The model requires a caloric threshold and a series of foraging options, each with a caloric yield defined by an average and a standard deviation as a measure of variability. Return rates are used to quantify resource yields, or the net calories gained per hour of effort in acquiring and readying the resource for consumption (Bettinger 1991a). Based on each option’s return relative to the requirement, the model predicts whether the forager is risk-averse or risk-prone and which options best solve the problem of meeting daily caloric requirements (Bettinger 1991a; Winterhalder 1986). Risk-averse foragers minimize exposure to variability that could result in caloric shortfall. Risk-prone foragers actively seek high variance resources, a tactic only used as last resort to avoid almost certain caloric shortfall (Bettinger 1991a).

With this model, it is possible to develop and test expectations regarding risk-sensitive foraging for prehistoric populations in the target environment, particularly given robust and localized paleoenvironmental/paleoclimatic proxy data. The current study uses the model and a central Rocky Mountain archaeological case study to determine whether foraging and settlement patterns shifted in response to climate-driven changes in resource variability during the MWP and LIA.

An archaeological case study of the z-score model requires not only a means to explore past foraging patterns but also a determination or reasonable suspicion of sufficient resource variability to warrant a risk-sensitive foraging strategy. To this end, this study uses the site known as High Rise Village (49FR5891) because it offers the means to characterize both environmental variability and corresponding risk-sensitive
foraging strategies. Discovered in 2006, High Rise Village is a large, high elevation residential site in the Wind River Range of western Wyoming (Adams 2010a) (Figure 1). The site’s predominantly Late Prehistoric (ca. 2800–250 cal B.P.) occupation, numerous residential features, and subsurface deposit make the site a good candidate for exploring late Holocene foraging strategies (Adams 2010a; Morgan, Losey, and Adams 2012). Further, the site’s alpine/subalpine setting is highly sensitive to climate change (Arno and Hammerly 1984). Environmental variability at the site is thus closely tied to climate variability, and past climate should consequently be a reasonable proxy for resource variability.

Figure 1. High Rise Village location map.
Research Design Summary

With High Rise Village as the case study, this thesis uses the z-score model to explore the relationship between MWP and LIA temporal variability, resource predictability, and Late Prehistoric foraging, mobility, and settlement at the site.

Research Question

How did changes in climate-driven resource predictability and associated foraging risk affect subsistence strategies and site use patterns at High Rise Village during the last millennium?

The z-score model was employed to develop predictions for how foragers would have coped with increasing resource variability and decreasing predictability between the MWP and LIA if they were indeed risk-sensitive. To this end, this study has two components, a paleoenvironmental reconstruction that uses a dendroclimatological dataset to characterize local climate variability and a behavioral reconstruction that uses archaeological datasets to explore its possible effects on foraging strategies and site use patterns.

Paleoenvironmental Reconstruction

Due to the often heterogeneous patterns of climate and its ecological ramifications, it is essential to determine local environmental responses to climate (Dunbar 2000; Mann 2002b; Mayewski et al. 2004; Stenseth et al. 2002). To this end, this study develops a paleoclimate proxy dataset for the site to determine whether
regional patterns of MWP stability and LIA variability hold for High Rise Village. The site’s treeline setting offers the opportunity to sample climate-stressed whitebark pine (*Pinus albicaulis*) and develop a tree-ring chronology that tracks annual climate data at High Rise Village.

To characterize modes of temporal variability at High Rise Village, the whitebark pine chronology is first compared against modern temperature, precipitation, and drought data to determine which of these variables primarily drove modern growth at the site, and thus which climate variable the tree-rings actually monitor (Fritts 1976). This study then uses wavelet analysis to determine dominant modes of climatic temporal variability during the MWP and LIA (Torrence and Compo 1998). Correlations between the chronology and an influential Pacific climate pattern in the region further characterize temporal variability at the site (Graumlich et al. 2003; Gray et al. 2003; Wang et al. 2010). Dominant modes of climatic variability are assumed to be indicative of environmental variability and resource predictability at High Rise Village.

**Behavioral Reconstruction**

The archaeological component relies on the z-score model to predict the response of risk-sensitive foragers to resource variability under MWP and LIA conditions. Using key resources in the High Rise Village catchment, the model predicts the risk-sensitive diet for both climate regimes. For each diet, corresponding archaeological expectations are developed for subsistence remains, mobility and technology requirements, and the frequency of site use during each period. Predictions
are tested at High Rise Village to determine whether risk, climate, and resource variability structured foraging strategies and site use patterns during the late Holocene.

Given high resource predictability, the MWP occupation of High Rise Village is predicted to be based around a diverse diet, as the majority of resources are highly likely to satisfy the required minimum. Macrobotanical samples and groundstone residue analysis from MWP components are expected to demonstrate plant resource use in addition to game, and flaked stone assemblages are expected to be relatively diverse, reflecting varied foraging and hunting activities. Further, the site is expected to be used more frequently during the stable MWP than the more variable LIA.

Conversely, LIA foragers are expected to have frequently avoided the site due to the unpredictability of most resources. Any use is expected to be transient and focused on more secure animal resources. During this period greater mobility and a hunting focus would lead to greater investment in bifacial tools, expected to be reflected in both tool and debitage assemblages. Macrobotanical and groundstone analyses should show minimal plant use as these resources do not guarantee the avoidance of caloric shortfall.

Results Summary

The dendroclimatological study produced an 835-year chronology that tracks annual climate conditions during final two centuries of the MWP and the entire LIA at High Rise Village. The chronology likely tracks both temperature and precipitation at the site, although this cannot be verified beyond the modern instrument record. As
expected, the MWP is primarily characterized by multidecadal modes of variability, indicating long-term environmental stability. Under these conditions, resources would have been predictable and minimally variable at the site. Conversely, the LIA is characterized by interannual variability and resources were likely highly variable and often unpredictable.

In terms of testing the z-score model expectations, this thesis met with varying degrees of success. In particular, crucial dietary expectations remain untested due to poor preservation of residues and macrobotanical remains in the site’s shallow, acidic soils. However, chronometric and flaked stone data indicate a distinct pattern of occupation during the Late Prehistoric at High Rise Village. Projectile points and radiocarbon dates indicate that the site was primarily occupied 1500–600 cal B.P., or roughly during the MWP. During this period, the flaked stone and groundstone assemblages indicate use was residential and based around a diverse diet. Further, the presence of Rosegate projectile points (Thomas 1981) suggests the site was used by Uinta Phase foragers from the river basins surrounding the Wind River Range (1800–900 cal B.P.) (Metcalf 1987; McNees 1992; Thompson and Pastor 1995). A high elevation component is a previously unexplored aspect of the Uinta Phase subsistence and settlement pattern. Use of High Rise Village decreased dramatically after 800 cal B.P.

While the limited success of this study precludes some discussion of risk-sensitive foraging at the site as envisioned under the z-score model, a regional consideration of the High Rise Village data indicate that climate-driven resource predictability partially structured site use during the MWP, the LIA. Chronometric data
demonstrate that site use peaked during the MWP and during a population boom in the region. During this period, High Rise Village offered stable, predictable resources for Uinta Phase foragers seeking foraging opportunities at the peripheries of the crowded Wyoming Basin. Site use then decreased dramatically between 800–600 cal B.P., predating the LIA and thus more likely related to regional population declines (Kornfeld et al. 2010) and improved lowland hunting opportunities (Byers et al. 2005; Smith 2005).

This thesis begins by introducing the reader to High Rise Village, including previous work at the site and its environmental and cultural contexts (Chapter 2). Chapter 3 provides the theoretical framework of this study, further familiarizes the reader with the z-score model, and details its application to High Rise Village. Chapters 4 and 5 present the methods and results for the dendroclimatological and archaeological components of this study respectively. Finally, Chapter 6 reorients the reader to the research question at hand, discusses the success of the study, and considers its contributions to greater regional and disciplinary discussions.
CHAPTER 2

RESEARCH CONTEXT

High Rise Village is well situated for a z-score model case study focused on how foragers may have coped with climate-driven resource variability during the Late Prehistoric in the central Rocky Mountains (1500–250 cal B.P.) (Kornfeld et al. 2010). The site’s residential features, subsurface deposit, and predominantly Late Prehistoric occupation (2800–250 cal B.P.) provide the means to investigate foraging strategies and site use patterns during the Medieval Warm Period (MWP; 1150–550 cal B.P.) and the Little Ice Age (LIA; 550–100 cal B.P.) (Bradley et al. 2001; Grove 2003; Herweijer et al. 2007; Hughes and Diaz 1994a, b; Lamb 1990; Mann 2002a, b). Further, the treeline setting offers the opportunity to implement a dendroclimatological study to characterize environmental variability at the site during the last millennium (Arno and Hammerly 1984; Fritts 1976). This chapter introduces the archaeology and physiographic setting of High Rise Village, followed by discussions of the site’s paleoenvironmental and culture history contexts.

**High Rise Village**

High Rise Village (48FR5891) is on a steep, southeast-facing slope between 3,225 and 3,320 m elevation in the northern Wind River Range. The approximately 440 by 220 m site includes at least 52 rock-ringed and leveled residential house floors associated with a surface assemblage includingdebitage, flaked stone tools, groundstone, and
temporally diagnostic projectile points (Figure 2). The site is well-preserved and includes shallow subsurface deposits within the residential features (Adams 2010a; Morgan, Losey, and Adams 2012). Following original site designations (Adams et al. 2006, 2007, 2008, 2010a), house floors are referred to as “lodges.”

Figure 2. High Rise Village site map with ecological setting and lodge distribution. Reproduced with permission from Morgan, Losey, and Adams (2012).

High Rise Village was discovered and initially recorded in 2006 by Richard Adams of the Office of the Wyoming State Archaeologist and a volunteer crew. The following three years saw extensive site mapping, a surface artifact inventory, and testing or excavation of 17 lodges (Adams 2010a; Morgan, Losey, and Adams 2012). Excavation produced eight radiocarbon dates from six lodges ranging from 4480–130 cal B.P. Table 1 reports all radiocarbon dates from the site, including dates from later work by Utah State University.
Table 1. High Rise Village Radiocarbon Dates Through the 2011 Field Season.

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<tr>
<th>Lab</th>
<th>Lab Code</th>
<th>Sample ID</th>
<th>Lodge</th>
<th>Context</th>
<th>$^{14}$C Age</th>
<th>cal B.C./cal A.D.</th>
<th>Cal B.P. (1-Sigma)$^a$</th>
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<tr>
<td>Beta</td>
<td>269156</td>
<td>FR5891 LODGE CC-2</td>
<td>CC</td>
<td>Sherd residue</td>
<td>130 ± 40</td>
<td>1810 ± 101 cal A.D.</td>
<td>160 ± 100</td>
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<tr>
<td>Beta</td>
<td>248565</td>
<td>FR5891 LODGE CC-2</td>
<td>CC</td>
<td>Structural timber</td>
<td>420 ± 50</td>
<td>1514 ± 74 cal A.D.</td>
<td>450 ± 80</td>
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<tr>
<td>Beta</td>
<td>245981</td>
<td>FR5891 LODGE S</td>
<td>S</td>
<td>Hearth</td>
<td>840 ± 40</td>
<td>1193 ± 39 cal A.D.</td>
<td>770 ± 50</td>
</tr>
<tr>
<td>Beta</td>
<td>290219</td>
<td>FR5891 LODGE D</td>
<td>D</td>
<td>Lodge fill</td>
<td>1070 ± 30</td>
<td>955 ± 42 cal A.D.</td>
<td>1000 ± 40</td>
</tr>
<tr>
<td>CAIS$^c$</td>
<td>8382</td>
<td>L26-EU2-FS2.7</td>
<td>26</td>
<td>Hearth</td>
<td>1210 ± 25</td>
<td>816 ± 41 cal A.D.</td>
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</tr>
<tr>
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<td>584 ± 23 cal A.D.</td>
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<tr>
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<td>484 ± 47 cal A.D.</td>
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<tr>
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<td>LSS-EU3-FS14</td>
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<td>SS</td>
<td>Lodge fill</td>
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<td>861 ± 35 cal B.C.</td>
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<td>Hearth</td>
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<tr>
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</tr>
<tr>
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<td>Lodge fill</td>
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<td>2528 ± 40 cal B.C.</td>
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<td>HRV 16.1.3-011</td>
<td>16</td>
<td>Charcoal smear</td>
<td>4010 ± 25</td>
<td>2530 ± 33 cal B.C.</td>
<td>4480 ± 40</td>
</tr>
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</table>

$^a$All dates calibrated using CalPal 2007 (Weninger et al. 2007) and the HULU calibration dataset (Weninger and Jöris 2008).

$^b$Beta Analytic, Inc., uncalibrated dates reported in (Adams 2010a)

$^c$University of Georgia Center for Applied Isotope Studies, reported in Morgan, Losey, and Adams (2012)
Temporally diagnostic projectile points also help date the site. Surface projectile points included five Archaic points and 23 Late Prehistoric points. Subsurface projectile points and ceramics from lodges were all Late Prehistoric, including Rose Spring points, other corner-notched points, Desert Side-notched, Tri-notched, and Cottonwood Triangular points. Rose Spring and corner-notched points date from approximately 1500–900 cal B.P. on the Plains (Kornfeld et al. 2010), 1500–600 cal B.P. in the mountains (Larson and Kornfeld 1994) and 1800–900 cal B.P. in the basins of southwestern Wyoming (McNees 1992; Thompson and Pastor 1995). Rose Spring points are referred to as Rosegate points here to acknowledge their overlap with Eastgate points (Justice 2002; Thomas 1981). Desert Side-notched, Tri-notched, and Cottonwood Triangular points date from 900–250 cal B.P. in the Plains and basins (Kornfeld et al. 2010; McNees 1992; Thompson and Pastor 1995), 600–250 cal B.P. in the mountains (Larson and Kornfeld 1994).

Koenig (2010) undertook an intralodge spatial analysis of artifact distributions relative to the hearth in Lodge S and determined that the lodges likely had aboveground superstructures. Koenig further pointed out that the investment involved in constructing lodges suggests the intent to reuse the site at a future date.

Based on several field seasons at the site and many more in the region, Adams (2007, 2008, 2010a) offered a model of subsistence and settlement for High Rise Village and five small but similar sites in the area. Under Adams’ model, these sites represent summer aggregations of families following resources upslope during the spring through fall when lowland productivity decreased, upland plant resources were in season, and
game species migrated upslope. High Rise Village was situated to take advantage of late spring/early summer root resources, late summer/fall pine nuts, and bighorn sheep (*Ovis canadensis*), which inhabit the area spring through fall (Thorne 1979). Adams argues that these resources were seasonally abundant, predictable, could be processed for storage, and were likely critical for overwintering at lowland camps. It is worth noting that Adams considers this pattern to have persisted during the last 4,500 years, and thus considers it to operate independent of climate.

In 2010, Christopher Morgan and Kenneth Cannon of Utah State University (USU) continued excavation of the site at the invitation of Adams. The 2010 USU Archaeological Field School excavated Lodges 22, 26, 49, SS, and W (Figure 2; data and methods reported in (Morgan 2011; Morgan, Losey, and Adams 2012). Excavation recovered groundstone, flaked stone tools and debitage, and radiocarbon samples from all five lodges.

Radiocarbon dates were consistent with previous dates (Table 1) and projectile points corresponded with Adams’ primarily Late Prehistoric assemblage. The excavation recovered thirteen corner-notched points, including seven Rosegates and two likely Rosegates. The remaining points compare favorably with Late Prehistoric corner-notched points typical of the area, particularly with Rosegate and other corner-notched points from Mummy Cave (Husted and Edgar 2002).

However, due to the difficulty in distinguishing some corner-notched and Rosegate points from Elko points (3500–1300 cal B.P.; Heizer and Baumhoff 1961; Justice 2002; Thomas 1981) or the very similar Pelican Lake points (approximately 3100–
1500 cal B.P.; Frison and Walker 2007; Kornfeld et al. 2010; Wettlaufer 1955), the possibility must be acknowledged that some points may be Archaic types and correspond with earlier radiocarbon dates at the site, specifically those from 2800–1500 cal B.P. (Table 1).

Lodge 16 was excavated in 2011, by a USU crew focused specifically on the thesis research reported here. The lodge produced flaked stone tools and debitage, groundstone, radiocarbon samples (Table 1), and four projectile points (Morgan, Losey, and Adams 2012). The projectile points were two corner-notched points, one side-notched, and one triangular point, all likely Late Prehistoric (see discussion in Chapter 5). However, a radiocarbon sample from the lodge dated to 4480 ± 40 cal B.P., an age similar to that found at Lodge 49 but inconsistent with the projectile points found in Lodge 16. Also during the 2011 field season, flotation samples were collected from the six lodges excavated in 2010 and 2011.

Physiographic Setting

The Wind River Range is a northwest/southeast trending range in the central Rocky Mountains, bounded by the Green River Basin to the west and the Wind River Basin to the east. The range rises abruptly from an elevation of approximately 2,000 m in the surrounding basins to over 4,200 m. The Wind River Range lies at the confluence of two North American climate patterns, the dry summer/wet winter of the Pacific Northwest and the wet summer/dry winter of the Southwest and Great Plains (Fall et al. 1995). Because of this, there is as much precipitation in the summer as during the winter (Fall et al. 1995), with a modern average annual total of 130–150 cm in the subalpine zone (Dunwiddie 1977). The same zone has a modern mean July temperature of 9.6˚C and a mean January temperature of -15.1˚C (Dunwiddie 1977).

The dry basins bounding the range are a sagebrush steppe zone dominated by big sagebrush (*Artemesia tridentata*) with Utah juniper (*Juniperus osteosperma*) and limber pine (*Pinus flexilis*) common among rocky outcrops (Reed 1976). The mountain forest belt is primarily coniferous, though aspen (*Populus tremuloides*) are locally common at lower elevations (Reed 1971). Lodgepole pine (*Pinus contorta*) dominates between 2,600 and 2,900 m elevation, with infrequent Douglas fir (Pseudotsuga menziesii) and limber pine (Reed 1976). Above 2,900 m is a subalpine mixed conifer forest made up of whitebark pine, limber pine, lodgepole pine, subalpine fir (*Abies lasiocarpa*), and Engelmann spruce (*Picea engelmannii*) (Reed 1976), interspersed with treeless “parks” of sagebrush (*Artemesia spp.*) (Lynch 1998). Whitebark pine is more dominant near treeline and occasionally forms near-homogenous stands (Owens et al. 1995).
Treeline is typically limited to a maximum elevation of 3,100 m, sometimes with krummholz whitebark pine and Engelmann spruce extending to 3,200 m. Above treeline is alpine tundra composed of hardy grasses, sedges, forbs and low, woody shrubs (Reed 1976).

High Rise Village straddles the modern alpine-subalpine ecotone with approximately three-quarters of the site within a whitebark pine (Pinus albicaulis) dominated stand of subalpine forest and one quarter above in alpine tundra (Figure 2). Water is available on site from a perennial spring as well as seasonal seeps and springs fed by snow accumulated and slowly released by a remnant rock glacier upslope of the site.

The primary game species available at High Rise Village include both seasonal migrants and nonmigratory species (Reed 1976). Migratory species include bighorn sheep, elk (Cervus elephas), mule deer (Odocoileus hemionus), moose (Alces alces), white-tailed ptarmigan (Lagopus leucura), and bear (Ursus americanus and Ursus arctos). The site is adjacent to a well-used bighorn sheep migration corridor and summer range (Thorne 1979). Marmots (Marmota flaviventris) are common and remain in the area year-round. Other nonmigratory animals include pika (Ochotona princeps), red squirrel (Tamiasciurus hudsonicus), and cutthroat trout (Oncorhynchus clarkii).

Plant resources at High Rise Village include whitebark pine nuts and geophytes as well as seeds and berries. Whitebark pine cones take two years to mature and come into season in late summer and fall; large crops are produced at irregular intervals (every four to eight years) with smaller crops and crop failures in between (Arno and
Hoff 1989; Tomback et al. 2001). In addition to pine nuts, there are several species of geophyte available in the meadows below the site and the alpine tundra above, including biscuitroot (*Cymenopterus* spp. and *Lomatium* spp.), sego lily (*Calochortus* spp.), and yampah (*Perideridia gairdneri*) (Adams 2010a). Also available are various species of chenopods (*Chenopodium* spp.), wild sunflower (*Helianthus annus*), and currants (*Ribes* spp.), a common understory component (Reed 1976).

**Paleoenvironmental Context**

There is relatively little paleoenvironmental work from the Wind River Range that considers late Holocene climate and environment, particularly at high elevations. Those few studies are discussed here, as well as a summary of Holocene climate from the greater region. Particular attention is paid to the MWP and LIA and temporal variability therein. All dates are given as calendar years before present unless otherwise noted.

The Early Holocene, 10,000–7500 B.P., saw the beginning of a warming and drying trend after the cool, wet Late Pleistocene (Davis et al. 2003; Fall et al. 1995; Zielinski and Davis 1987), though conditions varied across the region. Dune deposits from the Wyoming Basin indicate both dune activity due to a drying trend (Ahlbrandt et al. 1983) and stability due to a continuation of wetter conditions (Eckerle 1997). And, while many pollen studies indicate increasingly warm and dry conditions (e.g. Fall et al. 1995; Whitlock 1993), packrat (*Neotoma* spp.) midden data from the Bighorn Basin
(Lyford et al. 2002) and pollen from the northern Uinta Mountains (Munroe 2003) indicate cooler conditions persisted in some areas.

During the Middle Holocene, approximately 7500–4500 B.P., average temperatures rose and aridity increased, though Whitlock and Bartlein (1993) note the considerable variability in the timing and nature of aridity in the region. In the Wind River Range, Abies retreated while more dry-tolerant Picea persisted at higher elevations (Fall et al. 1995). In the Pryor Mountains, lower treeline was particularly high and Atriplex macrofossils were abundant in packrat middens (Lyford et al. 2003). The Wyoming Basin saw widespread dune activity (Eckerle 1997) as well as the expansion of drought-tolerant Utah juniper (Juniperus osteosperma) into the area (Jackson et al. 2002; Lyford et al. 2002). Yellowstone plant communities also became more xeric (Baker 1976; Whitlock and Bartlein 1993).

After 4500 B.P., conditions became wetter and cooler again. Treeline in the Wind River Range retreated (Fall et al. 1995), a trend observed across most of the North American interior (e.g., Mensing et al. 2012; Rochefort et al. 1994). During this period, the range also saw a resurgence of cirque glaciers, a further indication of cooling and an increase in precipitation (Dahms 2002). In the greater region, lower treeline in the Pryor Mountains expanded downslope as water availability increased (Lyford et al. 2002). Yellowstone pollen records indicate a more mesic assemblage of species (Baker 1976; Beiswenger 1991; Whitlock 1993) and studies in the southwestern Wyoming basins indicate that dunes stabilized (Eckerle 1997) and Utah juniper expansions halted (Lyford et al. 2002).
Beginning around 1800 B.P., dry conditions returned. Dunes were active again (Ahlbrandt et al. 1983) and glaciers retreated or disappeared (Davis 1988). Warm and increasingly drier conditions persisted through the MWP, 1150–550 yr B.P. (Bradley et al. 2001; Herweijer et al. 2007; Hughes and Diaz 1994a, b; Lamb 1990; Mann 2002a). Dunes remained active throughout this period without the necessary moisture to encourage plant colonization and subsequent stabilization (Ahlbrandt et al. 1983). Pollen cores from the region (Harding and Lowe 1998; Plager and Holmer 2004), small mammal remains from Yellowstone (Hadley 1996), and plant macrofossils from the Bighorn Basin (Lyford et al. 2002) all indicate more arid environments. Glacial retreat (Benedict 1985) and increased forest fire frequencies (Whitlock et al. 2003) across the region also indicate persistent warm, dry conditions. Tree-ring data indicate periods of drought in Wyoming and across the West during the MWP, including multidecadal “megadroughts” (Cook et al. 2004; Cook et al. 2010; Gray et al. 2004; Herweijer et al. 2007). Upper treelines across the continent ascended or stabilized with warmer alpine growing seasons (Luckman and Kearney 1986; LaMarche 1973; LaMarche et al. 1974; Lloyd and Graumlich 1997; Luckman 1993; Mensing et al. 2012; Scuderi 1987), though it is unknown whether this was the case in the Wind River Range.

The LIA, approximately 550–100 B.P. (Bradley and Jones 1992; Grove 2003; Lamb 1990; Mann 2002b), brought cooler, and sometimes wetter, conditions to the region (Schuster et al. 2000; Whitlock et al. 2002). Cooling and changes in precipitation were highly variable across the region (Whitlock et al. 2002), though it seems that alpine zones consistently experienced summer cooling (Brunstein 1996). Persistently low
summer temperatures made the already short alpine growing season more difficult for both animal and plant communities (Arno and Hammerly 1984). Throughout much of the Rockies, there was renewed glacial advance, including in the Wind River Range (Davies 2011; Richmond 1986; Schuster et al. 2000) and treelines across much of western North America reached their lowest elevations since the Pleistocene (Kearney 1982; LaMarche 1973; LaMarche and Stockton 1974; Lloyd and Graumlich 1997; Luckman 1993; Scuderi 1987). More mesic-adapted species again typify small mammal assemblages from Yellowstone (Hadley 1996), though a region-wide megadrought occurred early in the LIA (Cook et al. 2004; Cook et al. 2010; Gray et al. 2004; Herweijer et al. 2007). Frost rings in bristlecone pines (*Pinus aristata*) in Colorado and historical records from the Plains and Utah suggest that winters were quite severe during at least the latter portion of this period (Brunstein 1996).

*Climate variability during the last millennium*

Climate variability, particularly temporal variability, can have a considerable impact on how climate affects the environment (Dunbar 2000). How a species or an ecosystem fares under different climate regimes and adjusts to climate change can depend largely on whether variability occurs on an annual, decadal, or longer timescales (Hadley 1996; Inouye et al. 2000; Smith et al. 1998). Because this study is interested in resource variability as related to climate temporal variability, a discussion follows of differences in dominant variability patterns during the MWP and LIA.
In North America, the MWP is generally characterized by multidecadal variability (Cook et al. 2004; Cook et al. 2010; Hughes and Diaz 1994a, b; Kobashi et al. 2010). Cycling in precipitation and drought in the American West typically occurred over 30–70 years (Gray et al. 2003; Gray et al. 2004; Herweijer et al. 2007), and there are indications of centennial cycles as well (Gray et al. 2003; Herweijer et al. 2007; Wang et al. 2010). Conversely, the LIA is characterized by more frequent and rapid change (Dean et al. 1985; Kobashi et al. 2010; Mann 2002b). This period lacks the persistent, multidecadal patterns of the MWP (Gray et al. 2003; Herweijer et al. 2007) and it has been noted that unstable decadal or shorter periodicities are more common in cold background climates (Kobashi et al. 2010; Mann 2002b). Ice cores from the North American arctic further indicate that frequent change is more common during the LIA (Kobashi et al. 2010).

Reconstruction of environmental variability for the Colorado Plateaus by Dean et al. (1985) is particularly helpful in illustrating the differences in variability between the MWP and the LIA. The authors differentiate between low frequency variability (> 25 years) and high frequency variability (< 25 years) and combine stratigraphic, palynological, and tree-ring data sets to model climate across the region. During the latter two-thirds of the MWP, high frequency change dominants for 50 of 400 years, or 12.5 percent. During the LIA, it accounts for 230 of 400 years, or 57.5 percent.

Studies from the Wind River Range and the region show similar MWP and LIA patterns to the continental patterns discussed above. The MWP was characterized by warm, dry conditions (Fall et al. 1995; Gray et al. 2004; Watson et al. 2009) and climate patterns were often persistent, including multidecadal cycling (Gray et al. 2003). The
LIA is more complex and prone to much more rapid change. While Davies (2011) suggests that the onset of LIA conditions was not rapid in the Wind River Range, Naftz et al. (1996) and Schuster et al. (2000) determined that the transition from LIA to modern climate conditions occurred in as little time as a decade. Watson et al. (2009) found that interannual and decadal variability were prominent in tree-ring reconstructions for the last 400 years in the upper Wind River drainage. This included variability within a persistent drought, indicating that longer climate patterns during the LIA were not necessarily stable. Gray et al. (2003) also found much the same patterns in the adjacent Bighorn Basin.

There are distinct differences in temperature, precipitation, and temporal variability between the MWP and LIA in western Wyoming. The MWP was warm, dry, and characterized by multidecadal variability. In contrast, the LIA is a cool, often wetter period of interannual and decadal change. These contrasting characteristics and their effects on key food resources at High Rise Village form the basis of the High Rise Village z-score model (Chapter 3).

Culture History

For the archaeology of the Wind River Range, there are three relevant culture histories: Frison’s (1991; Kornfeld et al. 2010) Northwestern Plains chronology, the Wyoming Basin chronology developed by (Metcalf 1987) and others (e.g., McNees 1992, 1999; Thompson and Pastor 1995), and a collection of foothill–mountain adaptations discussed by Frison (1991, 1992, 1997), Larson (1990, 1997), and others (e.g., Bender
and Wright 1988; Husted 1974; Kornfeld et al. 2010; Metcalf and MacDonald 2012).

While these culture histories refer to distinct environments, this is not to say that people did not use more than one of these environmental types; there is evidence they did (e.g., Kornfeld et al. 2010; McNees 1999; Smith 2005). However, relationships between the three are not well understood (Smith 2005) and they are typically discussed separately. The culture histories are summarized in Figure 3.

High Rise Village is also relatively unique in that it is a large alpine/subalpine habitation site, rather than the more typical short-term camp or hunting-related site (Benedict 1992; Canaday 1997; Frison 1991; Kornfeld et al. 2010). To this end, the high-elevation archaeological context of the site is discussed as well, particularly the Rocky Mountains context as well as high-elevation habitation sites from the Great Basin and California. Dates are in calendar years before present unless otherwise noted.

*Paleoindian Period*

The Paleoindian Period, 14,000–8500 B.P. on the Plains (Kornfeld et al. 2010) and 14,000–9500 B.P. in the Wyoming Basin (McNees 1992; Smith 2005), is characterized by a highly specialized, large game-based economy (Kornfeld et al. 2010; Metcalf and MacDonald 2012). The period is subdivided into a series of complexes defined by their distinct projectile points. The first unequivocal use of the area is by Clovis peoples followed by increasing variety in projectile points. Some complexes appear sequential, others overlap in time and/or space and the relationships between them are poorly understood (Kornfeld et al. 2010).
<table>
<thead>
<tr>
<th>Years B.P.</th>
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<th>Phases</th>
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Figure 3. Summary of the Northwest Plains, Wyoming Basin, and Foothill–Mountain culture histories. Dashed horizontal lines are indistinct boundaries between time periods, and question marks indicate unknown but assumed boundaries.
Frison (1992, 1997) argues that as early as 11,500 B.P. an “ecological boundary” separates the classic Plains Paleoindians from a foothill–mountain adaptation, due to the disparate requirements of living in such different environments. The foothill–mountain adaptation represents an early manifestation of a more gathering-focused economy relative to the surrounding Plains and basins (Frison 1992, 1997; Husted 1974; Kornfeld et al. 2010; Metcalf and MacDonald 2012). As proposed by Frison, the foothill–mountain peoples were residentially mobile foragers who followed resources to progressively higher elevations spring through fall and overwintered in the foothills.

**Archaic Period**

The Archaic Period, 8500–1500 B.P. on the Plains and 9500–1800 B.P. in the Wyoming Basin, is primarily defined by the shift to a more diverse diet and an increase in sites. However, the nature and timing of these changes is complex. Because the three culture histories diverge during the Archaic, this section will first discuss Plains and foothill–mountain chronologies followed by the Wyoming Basin sequence.

**Plains and Mountains.** Frison’s (1991; Kornfeld et al. 2010) chronology divides the Archaic into three periods, the Early, Middle, and Late Plains Archaic. All are defined largely by projectile point types and, to a lesser extent, subsistence strategies. The Early Plains Archaic (8500–5000 B.P.) is defined by the shift from stemmed and lanceolate points of the Late Paleoindian complexes to side-notched points. Stratified open sites and cave deposits indicate a more diverse diet compared to earlier times, though large game hunting remains prominent (Bliss 1950; Husted and Edgar 2002; Kornfeld et al.
Larson (1990, 1997) contends that a mountain adaptation similar to that described by Frison (1992, 1997) persists in some areas of western Wyoming.

The Middle Plains Archaic (5000–3000 B.P.) is primarily defined by McKean points. The period sees a further increase in sites and a greater reliance on plant resources (Kornfeld et al. 2010). There are few known bison kills from this period, but many show intensive processing (Kornfeld et al. 2010). Mountain sites also tend to have McKean points as well as other nondescript dart points (Kornfeld et al. 2010; McNees 2006). Bender and Wright (1988) argue for broad diets in the mountains and seasonal use of high elevation environments around Jackson Hole.

The Late Plains Archaic (3000–1500 B.P.) brings an increase in organized, communal bison (*Bison bison*) kills associated with Yonkee, Pelican Lake, and Besant projectile points. Many sites point to late fall hunting and little is known about subsistence during the rest of the year (Kornfeld et al. 2010). However, basketry and digging sticks found at Spring Creek Cave (Frison 1965) and Daugherty Cave (Frison 1968) indicate a more diverse diet than the bison record suggests. Broad diets and Plains points as well as nondescript, corner-notched dart points characterize mountains sites during this period (Bender and Wright 1988; Kornfeld et al. 2010; McNees 2006).

**Wyoming Basin.** Metcalf (1987) western Wyoming Basin Archaic Period is broken into the Early and Late periods. The Early Archaic, 8500–3700 B.P., is further split into two phases. The Great Divide Phase, spanning 8500–6000 B.P., is characterized by a reliance on small game and plant resources and marks a relatively rapid transition to an Archaic lifestyle in the region (Smith 2005). Sites are typically
short term camps indicative of small, highly mobile groups. This is followed by the Opal Phase, 6000–3700 B.P., believed to be a local, basin-centric adaptation. The phase is characterized by repeated use of habitation sites, heavy focus on plant resources, especially roots, and the use of slab-lined and unlined basins for storage and roasting (Francis 2000; Smith 2005; Smith and McNees 2011).

The Late Archaic Period, 3700–1800 B.P., is also divided into two phases: the Pine Spring Phase, 3700–2900 B.P., and the Deadman Wash Phase, 2900–1800 B.P. The Late Archaic is characterized by increased reliance on big game and decreased use of plant resources (Lubinski 2000; McKern 1987; Smith 2005; Smith and McNees 2011). The Pine Spring Phase sites tend to be small, short-term camps with a hunting focus and little evidence of plant processing. McKean and other projectile points indicate the area was primarily used by outside groups. The Deadman Wash Phase marks the transition from predominantly McKean points to corner-notched styles and continued sporadic use of the region by outside peoples hunting big game.

Late Prehistoric Period

Plains. The Late Prehistoric begins with the wide adoption of the bow and arrow and a shift to side- and corner-notched arrow points (Kornfeld et al. 2010). On the Plains, the Late Prehistoric, 1500–250 B.P., is first defined by the corner-notched Avonlea complex, later replaced by various side-notched, tri-notched, and triangular points by approximately 900 B.P. The period is best known for its “sophisticated” communal bison kills. However, large, slab-lined basins with evidence of bone greasing
(Kornfeld et al. 2010), small game remains (Kornfeld et al. 2001; Frison and Walker 2007), and groundstone indicate a relatively broad diet (Kornfeld et al. 2001; Kornfeld et al. 2010).

**Foothill–Mountain.** Foothill–mountain groups during this period use corner-notched points often distinct from Plains styles (McNees 2006; Scheiber and Finley 2010). After 600 B.P., Desert Side-notched, Cottonwood Triangular, and Tri-notched points replace corner-notched varieties (Larson and Kornfeld 1994; Scheiber and Finley 2010; Thomas 1981). Also characteristic of Late Prehistoric mountain sites are sheep traps, Intermountain pottery, and soapstone bowls, all thought to be evidence of Shoshonean peoples in the area (Adams 2010a; Frison 1991; Frison and Wilson 1975; Kornfeld et al. 2010). Faunal remains from Mummy Cave and other sites in the region indicate that diets were broad but based around sheep (Husted and Edgar 2002; Loendorf and Stone 2006). Adams (2010a) argues for broad diets and season driven elevational mobility, similar to mountain adaptations discussed for previous time periods. Based on a region-wide obsidian study, Scheiber and Finley (2011a) demonstrate that social networks and/or travel circuits were quite broad during the Late Prehistoric. This pattern appears to persist until the arrival of the horse when there is an abrupt change in mobility patterns, a breakdown of traditional networks, and people begin to rely on local obsidian sources.

**Wyoming Basin.** In the Wyoming Basin, the Late Prehistoric Period, 1800–250 B.P., is divided into the Uinta Phase from 1800–900 B.P. and the Firehole Phase from 1000–250 B.P. The Uinta Phase is characterized by Rosegate points (typically referred to
as Rose Springs) and a return to a basin-centric adaptation similar to the Opal Phase, including house pits, large basin features, and greater reliance on small game and plant resources. Some residential sites are repeatedly reused throughout the period, particularly those with access to predictable resources. Uinta Phase subsistence appears to be focused on small seeds, though roots continue to play an important role (Smith 2005; Smith et al. 2001).

Between 1000–900 B.P. there is a dramatic decline in Uinta Phase sites and the beginning of the Firehole Phase. Rosegate points are replaced by Desert Side-notched, Tri-notched and Cottonwood Triangular points and ceramics become more common (McKern 1987; Metcalf and MacDonald 2012; Smith 2005). Subsistence focus shifted to big game, especially bison, with minimal evidence of plant procurement and processing (Lubinski 2000; Smith 2005). The return to hunting is thought to be linked to climate conditions favoring grasses and an abundance of large game (Byers et al. 2005). The Firehole Phase ended when the introduction of European trade goods, horses, and firearms reorganized local lifeways.

Most of the Shoshone of the region were relocated to the Wind River Reservation in A.D. 1868 (Shimkin 1986). By this time there were distinct differences between Shoshone groups in the area, as noted by early explorers and later ethnographers (Hultkrantz 1961; Loendorf and Stone 2006; Nabokov and Loendorf 2004; Shimkin 1986). The Mountain Shoshone, or Sheepeaters, lived in small, mobile groups in the mountains of western Wyoming and specialized in sheep hunting. They lived in distinct log structures, used steatite vessels, interacted cautiously and
infrequently with Euro-Americans, and often shunned their trade goods and horses (Hultkrantz 1961; Scheiber and Finley 2010, 2011a; Shimkin 1986). Conversely, the Plains, Eastern, or Wind River Shoshone were horse mounted bison hunters. They were highly mobile and ranged widely in the basins and on the Plains. Unlike their mountain counterparts, they actively engaged with explorers and settlers. It is unknown how far into the past these differences in lifeways extend, especially to what extent there was a distinct mountain group before the arrival of the horse (Scheiber and Finley 2011a). Some argue for their existence for at least a millennium, if not several (Francis and Loendorf 2004; Husted 1995; Husted and Edgar 2002; Loendorf and Stone 2006) while others argue that their arrival is a more recent manifestation (Wright 1978).

Closely tied to the discussion above is the regional debate as to when the Shoshone became a presence in prehistoric Wyoming, and whether they were migrants into the area or an indigenous manifestation (Larson and Kornfeld 1994). Given the ethnographic record and similarities with Great Basin peoples, the Shoshone in Wyoming are often associated with a series of Late Prehistoric artifacts, log structures and rock art motifs (Adams 2010a; Francis and Loendorf 2004; Kornfeld et al. 2010; Larson and Kornfeld 1994). Because of these associations, some argue for population movements from the Great Basin over the last 1,000 to 2,000 years (Larson and Kornfeld 1994; Loendorf and Stone 2006).

This timing is consistent with much of the research and discussion of the origins of the distributions of the Great Basin Numic language speakers (e.g., Bettinger and Baumhoff 1982; Hill 2001; Kaestle and Smith 2001; Madsen and Rhode 1994; Simms
2008; Sutton 1986; Sutton and Rhode 1994; Thomas 1994). As early as the 1930’s, archaeologists recognized a distinct change in settlement and subsistence strategies in the Great Basin and its peripheries between 500 and 1500 years ago, perhaps related to the expansion into the area by the Numic speakers (e.g., Madsen 1994; Steward 1937, 1940). Lamb’s (1958) glottochronological date for the Numic expansion was later used to corroborate these same findings. Relying on previous work on the classification and distribution of Numic languages by Kroeber (1925) and others, Lamb (1958) argued that Numic language speakers spread to their historic distributions from the southwestern Great Basin beginning at least 1,000 years ago. Subsequent research has broadened to include several millennia of prehistory and much of the American West (e.g., Hill 2001; Simms 1994, 2008). However, some Wyoming archaeologists argue for deeper, indigenous origins of the Wyoming Shoshone (Holmer 1990; Husted and Edgar 2002), while still others argue for a presence of less than 500 years (Hultkrantz 1987; Wright 1978, 1984).

**High-Elevation Context**

*Rocky Mountains.* The preceding culture histories were primarily constructed from Plains and Wyoming Basin sites (Smith 2005) the role of alpine and subalpine environments in prehistoric landscape use patterns remains less well understood than their lowland counterparts. Further, what little is known about mountain lifeways was “developed primarily on the basis of snapshots provided by individual components or sets of distinctive interrelated or contemporaneous components at sites in the foothill–
mountain zone” (McNees 2006:70). Further, the majority these “snapshots” come from a mere handful of stratified sites, such as the Lookingbill site (Kornfeld et al. 2001), Medicine Creek Lodge (Frison and Walker 2007; Kornfeld et al. 2010), and Mummy Cave (Husted and Edgar 2002; McCracken 1978).

Nonetheless, Black (1991), Bender and Wright (1988; Wright et al. 1980), and Benedict (1992) have proposed models of mountain settlement and subsistence, all largely based on Binford's (1980) forager-collector model and associated thinking about the causes of and constraints upon residential vs. logistical mobility. Residential mobility entails movement by an entire residential group from one resource patch to another as the patch immediate to camp is exploited and depleted. Logistical mobility entails individuals and small groups making planned forays to specific, sometimes distant, patches to obtain, oftentimes process, and then bring resources back to a residential base.

Black (1991) “Mountain Tradition” describes the use of seasonally productive upland environments throughout at least the Late Paleoindian and Early Archaic periods in the Rocky Mountains. The Mountain Tradition is an elevational seasonal round that began in the foothills in spring, followed plant resource maturation and game migrations upslope through the early fall, and retreated to the foothills for the winter. Mobility patterns included both residential and logistical organization. Many spring and summer activities were organized logistically around base camps located in large mountain valleys and with short-term camps and activity stations throughout the surrounding elevational zones. High elevation environments were used both
residentially and logistically, though residential use was short-term. In many parts of the Rockies, Black argues this pattern persists through at least the Archaic. Frison (1992, 1997), Larson (1990, 1997), and Adams (2010a) discuss very similar patterns in western Wyoming, as does Benedict (1992) for Colorado’s Front Range.

Bender and Wright (1988; Wright et al. 1980) propose a similar pattern for the Jackson Hole area of Wyoming. The authors describe a seasonal succession of occupations by family units targeting increasingly higher elevation resources spring through fall and overwintering in the foothills. The occupation of each elevational zone was centered around a base camp, from which task specific groups procured a wide variety of resources from throughout the zone. This pattern began between 3,000 and 4,000 years ago and persisted through the Late Prehistoric.

The third high-elevation use model comes from Benedict (1992), who describes a Late Prehistoric seasonal “circuit,” encompassing much of north-central Colorado and a portion of southern Wyoming. Again, organization is primarily logistical. In spring, foragers dispersed from overwintering sites in the foothills east of the Front Range. They split into small, likely residentially organized groups and headed north into the Laramie Basin of southern Wyoming, taking advantage of lowland spring resources while higher elevations were still inaccessible. In early summer, people traveled south into the mountains to North Park on the west side of the Front Range as mountain resources came into season and game migrated upslope. As summer progressed, people followed resources south into Middle Park and closer to the crest of the Front Range. Late summer and early fall saw increasingly larger aggregations of people in Middle Park and
logistical foraging up into the alpine zone, primarily for individual and communal hunting. By October, people descended and dispersed to winter residential camps east of the Front Range.

Many questions remain as to how sites in the upland environments of western Wyoming were used, how they relate to lowland components, and how these relationships vary by region and through time. However, this is slowly changing and the high places of western Wyoming are being increasingly studied. In particular, work in the Wind River Range (e.g., Adams 2007, 2008, 2010a) and the Absaroka Mountains (e.g., Eakin 2005; Scheiber and Finley 2010, 2011a, b) is illuminating the prehistoric and postcontact use of these environments. Adams (2010a) extends ideas from Black's (1991) Mountain Tradition and Frison's (1992, 1997) Foothill–Mountain adaptation to the Late Archaic and Late Prehistoric in the Wind River Range. Eakin (2005) and Finley and Finley (2004) explore the florescence of Late Prehistoric and early Historic sheep trapping and upland environment use patterns at Boulder Ridge in the Absaroka Mountains. Scheiber and Finley (2010) offer further discussion of the Boulder Ridge sites in terms of changes in technology, mobility, and social relationships related to contact with Euro-American goods and settlers. Scheiber and Finley (2011a, b) consider these same topics across the region in terms of obsidian sources, ceramic sources, and mobility.

*Great Basin and California.* Beyond regional discussions, High Rise Village is also one of several unique, large alpine residential sites in North America, including Alta Toquima in the Toquima Range of central Nevada (Thomas 1982, 1994) and sites in the
White Mountains of eastern California (Bettinger 1991b). Because of the predominance of hunting sites in the mountains of the American West (Benedict 1992; Canaday 1997; Frison 1991; Kornfeld et al. 2010), these sites stand out because they yield evidence for residential occupation for what may be entire seasons of use and a wide range of activities. They consequently offer insight into human behavior in these environments and a different perspective on the prehistoric use of high-elevation areas.

Alta Toquima consists of 28 rock-ringed, stacked stone residential structures and rich subsurface deposits, including abundant groundstone and ceramics indicative of extensive plant food processing (Thomas 1982, 1994). Radiocarbon dates indicate the structures were used from perhaps as early as nearly 1,900 years ago through to the very late Late Prehistoric; the majority of dates are approximately 1100–900 B.P.

Bettinger (1991a) work in the White Mountains revealed 13 residential sites, all with at least one rock-ringed residential structure and groundstone. The vast majority of the radiocarbon dates for the sites indicate most occupation occurred within the last 900 years, and particularly the last 500 years. The diet at the sites was quite diverse including small mammals, such as marmots (Grayson 1991), and many plant resources (Scharf 2009). Unexpectedly, many of the plant resources were lower-elevation species transported to the site (Scharf 2009).

Bettinger (1991a) argues these high elevation sites were established due to population pressure and resource shortages in the lowlands related to the spread and growth of groups speaking Numic languages. To explain this, Bettinger uses the traveler-processor model (Bettinger and Baumhoff 1982), whereby Numic language
speaking peoples with a high-cost, plant intensive diet were able to support larger populations and outcompeted the previous inhabitants who relied on a low-cost diet focused on large game. Subsequent growth in the Numic populations and the associated resource reductions in the lowlands eventually made the cost of living and foraging at the alpine villages comparable to the lowlands, and thus acceptable.

However, Grayson (1991; Broughton and Grayson 1993) and Scharf (2009) found little evidence of the increase in diet diversity expected under the traveler-processor model. Grayson (1991) suggested that the alpine villages may have been the result of an intensification of preexisting high elevation strategies driven by population growth, but not population competition and replacement. Similarly, Rhode and Madsen (1994) point out that there is little evidence of prolonged interaction between Numic-speaking groups and the previous inhabitants of the region, as would be expected for competition and eventual replacement. Canaday's (1997) extensive survey of five Great Basin mountain ranges also found little evidence that population pressure or replacement were sufficient to explain these high elevation sites. Hildebrandt (2013) further suggests that environmental structure and productivity at mid- and lower-elevations and ease of access to alpine environments decreased the costs of subsidizing high elevation villages with lower elevation resources in some places, such the Toquima Range. These locations were more profitable and sustained villages during the Late Prehistoric, while ranges lacking these features did not, such as the adjacent Toiyabe Range.
Also worth mentioning are several less well known high-elevation residential sites from California and Utah. This includes “Summit Village” in the Sierra Nevada above Owens Valley (Morgan 2006). The site is similar to those found in the White Mountains, including residential features and groundstone, and also dates to the final centuries of the Late Prehistoric. In Utah, work from the Uinta Mountains (Knoll 2003; Johnson and Loosle 2002; Watkins 2000), the Oquirrh Mountains (Janetski 1985, 1997), the Pahvant Range (Morgan, Fisher, and Pomerleau 2012), and the Fishlake Plateau (Janetski 2010; Simms 1979) indicate residential use of high-elevation environments was likely related to Fremont intensification.

High Rise Village and the other high-elevation residential sites of the American West can help researchers address the greater question of why people use high-altitude environments in different ways. Some archaeologists consider high-elevation environments to be resource poor, calorically demanding environments. Aldenderfer (2006) in particular argues that people will only begin to use these environments when conditions degrade in previously productive environments, such as through population pressure or environmental degradation. This is what Bettinger (1991a) suggests in the Great Basin.

Conversely, there are others who see these same environments as favorable and productive, offering a broad selection of resources in a relatively small area (e.g., Bender and Wright 1988; Black 1991; Madsen and Metcalf 2000; Walsh et al. 2006). This latter point of view is particularly popular with regard to the mountains of western Wyoming.
(e.g. (Adams 2010a; Bender and Wright 1988; Frison 1992; Husted 1974; Wright et al. 1980). High Rise Village potentially offers some insight into this debate.

The paleoenvironmental, culture history, and high-elevation contexts of High Rise Village ground research at the site and offer many avenues for research, ranging from local and regional patterns to broader discussions of human–environment interactions. This study brings together these sometimes disparate threads to investigate the role climate temporal variability and resource predictability played in foraging strategies and site use patterns at High Rise Village.
CHAPTER 3
THEORETICAL FRAMEWORK AND MODEL EXPECTATIONS

Using High Rise Village as a case study, this project uses the z-score model to investigate how foragers coped with climate-driven changes in resource variability. The post-encounter return rates for five key resources are manipulated to account for climate temporal variability and subsequent effects on resource variability during the Medieval Warm Period (MWP; 1150–550 yr B.P.) and the Little Ice Age (LIA; 550–100 B.P.) (Bradley et al. 2001; Bradley and Jones 1992; Hughes and Diaz 1994a; Mann 2002a, b). Based on resource return rates, the model is used to predict how changes in resource variability could reorganize foraging strategies and site use patterns at High Rise Village.

Modern climate change studies show that temporal variability in climate can have considerable effects on the health, population structure, and body size of animal resources, and thus on post-encounter return rates. Of the resources immediately available to foragers at High Rise Village, effects on marmots (Marmota flaviventris) include fluctuating body size, changes in mating frequency and success, and variability in litter and offspring size (Inouye et al. 2000). Much of this is attributable to the availability of forage as well as disruptions to hibernation and breeding cycles (Inouye et al. 2000). Bighorn sheep (Ovis canadensis) are also sensitive to climate change, especially as related to food availability and quality (Douglas 2001; Epps et al. 2004). Unhealthy sheep are also less resistant to disease (Douglas 2001). Periods of variable
recruitment, health, and susceptibility to disease are expected to lead to more variable individual size within populations. Resource body size is assumed to be positively related to return rates and thus serves as a proxy for the same (Broughton 1994; but see Byers and Ugan 2005).

Plant resources are also affected by temporal variability in climate, particularly in terms of productivity. While whitebark pine (Pinus albicaulis) populations remain fairly stable in variable climate conditions, cone yields become increasingly variable in size and mast years become increasingly infrequent and irregular (Arno and Hoff 1989; Tombback and Linhart 1990). Geophyte patches are also typically stable; however, root weights and caloric content are variable within patches (Smith and McNees 2005) and are expected to be more so under variable climate conditions. Though resilient to some climatic change (Harris 1969), geophytes nonetheless rely on early spring water availability for the development of starchy storage organs (Harris 1969; Housley 1994). Variability in moisture availability, whether directly through precipitation or indirectly through temperature and spring melt, would affect geophyte development.

All of these effects on plant and animal resources are exacerbated as the periodicity of climate fluctuations become more frequent. In short, as climate becomes more variable, so do resource return rates, meaning the expected rate of return of each resource also becomes more unpredictable. Resource variability and the associated unpredictability present a challenge for foragers, for whom the likelihood of caloric shortfall increases with variability (Winterhalder 1986). Under these conditions, foragers are expected to adopt foraging strategies that actively manage the risk of
caloric shortfall. To investigate these strategies at High Rise Village, this study uses the z-score model to predict risk-sensitive foraging strategies based on climate-driven resource variability during the MWP and LIA. Predictions are tested at the site to determine whether the risk associated with climate-driven resource variability structured foraging decisions at High Rise Village.

This chapter begins by introducing risk-sensitive foraging theory, followed by a discussion of the z-score model and how it is used here to investigate risk-sensitive foraging strategies. Lastly, the High Rise Village z-score model is described, including the definition and quantification of model variables, and the model hypotheses and associated archaeological expectations.

**Risk-Sensitive Foraging Behavior**

Risk is defined as the probability of falling below a required minimum caloric threshold (Winterhalder 1986). While the forager can have an idea of this probability when faced with a foraging decision, risk cannot be overcome by acquiring more information (Stephens 1988). This is in contrast to uncertainty, or incomplete knowledge of foraging outcomes, which can be overcome with more information (Winterhalder et al. 1999).

Rather than being overcome, risk must be managed, typically in one of two ways: risk-averse or risk-prone behaviors (Stephens 1988). Risk-averse behavior seeks to avoid or minimize the effects of variable outcomes by favoring certain, but potentially less rewarding outcomes (Bettinger 1991a; Stephens 1988). This is the expected
strategy when the average outcome of a behavior is sufficient for an organism’s needs (Caraco et al. 1980). Conversely, risk-prone behavior actively seeks options with unpredictable but potentially large returns over more certain, but less rewarding outcomes (Bettinger 1991a; Stephens 1988). This type of behavior is expected when outcomes are not likely to meet an organism’s needs and it therefore might be worth gambling on the chance of a better than expected return (Caraco et al. 1980).

Studies show that humans do sometimes behave in risk-averse manners. Many foragers and farmers actively minimize subsistence outcome variability and employ a variety of means to do so, such as diversification, sharing, mobility, storage, technological strategies, and exchange (e.g., Baksh and Johnson 1990; Goland 1991a, b; Hawkes et al. 1995; Kaplan et al. 1989; Winterhalder and Goland 1997). Risk-prone behavior remains little studied (Winterhalder et al. 1999), though there is some evidence that humans will switch to risk-prone strategies under dire circumstances when failure all but guaranteed and there is nothing to lose by gambling on the slim chance of a better than expected outcome (Colson 1979; Fitzhugh 2001; Kohler and Van West 1996).

Foraging models from optimal foraging theory (OFT) offer a means to predict risk-sensitive decision making. OFT is the study of foraging behavior with the assumption that individual behavior tends to be efficient given a goal and different foraging options, each with a return (Bettinger 1991a). Foraging returns are typically quantified as return rates, or calories gained per unit of time. Goals vary by model and include maximization of caloric gain, time minimization, as well as avoiding caloric
shortfall. Given a series of foraging options and a goal, quantitative models are used to predict foraging strategies which can then be tested against observed behavior to determine whether people are indeed foraging in the expected manner. Two OFT models, the diet breadth model (MacArthur and Pianka 1966) and the patch choice model (Charnov 1976), are worth discussing here to clarify difficulties in archaeological applications of the risk-sensitive model discussed below.

The diet breadth model is a contingency model and predicts whether or not a forager will pursue a resource upon encounter (Bettinger 1991a, 2009). These decisions are modeled based on resource caloric content (in kcal), the time it takes to encounter the resources while foraging (search time), and the time after encounter it takes to acquire and prepare the resources (handling time). To maximize returns, the forager will always prefer the resource that provides the highest post-encounter return rate (kcal/handling time) as well as any others with a post-encounter return rate greater than the return expected from continuing to search for higher return resources (and thus accruing both search and handling times). Based on this, the diet breadth model predicts which resources should appear in a forager’s diet. The model is thus readily applied to the coarse-grained archaeological record where the presence/absence (and relative quantity) of a resource can often be determined.

The patch choice model (Charnov 1976) is used to predict how long foragers should spend foraging in a resource patch given a landscape of resource patches. The net gain from a patch necessarily decreases through time as resources encounters are frequent at first, and then progressively lower as it requires greater effort to find
thinning resources. Based on the diminishing caloric gain from a patch and the search
time needed to find the next patch, the model predicts at what point searching for a
new patch becomes preferable to the current patch’s returns and the forager should
leave. While only moderately more complex than the diet breadth model,
archeological applications are difficult. In particular is the difficulty in accurately
generating prehistoric resource abundances within patches and patch distributions in
the landscape. This requires Geographic Information Systems (GIS) simulations using
digitized environmental parameters and often extensive paleoenvironmental work to
accurately reconstruct the prehistoric foraging landscape (Raven and Elston 1989; Smith

Risk-sensitive OFT models were initially developed in response to perceived
overgeneralization in the existing OFT models, such as the diet breadth model
(Winterhalder et al. 1999). The diet breadth model uses fixed, average return rates to
predict foraging behavior and do not account for natural variability in resources or
return rates. A series of models were developed that allow return rates to vary and
capture the unpredictable variability inherent in foraging; these models predict how
foragers should cope in a variable environment, whether in risk-averse or risk-prone
manners (Stephens 1988; Winterhalder et al. 1999). To determine whether foragers
were risk-sensitive at High Rise Village and if strategies changed between the MWP and
LIA, this thesis uses one of the simplest and earliest risk-sensitive models, the z-score
model.
The Z-Score Model

The z-score model was initially developed by ecologists Stephens and Charnov (1982) as a variation on the patch choice model to better account for the inherent variability in patch returns and associated risks of caloric shortfall. Shortly thereafter, Winterhalder (1986) suggested that the z-score model could also be used to understand how risk influences human decision making. Several applications of the z-score model to anthropological issues are discussed below, in an effort to elucidate and manage the problems of employing the z-score model in archaeological research.

Goland (1991b) used the model to understand the role of risk in household farming plot size and distribution with modern populations in the Peruvian Andes. She determined that the use of several small, well dispersed plots effectively minimized the risk of production shortfall due to the harsh environment and other uncontrollable factors. Elston and Brantingham (2002) discussed the model’s utility in understanding changes in lithic technology among hunters in northeastern Asia during the late Pleistocene/early Holocene. The authors argue that the transition from single component projectile points to microblade technologies may have helped foragers cope with greater variability in large game hunting returns because of their greater effectiveness in close quarters, reusability, and better performance in very cold conditions.

Ariane Pinson (1999) hypothesizes that the risk of starvation may have played a critical role in foraging decision making during the highly variable Late Pleistocene/Early
Holocene transition and that behavior should have either been risk-averse or risk-prone. Risk-averse foragers are expected to rely on a diverse diet, particularly low-variance, low-return plant and small animal resources, and should favor diverse habitats with access to these resources. Conversely, risk-prone foragers are expected to prefer high-variance large game and their corresponding habitats. Based on an abundance of lagomorph bone relative to artiodactyl bone and projectile point distributions in or near diverse habitats, Pinson argues that early Holocene foragers were risk-averse.

However, there are undeniable challenges in applying the model archaeologically, particularly in quantifying the necessary foraging data. While Goland (1991b) is able to quantify agricultural metrics, Pinson (1999) relies on the model to frame foraging hypotheses and foregoes a mathematical application. The z-score model as Pinson applies it avoids dealing with the likelihood of encountering prey, which is based on prey abundance. Pinson’s failure to employ quantitative data in her estimates is most likely due to the difficulty of obtaining data on the prehistoric abundance of a given resource in a resource patch, and thus prehistoric patch (i.e., spatially-based) return rates. In short, modeling past resource abundance was (and is) beyond the ability of even the most robust paleoenvironmental proxy data and ecological modeling. This consequently limits the very types of quantitative predictions that are the real value of the z-score model.

In an effort to avoid the problems encountered by Pinson yet still employ the quantitative strengths of the z-score model, this study takes a simplified approach to modeling risk-sensitive foraging. Rather than being spatially (and abundance-based) like
the patch-choice model, this study takes space and resource abundance out of the
equation and instead relies on variability in prey package size to account for climate’s
effect on variability in resource return rates. In much the same manner as resources are
ranked in the diet breadth model, this application uses post-encounter return rates to
predict the risk-sensitive forager’s diet at High Rise Village. To do so, the z-score
formula is used as a statistical test of each individual resource’s likelihood of fulfilling a
required minimum return rate given its range of variability about a mean expected
return rate.

Using the formula below, a z-score is used to determine the probability that \( m \)
will not be included within the normal curve of the dataset represented by the mean (\( \mu \))
and standard deviation (\( \sigma \)) (Utts and Heckard 2011). A z-score indicates how many
standard deviations \( m \) is from the mean. The corresponding \( p \)-value determines the
probability \( m \) is included and is generated with a z-score table or statistical software.

\[
Z = \frac{(m - \mu)}{\sigma}
\]

When used as a foraging model, \( m \) represents a required minimum return rate,
and \( \mu \) and \( \sigma \) are the mean return rate and standard deviation for each foraging option
included in the model. The required minimum return rate is the lowest hourly rate a
forager can maintain for a given work day to fulfill a daily caloric requirement. The
resulting z-values for each resource and their corresponding \( p \)-values give the
probability that each resource is likely to fulfill the requirement. These are then used to
generate hypotheses about foraging behavior and the consequent archaeological expectations.

The first step in generating hypotheses is to determine whether foragers are expected to be risk-averse or risk-prone, based on mean return rates ($\mu$) and the minimum requirement ($m$) (Bettinger 1991a). Foragers are expected to be risk-averse when at least one mean is greater than the minimum requirement ($r > m$). Under these conditions, foragers should prefer the options with the smallest $z$-scores and greatest probabilities of fulfilling the requirement. If all of the means are below the minimum requirement ($r < m$), foragers are expected to be risk-prone, or willing to gamble on the chance of exceeding the requirement, no matter how unlikely. In this instance, foragers should opt for highly variable options.

In terms of the expected risk-averse/risk-prone diet, the resource most likely to avoid caloric shortfall (smallest $z$) is always the best solution to the foraging problem (Bettinger 1991a). But in terms of predicting diet, the other resources should be considered as well. Those resources with $z$-scores comparable to the smallest $z$-score are similarly likely to avoid shortfall should also expected to be taken. Rather than limiting hypotheses to the single best resource, this allows a more general idea of the risk-sensitive diet, particularly in terms of whether the diet should be dominated by animal resources, or whether plant resources play a crucial role in risk management.

Most importantly, the $z$-score model generates predictions that are testable. Foragers exhibiting a risk-minimizing adaptive strategy leave an archaeological signature with identifiable characteristics. Faunal and macrobotanical assemblages should be
dominated by those resources with the smallest z-values. Artifacts should show this as well, particularly in terms of game- vs. plant-dominated diets. For example, there should be a greater abundance of groundstone associated with a plant-dominated diet than a game-dominated diet.

Further, if environmental change causes the mean return rates and/or standard deviations of available resources to change, the adaptive strategy may shift from a risk-averse to a risk-prone strategy, or vice-versa. Or, the shift may be less dramatic, but nonetheless cause a reorganization of targeted resources in order to maintain a risk-averse or risk-prone strategy. With the z-score model, these changes can be modeled to produce hypotheses and expectations that can be tested in the field.

The High Rise Village Z-score Model

The High Rise Village study uses the z-score model to predict how risk-sensitive foragers should cope with differences in climate-driven resource variability between the MWP and the LIA. To simulate the effects of these climate periods on resources at High Rise Village, two general climate scenarios were defined and incorporated into the model. Following Dean et al. (1985), low frequency change, here called stable climate, is defined as change that cycles over periods longer than a human generation (ca. 25 years), including multidecadal and greater modes of variability. This scenario corresponds with the MWP. Deviating from Dean, a variable climate is here defined as change cycling in less than 25 years, including decadal and interannual modes of variability. This corresponds with the LIA.
Based on the climate-driven changes in resources discussed above, the current study models the risk-sensitive diet under each climate scenario. The High Rise Village z-score model uses published post-encounter return rate ranges to derive average return rates and standard deviations for the five resources under stable and variable conditions. Below is a description of the model variables and their derivation followed by the application of the model and a discussion of the hypotheses and corresponding archaeological expectations generated from the model's output.

**Model Variables**

*Daily Caloric Requirement.* The High Rise Village z-score model treats foragers not as autonomous individuals, as is typical for a contingency model like diet breadth, but rather as members of a group. Groups typically include members who do not completely provide for themselves, such the young, the old, and the infirm (Kelly 2007). This places greater stress on adult foragers and is here considered important when determining the minimum requirement of a risk-sensitive forager.

Based on Kelly (2007; Table 3-6), the average daily caloric consumption of eight modern hunter-gatherer groups is 2,440 kcal/day. Using this average as a starting point, it is rounded up to a daily minimum of 3,000 kcal to account for increased energy demands in high-altitude environments (>2,500 m asl; Aldenderfer 2006).

This model further assumes an average work day of eight hours. Based on Kelly (2007; Table 1-1), the average working day for hunter-gatherer men and women ranges from 3.8–9.5 hours and averages 6.5 hours. This base work day was rounded up to eight
hours to account for slower work due to steep and rugged terrain and decreased oxygen at altitude. If 3,000 calories need to be obtained in eight hours, a base rate of 375 kcal/hr. must be maintained by adult foragers providing only for themselves.

The above base rate was then increased to account for adults having to also provide for less productive group members. Literature on how much hunter-gatherer children contribute to their own caloric needs varies from heavy involvement among the Hadza (Hawkes et al. 1995) to very little among the Dobe !Kung (Draper 1976). With this variability in mind, it is assumed that most adult foragers produce 50 percent more calories per hour than is personally required in order to provide for some group members. By multiplying the minimum rate calculated above by 150 percent, the resulting minimum required rate is 563 kcal/hr.

Foraging Options. The modeled foraging options at High Rise Village are: bighorn sheep, marmots, whitebark pine nuts, biscuitroot (*Cymenopterus* spp. and *Lomatuim* spp.), and wild sunflower (*Helianthus annus*). This is an admittedly limited array of resources; however, this decision was made to simplify the model by limiting foraging to those most likely to constitute the basis of the prehistoric High Rise Village diet. It is suspected that sheep, whitebark pine, and geophytes played a crucial role at the site (Adams 2010a). This study includes marmot because they are ubiquitous at the site, high in fat (Barash 1989), and a known alpine resource in the area (Bliss 1950; Frison 1983).

While not discussed in the High Rise Village literature, sunflower is included in the model to investigate how small seeds fare in the model. Small seeds appear to have
played a significant role in the basins surrounding the Wind River Range during the early Late Prehistoric (McNees 1992; Smith 2005; Thompson and Pastor 1995) and at the White Mountains villages (Scharf 2009) in eastern California. Sunflower is used here as it was likely available near the site (Stubbendieck et al. 2003) and its return rate is relatively average for a seed (e.g., Simms 1987), making it reasonably representative to include in the model as a proxy for small seeds.

*Return Rates.* The High Rise Village z-score model relies on Simms' (1987) post-encounter return rates for sheep, pine nuts, and sunflower seeds. The biscuitroot return rate is from Smith and McNees (2005). Low and high return rate values were averaged to generate average return rates (Table 2). Marmot return rates were derived as described below.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Return Rates (kcal/hr.)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Sheep</td>
<td>17,971</td>
<td>31,450</td>
</tr>
<tr>
<td>Marmot</td>
<td>15,725</td>
<td>17,971</td>
</tr>
<tr>
<td>Pine Nuts</td>
<td>841</td>
<td>1,408</td>
</tr>
<tr>
<td>Biscuitroot</td>
<td>1,054</td>
<td>1,867</td>
</tr>
<tr>
<td>Sunflower</td>
<td>467</td>
<td>504</td>
</tr>
</tbody>
</table>

There have been no attempts to define marmot return rates. For this reason, this study estimates its own. Marmots typically weigh 3–5 kg with an average of 2.4 kg (Barash 1989). From personal experience, the dressed weight of an adult marmot is approximately 2 kg. Following Simms' (1987) treatment of jackrabbit and cottontail
body weights, this number was reduced to account for the juvenile portion of the population, becoming 1.8 kg. This study used Simms’ bighorn sheep calories per kilogram (1,258 kcal/kg) rather than his jackrabbit calories per kilogram (1,079 kcal/kg) to account for higher marmot body fat percentages. Marmots can have up to 40 percent fat (Barash 1989) as compared to 3.3–9.0 percent for jackrabbits (Collopy 1986) and the caloric density of fat is greater than twice that of muscle/protein (9 kcal/g vs. 4 kcal/g; USDA 2012). Accounting for more fat is particularly relevant for marmot return rates in the summer and early-fall months when their fat content is at its annual highest (Barash 1989) and when High Rise Village is expected to have been occupied (Adams 2010a). This gives an average of 2,264 kcal per individual marmot. Simms’ jackrabbit handling times are used (.07–.08 hr./kg) giving a return rate range of 15,725–17,971 kcal/hr. While future work is needed to properly define marmot return rates, the rate developed here is likely sufficient for predictive purposes.

Similar to marmots, there is no accepted return rate for whitebark pine nuts. Rhode (Rhode 2010) developed a return rate for limber pine (Pinus flexilis), a very similar species, but does not account for processing time, a critical component of microeconomic foraging cost-benefit analyses. For this reason, Simms’ (1987) pinyon pine (Pinus monophylla) values were used; both species’ nuts are similar.

**Standard Deviations.** Defining a resource return rate standard deviation presents a considerable problem when using the z-score model. Most available return rates were developed from relatively few data points (e.g., Simms 1987) and it is consequently not possible to directly calculate most relevant standard deviations from
published data. Further, these experiments have not been replicated and it is unknown how representative these values are and whether return rates have the normal distributions necessary for conducting a z-score type study. Because a measure of variability plays a crucial role in the z-score model and standard deviations cannot be calculated, proxy standard deviations are determined instead. A proxy is derived for each resource under both climate scenarios (Table 3), with the assumption that return rates will fluctuate more under variable climate conditions. The proxies are derived from return rate ranges so as to reflect the inherent variability of each resource.

Table 3. Average Return Rates and Proxy Standard Deviations by Climate Scenario.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Return Rates (kcal/hr.)</th>
<th>Proxy Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Stable</td>
</tr>
<tr>
<td>Sheep</td>
<td>24,711</td>
<td>4,583</td>
</tr>
<tr>
<td>Marmot</td>
<td>16,848</td>
<td>764</td>
</tr>
<tr>
<td>Pine Nuts</td>
<td>1,125</td>
<td>193</td>
</tr>
<tr>
<td>Biscuitroot</td>
<td>1,461</td>
<td>276</td>
</tr>
<tr>
<td>Sunflower</td>
<td>486</td>
<td>13</td>
</tr>
</tbody>
</table>

The standard deviations under the stable climate scenario are calculated by assuming that 68 percent of the values in a data set lie within one standard deviation of the mean, or within 34 percent on either side of the mean (Utts and Heckard 2011). With this in mind, the proxy standard deviation of each resource was calculated as 68 percent of the range, or 34 percent of the range on either side of the mean. This assumes that published ranges are representative of the full spread of possible resource return rates.
Under the variable climate scenario, the proxy standard deviations are the full ranges described above. The ranges offer a measure of maximum variability for each resource and while perhaps slightly exaggerating variability beyond two standard deviations, this proxy allows the model to simulate the most extreme periods of resource return rate variability.

**Hypotheses and Expectations**

Using the average return rates and proxy standard deviations above, z-scores and corresponding p-values were calculated for each resource under both climate scenarios (Table 4). A resource’s probability of fulfilling the minimum requirement determined whether it was included in the hypothesized diets for MWP and LIA occupations of High Rise Village. The hypothesized diets imply archaeological expectations of resource choice and technology. Faunal remains are not considered here because of their poor preservation at the site. See Table 5 at the end of this section for a complete summary of expectations.

**Table 4. Resource Z-score and Probability of Success by Climate Scenario.**

<table>
<thead>
<tr>
<th>Resource</th>
<th>Stable Climate Scenario</th>
<th>Variable Climate Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>z-score</td>
<td>p-value</td>
</tr>
<tr>
<td>Sheep</td>
<td>-5.27</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Marmot</td>
<td>-21.32</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Pine Nuts</td>
<td>-2.92</td>
<td>.0018</td>
</tr>
<tr>
<td>Biscuitroot</td>
<td>-3.25</td>
<td>.0006</td>
</tr>
<tr>
<td>Sunflower</td>
<td>6.12</td>
<td>1.000</td>
</tr>
</tbody>
</table>
Because most mean return rates are above the minimum return rate \((r > m)\) in both scenarios (Figures 4–7), foragers at High Rise Village should always act as risk-minimizers and pursue those resources with the smallest \(z\)-scores (Bettinger 1991a). 

**Stable Climate/Medieval Warm Period**

*Hypothesis.* In a stable climate, the risk-minimizer’s diet at High Rise Village is diverse, resulting in decreased residential mobility, greater diversity in flaked stone tools and debitage, and less diversity in tool materials.

Given environmental stability and low resource variability, nearly all the resources have a high likelihood of allowing foragers to avoid caloric shortfall. As shown in Table 4 above and Figures 4 and 5 below, only seeds fail to satisfy the requirement. This means that any, and likely all, of the resources with high probabilities were used at High Rise Village during the MWP while seeds should not have been used.

Based on the hypothesized diversity of plant and animal resources in the diet and the proximity of these resources to High Rise Village, it is expected that the site was used residentially by people intent on exploiting both plant and animal resources. The site provides immediate access to plant and game resources as well as excellent access to the greater alpine/subalpine zone in the area. With this in mind, High Rise Village could have served as a residential base for either residentially mobile foragers intent on local resources or more logistically organized foragers using the site as a base from which to exploit the greater area. Either way, the diversity of resources used at High
Rise Village would have led to more time spent exploiting resources in the area resulting in decreased mobility (Elston and Zeanah 2002; Kelly 2007; Zeanah 2004).

Figure 4. Stable climate resource return rate means and standard deviations relative to the required minimum.

Figure 5. Stable climate plant resources relative to the required minimum.
Macrobotanical Remains and Groundstone Residue Analysis. Under stable conditions, both pine nuts and biscuitroot are expected to be important components of the diet. To reflect this, macrobotanical remains from flotation samples are expected to provide evidence of pine nut processing in the form of charred pine nut hulls. Ethnographically, pine nuts were often parched before being hulled, leaving behind charred hull fragments (Janetski 1999; Moerman 2010; Steward 1938). Root remains are not expected from flotation, due to their poor preservation in archaeological contexts (Carbone and Keel 1986; Smith et al. 2001). However, groundstone residue analysis is expected to indicate processing of both resources.

Flaked Stone Tools. The MWP flaked stone tool assemblage is expected to reflect residential use and a diversity of activities associated with a diet that relies on both animal and plant resources. Formal bifacial tools, though likely important given their portability, versatility, and hunting utility, were not necessary for many activities and are not always worth the initial investment of time and higher quality toolstones (Cowan 1999; Kelly 1988). In contrast, informal flake tools derived from cores are expedient, effective for many activities, and readily made from most toolstones (Cowan 1999). Informal tools are expected in greater numbers when residential stays are longer and site activities are diverse (Cowan 1999). As a longer-term residential camp used for both hunting and gathering activities, the High Rise Village assemblage is expected have a substantial proportion of informal tools as well as bifacial tools in MWP components.

Debitage. If core and bifacial technologies are both important components of the High Rise Village tool kit during the MWP, this is also expected to be reflected in the
debitage from tool manufacture and repair (Cowan 1999; Kelly 1988). The MWP assemblage is expected to have substantial proportions of debitage indicative of both bifacial and core reduction.

**Obsidian.** The diversity of obsidian sources represented in the MWP assemblage is expected to be low due to decreased mobility associated with increased diet diversity. The increased time spent per residential occupation provides less opportunity for raw materials to move further away from their sources before being depleted, discarded, or lost, keeping the overall diversity of the forager’s obsidian assemblage relatively low (Jones et al. 2003). Further, because informal as well as formal tools are expected, it is less necessary to actively seek high quality materials, such as obsidian (Cowan 1999). Local cherts or even quartzite are likely sufficient for many activities, further reducing obsidian diversity. For these reasons, the closest obsidian sources to High Rise Village are expected to dominate the assemblage, namely those near Jackson Hole, Wyoming (Connor and Kunselman 1995; Scheiber and Finley 2011b; Schoen 1997).

While the greater representation of local sources is expected under most circumstances (Jones et al. 2003), this expectation serves primarily to contrast obsidian expectations under the variable climate scenario.

**Dating.** During the MWP, High Rise Village offers the risk-sensitive forager a variety of seasonally available resources that are likely to satisfy energy requirements for them and their dependents. Because of the stability of the MWP environment and the diversity and predictability of acceptable resources, it is expected that High Rise Village was used more frequently during the MWP than the LIA. It is expected that
there will be more Rosegate projectile points (1500–600 B.P.; Kornfeld et al. 2010; McNees 1992; Thomas 1981) than later varieties and that more radiocarbon samples date to this period than later.

*Variable Climate Scenario/Little Ice Age*

*Hypothesis.* In a variable climate, the risk-minimizer’s diet at High Rise Village is dominated by animal resources, resulting in greater residential mobility or logistical use of the site, greater investment in bifacial technology and increased toolstone diversity.

Increased resource variability under this model decreases diet diversity and foragers are expected to largely concentrate on animal resources to minimize risk of caloric shortfall (Table 4, Figures 6 and 7). Pine nuts and biscuitroot drop from a >99 percent likelihood of fulfilling the requirement to 84 percent and 86 percent respectively. While probably still eaten, it is hypothesized that their importance in the diet decreased as foragers focused on higher probability animal resources. Seeds remain excluded from the diet.

Foragers who map on to animal resources often travel frequently as resource patches are more rapidly depleted (Binford 1980; Kelly 2007) and the LIA assemblage at High Rise Village should be dominated by evidence of shorter stays by mobile peoples focusing on hunting, whether residential or logistical.

*Macrobotanical Remains and Groundstone Residue Analysis.* Due to climate-driven return rate variability, sheep and marmot are more reliable resources than pine
Figure 6. Variable climate resource return rate means and standard deviations relative to the required minimum.

Figure 7. Variable climate plant resources relative to the required minimum.
nuts and roots. Flotation samples from LIA components should be largely devoid of floral subsistence remains and residue analyses should indicate little use of plant resources.

Flaked Stone Tools. Foragers at High Rise Village under variable conditions are expected to have relied heavily on animal resources as plant resources drop out of the risk-minimizing diet, necessitating greater mobility (Kelly 2007). Greater mobility, whether residential or logistical, requires tools that are easily portable, versatile, and repairable, meaning bifacial tools dominate the tool kit (Cowan 1999; Kelly 1988). In contrast, informal tools are less well suited to the requirements of highly mobile foragers, being more consumptive of toolstone and less portable (Cowan 1999). Due to greater mobility associated with a hunting-focused economy, the LIA assemblage is expected to have a greater proportion of bifacial tools relative to expedient tools.

Debitage. Because bifacial technology is expected to be particularly important, biface thinning flakes and pressure flakes are expected to constitute a greater proportion of the assemblage than core reduction flakes (Cowan 1999; Kelly 1988). Foragers reliant on bifacial technology produce a greater proportion of biface thinning and pressure flakes because tools are curated and frequently reworked (Cowan 1999; Kelly 1988).

Obsidian. Greater diversity sources is expected to be represented in LIA components as artifacts remain part of the toolkit longer with greater mobility, shorter stays at sites, and greater tool curation let (Cowan 1999; Jones et al. 2003). In particular, more distant sources are expected to be better represented. In addition, a
reliance on bifacial technology tends to require higher quality toolstone (Cowan 1999), of which obsidian is readily available throughout the greater region (Scheiber and Finley 2011b; Smith 1999), further contributing to greater diversity.

_Dating._ Due to the decreased security of relying on a few, mobile resources to fulfill necessary energy requirements, it is expected that the overall frequency of occupations of High Rise Village will decrease during the LIA. Increasing climate-driven resource return rate variability during the LIA is expected to decrease resource return rate predictability and further contribute to decreased use of the site as foragers seek more secure resources.

If High Rise Village was used less during the LIA than during the MWP, it is expected that there are considerably fewer radiocarbon samples and projectile points dating to this period (post-550 B.P.), namely side-notched, tri-notched, and unnotched points (Larson and Kornfeld 1994; Scheiber and Finley 2010; Thomas 1981).

<table>
<thead>
<tr>
<th>Data</th>
<th>Stable Climate/MWP</th>
<th>Variable Climate/LIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macrobotanical</td>
<td>Pine Nuts and Roots</td>
<td>Few Plant Resources</td>
</tr>
<tr>
<td>Groundstone Residue</td>
<td>Pine Nuts and Roots</td>
<td>Few Plant Resources</td>
</tr>
<tr>
<td>Flaked Stone Tools</td>
<td>Formal and Informal Tools</td>
<td>Formal Tools</td>
</tr>
<tr>
<td>Debitage</td>
<td>Core and Bifacial Reduction</td>
<td>Bifacial Reduction</td>
</tr>
<tr>
<td>Obsidian Sourcing</td>
<td>Decreased Diversity</td>
<td>Greater Diversity</td>
</tr>
<tr>
<td></td>
<td>Jackson Hole Sources</td>
<td>More Distant Sources</td>
</tr>
<tr>
<td>Dating</td>
<td>Primarily MWP Occupation</td>
<td>Little LIA Occupation</td>
</tr>
</tbody>
</table>

It is worth noting that the expectations for risk-sensitive foraging during the MWP and LIA largely conform to previously discussed subsistence and mobility patterns.
in the Wyoming Basin during these periods. The MWP–Rosegate period at High Rise Village roughly coincides with the Uinta Phase, 1800–900 B.P. (McNees 1992; Metcalf 1987; Smith 2005; Thompson and Pastor 1995). The Uinta Phase is characterized by house pits and a reliance on small game and plant resources, very similar to the diverse diet and long residential stays at High Rise Village predicted above. The LIA occupation (post-600 B.P.) similarly echoes the highly mobile, large game-based economy of the Firehole Phase, 900–250 B.P. (McNees 1992; Metcalf 1987; Smith 2005; Thompson and Pastor 1995).
CHAPTER 4

THE HIGH RISE VILLAGE WHITEBARK PINE (PINUS ALBICAULIS)

DENDROCLIMOTOLOGICAL STUDY

As incorporated into the High Rise Village z-score model, the Medieval Warm Period (MWP) is characterized by multidecadal climatic variability (i.e., >1 human generation) and therefore is modeled as a period of relatively high predictability with regard to resource return rates. In contrast, the Little Ice Age (LIA) is a period of interannual or decadal climatic variability and is consequently modeled as a period of increased unpredictability with regard to resource return rates. These assumptions form the basis for previously discussed standard deviation calculations (Chapter 3) and are integral to the model and its predictions. However, these assumptions are based on regional characterizations of the MWP and LIA and are unverified at the site.

Due to the often heterogeneous patterns of climate and its ecological ramifications, it is essential to determine local patterns when investigating local responses to climate change (Dunbar 2000; Mann 2002a; Mayewski et al. 2004; Stenseth et al. 2002). This is particularly true when working in topographically complex landscapes (Poage et al. 2000), such as the mountains of western Wyoming. While Holocene climate trends were similar throughout the region, trends often varied in timing, intensity, and duration depending on location (Harding and Lowe 1998; Kornfeld et al. 2010; Whitlock and Bartlein 1993).
As a means to verify model assumptions and to generate paleoclimate data that are locally relevant to High Rise Village, this study develops a whitebark pine (Pinus albicaulis) chronology for the immediate site area. Perkins and Swetnam (1996) demonstrated that growth in high elevation whitebark pine was consistently and sufficiently sensitive to climate variables for dendroclimatological studies. Further, the site’s treeline setting is an ideal location for a high-elevation climate study (Fritts 1976; Tranquillini 1979). Climate variables, particularly temperature, are the primary factors limiting growth in trees living at the elevational edge of their range. Changes in these variables are “recorded” in annual tree ring widths as trees respond to yearly conditions (Fritts 1976). By sampling trees near treeline, it is possible to characterize past climate, including patterns of variability. In this case, it is assumed that ring-width variability is a reasonable proxy for conditions affecting resources at High Rise Village.

The following chapter begins by detailing field and laboratory methods and the analyses undertaken to extract climate trends from the tree-ring data. The following section reports results and the chapter concludes with a discussion of the results in terms of the above climate expectations and the High Rise Village z-score study.

Methods

Sampling was opportunistic, focusing on trees that could yield both the necessary ring-width variability and maximize cumulative time depth. This study primarily sampled old trees near treeline and above treeline remnants in the immediate vicinity of High Rise Village.
Sampling followed typical dendrochronological procedure as discussed by Fritts (1976) and Speer (2010). When possible, two samples per tree were collected given that rot limited some sampling opportunities. Each tree was assigned a field sample number (WRR-WM-WBP-##), described, photographed, and had its Universal Transverse Mercator (UTM; NAD 1983, Zone 12N) coordinates recorded using a Garmin handheld GPS unit (2–3 m accuracy).

Cores were dried, mounted, and sanded to reveal ring-widths in cross section. Nine samples were skeleton plotted to determine whether samples crossdated (for procedure see Stokes 1968 and Speer 2010). This procedure confirmed that the samples followed a collective pattern of tree-ring variability and thus could be used to date samples of unknown age (see below) and investigate the collective signal (e.g., climate).

Once crossdating was confirmed, the remaining samples were dated by more expedient methods. Samples from living trees were dated to their last year of growth. The remaining samples were dated using the marker year approach (Yamaguchi 1991): rings with distinct characteristics were identified and dated in living tree samples and were then used to date samples of unknown age. Once dated, all ring-widths were measured to the nearest 0.001 mm using a Velmex stage, a Clearview stereozoom microscope, an Accurite encoder, and a Quick-Check display. The program MeasureJ2X (VoorTech 1999) was used to digitize, record, and save measurements.

Twenty of the oldest samples were selected to build the site chronology. Previously assigned sample ages were verified using ring-width measurements and the
program COFECHA (Grissino-Mayer 2001; Holmes 1983). COFECHA iteratively calculates a correlation coefficient between each individual series against the master chronology calculated from all other tree-ring series. The program flags series segments where correlations fall below a 99 percent confidence level and checks for a better match within +/- 10 years. Series with flagged segments are checked for measurement errors, missing or double rings, and other problems that affect dating and corrected accordingly.

Standardization

Using the program ARSTAN (Cook 1987), the tree-ring chronology was standardized to isolate climate-driven growth trends while removing unwanted noise caused by individual growth and stand dynamics. The program fits a standardization curve (defined by the researcher) to the measurements from each core and calculates an index value for each tree-ring. If multiple cores were taken from a tree, the yearly index values are averaged so as to not over-represent trees with multiple cores. Yearly index values for all samples are then averaged using a robust bi-weight mean to create a site-level master chronology (Cook 1987).

The current study used a 100-year cubic spline to preserve low-frequency variability in tree-ring values and isolate long-term climate signals. A 100-year cubic spline leaves 50 percent of the variance at 100 years, 99 percent at 31.69 years, and 1 percent at 315.43 years (Speer 2010). This spline length clarifies long-term trends and was appropriate for the 835-year chronology developed here. A shorter spline would
potentially have resulted in too much noise and obscured low-frequency trends while a longer spline could remove the desired climate signal.

Of the four chronologies produced by ARSTAN, the ‘arstan’ chronology was used for all subsequent analyses. This chronology type was developed to contend with high autocorrelation while maximizing a chronology’s climate signal (Cook and Holmes 1986). Autocorrelation occurs when factors from one year’s growth affects growth in subsequent years and can artificially skew correlation statistics during analysis (Speer 2010). Strong, positive autocorrelation is common in high elevation chronologies (LaMarche and Stockton 1974), including whitebark pine (Perkins and Swetnam 1996).

However, while most autocorrelation is unwanted, some may be related to climate and could provide important insight into annual growth (Speer 2010). By using an arstan chronology an effort is made to remove only nonclimate autocorrelation (Speer 2010). The chronology retains autocorrelation shared by most or all individual series in the chronology and assumed to be related to climate while removing that unique to one or a few trees and likely due to individual and local factors (Cook and Holmes 1986).

The raw measurements and final chronology developed here will be submitted to the International Tree-Ring Data Bank (Grissino-Mayer and Fritts 1997) in 2013.

Response Function Analysis

The chronology was then transferred to a third program, DENDROCLIM 2002 (Biondi and Waikul 2004), to identify climatic variables driving annual growth. The
program produces correlation coefficients between chronology growth patterns and meteorological data using both single and moving intervals. Single interval analyses indicate overall relationships between the climate variable in question and growth patterns by averaging annual correlation coefficients across the temporal span of the climate data in question. Moving interval analyses produce annual correlation coefficients and offers the means to determine whether growth responses change through time. Bootstrapped confidence intervals estimate the statistical significance of the observed correlations.

For the single interval analysis, the High Rise Village chronology was correlated against modern temperature, precipitation, and drought data. Each year of growth was analyzed against 24 months of meteorological and drought data, beginning in January of the previous year and ending in December of the current year. This window of analysis was used to fully encompass the water year (previous year October to current year September), which often strongly influences annual growth (Fritts 1976). The analysis determined which climate variable(s), and in what month(s), primarily drove growth at the site. By doing so, this analysis also indicates which climate variable(s) likely produce the patterns of temporal variability determined in later analyses.

To determine whether response to temperature and precipitation changed through time, moving interval analysis was undertaken using the same temperature and precipitation data as above. Different methods were used to determine whether the response to drought changed, which are discussed below.
Due to a lack of reliable local instrument data and poorly representative climate divisions, this study used Parameter–elevation Regression on Independent Slopes Model (PRISM) temperature and precipitation data (Daly et al. 1997). PRISM data for maximum monthly temperatures and average monthly precipitation from 1895–2011 were obtained from the WestMap Climate Analysis and Mapping Toolbox managed by the Western Regional Climate Center at the Desert Research Institute (Western Regional Climate Center 2012). The data have 4 km$^2$ resolution and were queried for Whiskey Mountain, the location of High Rise Village and the whitebark pine forest employed in this study. Dai Palmer Drought Severity Index data were obtained from the National Oceanic and Atmospheric Association, Earth System Research Laboratory, Physical Sciences Division, Boulder, Colorado (Dai et al. 2004). This data set provides monthly PDSI values derived from instrumental data from 1870 to 2005.

This thesis also explored whether the correlation between growth and drought changed through time, which required a different PDSI dataset. While the above analyses are limited to instrumental data with monthly resolution, this further analysis required annual PDSI values from drought reconstructions. Centered 31-year running correlation coefficients (Pearson’s $r$) were calculated between the full arstan chronology and tree-ring reconstructed PDSI values to investigate the relationship between growth and drought.

Annual PDSI data developed by Cook and Krusic (2003) were obtained from the North American Drought Atlas (NADA), managed by the Tree-Ring Lab at the Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York. The NADA data
offer 2,005 years of summer drought values reconstructed from a continent-wide gridded network of 835 tree-ring chronologies. Data were queried for the grid point nearest High Rise Village, grid point 101 near Pinedale, Wyoming. While this grid point is on the west slope of the Wind River Range and wetter than the east slope where High Rise Village is located, it is the most representative grid point available.

Spectral Analysis

To determine MWP and LIA patterns of variability at High Rise Village, the arstan chronology was analyzed using spectral analysis. Spectral analysis offers the means to extract information about frequencies from a signal (RSI 2006). A test of significance, often built in to the analysis, determines which frequencies are dominant. When used in climate analysis, spectral analysis is used to isolate primary patters of periodicity within a time series, such as a tree-ring chronology.

Of the types of spectral analysis, the current study uses wavelet analysis for its ability to determine diachronic patterns. Wavelet analysis not only determines dominant modes of variability, but also demonstrates how modes change though time (Torrence and Compo 1998). In the simplest sense, wavelet analysis converts time series values into correlation coefficients which represent frequencies in time. This process is briefly outlined below; for a complete discussion see Torrence and Compo (1998) and RSI (2006).

Wavelet analysis first requires that the user select a wavelet function appropriate for the information of interest within the time series (Torrence and Compo
The wavelet function is used to extract frequency information from the time series and different functions are better for specific types of data. Next, the time series is padded with sufficient zeroes at either end of the series to double the length of the series and minimize edge effects from continuous analysis on a time series of finite length (Torrence and Compo 1998). Time series values are then transformed so as to be comparable to the wavelet function and correlated against shifted, stretched, and compressed versions of the wavelet (RSI 2006). Analysis with multiple versions of the wavelet amounts to multiple scales of analysis at each time interval and allows for the determination of multiple frequencies within the time series. The analysis produces correlation coefficients, or wavelet coefficients, which represent all frequencies found at every scale for each time interval.

Together the wavelet coefficients provide a picture of the frequency-time relationships within the time series. These relationships are presented graphically as a wavelet power spectrum, a surface with color contours plotted in time (x-axis) and frequency (y-axis). Each contour represents a range of powers, related to correlation strength; warmer colors denote greater power. The cone of influence, a crosshatched area, shows those areas where edge effects are significant and contours may not be representative of frequencies within the data (Torrence and Compo 1998).

Significant frequencies are determined by comparing the generated surface against a background spectrum, typically derived from white or red/Brownian noise (Torrence and Compo 1998). The background provides a surface of known characteristics against which to compare the peaks (positive correlations) and dips
(negative correlations) of the time series’ surface. The chi-square distribution is used to identify those areas which differ significantly from the background. These areas show dominant frequencies through time and are outlined in black.

A second graph, the global spectrum, illustrates which frequencies dominate the entire time series (RSI 2006). The global spectrum is a line graph, displayed in Figure 12 to the right of the wavelet power spectrum and with the same y-axis (frequency). A solid black line represents the time series’ frequencies. A dashed line is the significance threshold, using the same parameters as for the wavelet power spectrum. Dominant frequencies are those y-axis values where the black line exceeds the dashed on the x-axis.

For the wavelet analyses, this project used the Interactive Wavelet Plot available through the Department of Atmospheric and Oceanic Sciences at the University of Colorado, Boulder (Torrence and Compo 1998). This study chose a Morlet wavelet function as the analyzing function and a red noise background for significance tests. A Morlet wavelet is well-suited for isolating oscillating frequencies, such as those expected in climate data (Torrence and Compo 1998).

**Climate Period Analysis**

Due to distinct patterns of variability determined by the running correlation with PDSI and the wavelet analysis, an additional analysis was undertaken to further characterize differences in variability between the MWP and LIA at High Rise Village. Multidecadal variability apparent in both analyses suggested Pacific Decadal Oscillation
(PDO) influence on temperature and precipitation patterns at the site. However, influence did not appear to be consistent across both climate periods. Characterizing possible PDO influence offered a means to further understand climate variability at the site and differentiate the MWP and LIA.

The PDO is a pattern of regularly alternating sea surface temperatures north of 20° N in the Pacific Ocean with considerable influence on North American climate patterns (Biondi et al. 2001; Gershunov and Barnett 1998). The PDO shifts between warm/positive and cool/negative phases on a roughly 20–30 year time scale. Positive PDO phases are often associated with decreased precipitation at high elevations in the central and southern Rocky Mountains (Biondi et al. 2001; Graumlich et al. 2003; Gray et al. 2003). The analysis undertaken here determined the strength of PDO influence for both climate periods.

To this end, the arstan chronology was correlated against annual PDO index values. The ring-width index (RWI) values were smoothed using a centered 31-year running average to focus the analysis on long-term patterns within the chronology. A 31-year smoother was chosen because it encompassed the significant multidecadal periodicity indicated by the wavelet analysis. Because this study is interested in differences between the MWP and LIA, the data sets were correlated by climate period. As allowed by the chronology’s 835 year time depth, the periods were defined as the final two centuries of the MWP, (A.D. 1200–1400), all of the LIA (A.D. 1401–1850), and the modern period (A.D. 1851–1988). The modern period was included to provide further contrast post-LIA.
For each climate period, a Pearson product–moment correlation coefficient ($r$) was calculated to determine the direction and statistical significance of each correlation. The correlation coefficient ranges from negative one to positive one and its sign corresponds with the sign of the relationship. A coefficient of zero indicates no relationship while a one indicates a perfect relationship.

MacDonald and Case (2006) developed the PDO dataset used here, available for download from the National Oceanic and Atmospheric Administration’s World Data Center for Paleoclimatology, Boulder. Developed from tree-ring data, the dataset spans A.D. 993–1996 with annual resolution.

**Results**

*Chronology Characteristics*

Forty-one trees were sampled in the immediate vicinity of High Rise Village for a total of 66 individual cores (Figure 8). The master chronology was compiled from 20 series and encompasses A.D. 1177–2011 (835 years), including all of the LIA and the final two centuries of the MWP (Figure 9). The MWP sample size is small ($n \leq 4$, Figure 9) and it must be acknowledged that the data may not be representative of the MWP as whole. MWP patterns at High Rise Village are therefore necessarily tentative. Short samples and complacency prevented the inclusion of many samples, including all above treeline remnants.
Figure 8. High Rise Village dendroclimatological study area with site boundary and sample locations. Green triangles indicate sampled trees. The site is contained in the yellow shaded area.

Figure 9. The standardized High Rise Village ‘arstan’ chronology with corresponding annual sample size.

Chronology measures generated by COFECHA and ARSTAN illustrate the chronology’s potential for further analysis (Table 6). An average series intercorrelation
of .536 indicates that the 20 final samples strongly follow a common pattern and cross-date well. However, mean sensitivity is .180, indicating low variability and a common signal indicative of high precipitation areas (Grissino-Mayer 2001). While considered too weak for climate reconstruction, sensitivity is adequate for the analyses discussed above which do not require the same degree of tree-ring variability to ensure statistically significant results (Speer 2010). Average autocorrelation is high at .823, as expected for a high-elevation species that retains its needles for several years (Grissino-Mayer 2001; LaMarche and Stockton 1974), such as whitebark pine.

Table 6. Chronology Characteristics.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>WRR - WM - WBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Trees Cored</td>
<td>41</td>
</tr>
<tr>
<td>Number of Cores</td>
<td>66</td>
</tr>
<tr>
<td>Number of Dated Series</td>
<td>20</td>
</tr>
<tr>
<td>Average Core Length (years)</td>
<td>383.6</td>
</tr>
<tr>
<td>Master Chronology</td>
<td>1177–2011</td>
</tr>
<tr>
<td></td>
<td>(835 years)</td>
</tr>
<tr>
<td>Series Intercorrelation</td>
<td>.536</td>
</tr>
<tr>
<td>Mean Sensitivity</td>
<td>.180</td>
</tr>
<tr>
<td>Autocorrelation</td>
<td>.823</td>
</tr>
<tr>
<td>Expressed Population Signal</td>
<td>.7959</td>
</tr>
</tbody>
</table>

The final metric is derived from the standardized chronology produced in ARSTAN. The expressed population signal (EPS) is a further measure of the strength of a chronology’s common signal, in this case the stand-level climate signal. EPS for the High Rise Village chronology is .7959. A value of .85 is typically used as a cutoff for signal strength (Cook and Kairiukstis 1990; Wigley et al. 1984) and the weak signal for the
chronology is acknowledged. However, this study is not interested in climate reconstruction, which requires a high EPS, and the signal is likely sufficient for determining differences in modes of temporal variability between the MWP and LIA.

**Response Function Analysis**

Climate variable analysis determined that during the last 116 years, annual growth correlated significantly with current year early-spring and late-fall conditions (Figure 10). Specifically, growth correlates positively with April, May, and November maximum temperatures and with April average precipitation. Further, moving window analyses with both variables indicated that growth responded consistently throughout the instrumental record, indicating these relationships may also be consistent throughout the chronology. Growth did not correlate significantly with drought. Because growth is limited by both temperature and precipitation in a consistent manner during the last century, variation determined in subsequent analyses may also be a function of both climate variables.

While response function analysis indicated a negative nonsignificant relationship to drought for the instrumental period (Figure 10), running correlation coefficients for the entire chronology determined this relationship is not constant. Instead, correlations between growth and annual PDSI oscillate between positive and negative in a semiregular, multidecadal manner throughout the last eight centuries (Figure 11).
Figure 10. Correlation coefficients by climate variable and month.

Figure 11. Thirty-one-year running correlation between climate-driven growth and PDSI.

Spectral Analysis

Wavelet analysis revealed distinct differences in dominant periodicities during the MWP and LIA. The wavelet power spectrum and global wavelet are presented in the lower portion of Figure 12. The MWP shows a variety of periodicities, including strong
periodicities at 30–100 years. The cone of influence and global wavelet indicate that 30-year periodicities dominate the MWP as well as later portions of the chronology. In contrast, throughout most of the LIA, significant variability occurs at two to four years, though early and late portions follow patterns similar to the MWP. The wavelet power spectrum clearly indicates that the MWP and LIA are characterized by dramatically different patterns of temporal variability at High Rise Village.

![Wavelet Power Spectrum](image)

Figure 12. The running correlation between climate-driven annual growth and the Pacific Decadal Oscillation (PDO) and the wavelet power spectrum. Results are subdivided by climate period. The global wavelet is at the bottom right.

**Climate Period Analysis**

The running correlation between the smoothed RWI values and the PDO index values further indicate distinct differences between the MWP and LIA. Results are presented above the wavelet power spectrum in Figure 12.
For the MWP, there is significant positive correlation between climate-driven growth at High Rise Village and PDO ($r = .565, p < .001$). In contrast, LIA growth does not correlate with PDO ($r = .063, p = .104$). As with the wavelet analysis, there are distinct differences in temporal variability and broader climate influences between the MWP and LIA. Modern climate conditions bring a new pattern to the site with weak positive correlation between growth and PDO ($r = .221, p = .003$).

**Discussion**

The preceding analyses indicate that during the last century, annual growth in whitebark pine at High Rise Village responded to variation in both temperature and precipitation. Further, there are distinct differences in modes of variability and climate expression between the MWP and LIA at the site. The following discussion first characterizes the relationship between annual growth and climate at High Rise Village. The differences between the MWP and LIA are considered next, particularly in terms of environmental and resource variability and foraging risk. These differences are weighed in terms of the High Rise Village z-score model and the environmental assumptions it is built upon.

**Growth and Climate at High Rise Village**

*Temperature and Precipitation.* Response function analysis determined that during the last 116 years, growth consistently correlated positively with high early-spring temperatures and precipitation and late-fall temperatures. The correlation
implies above average growth in years with at least one of the following features: a warm early-spring, a warm late-fall, a wet early-spring. Because extreme cold disrupts photosynthesis and respiration, growing season temperatures often limit growth in high elevation conifers (Fritts 1976; Tranquillini 1979). A warm early-spring or late-fall extends the growing season, potentially leading to greater ring width.

It is worth noting that the correlation between growth and November temperature may not indicate a causal relationship as late season growth in high elevation whitebark pine has often ceased before November (Tomback et al. 2001). If this is the case, current year ring width cannot be the result of late-fall conditions during the same calendar year. Instead, this relationship may be the result of autocorrelation, previously determined to be high in this chronology, and current year late-fall above average temperatures may influence subsequent growth.

Insufficient water can also limit growth at high elevations, particularly on a relatively dry, south-facing slope (Tranquillini 1979), such as at High Rise Village. A wet early-spring means more water is available to roots, whether immediately or by augmenting the year’s snowpack and extending water availability during the summer. The positive correlation with early-spring temperature likely also relates to water availability at the site. In early-spring, most water remains trapped as snow and is inaccessible to trees. A warm spring ensures early melt. Further, the positive effects of an early melt are likely augmented by the remnant rock glacier upslope of the site, which retains water and ice well beyond the spring thaw and ensures a steady release of snow melt well into summer.
High elevation whitebark pine studies in central Idaho (Perkins 2001; Perkins and Swetnam 1996) found similar underlying relationships between climate variables and growth using 95 years of instrumental data. In particular, early season temperature plays a critical role in growing season length, and together, temperature and precipitation control growing season moisture availability. This complex relationship between growth and available moisture and temperature is common in high elevation pines in the western United States (Kipfmüller and Salzer 2010).

PDSI. The influences of temperature and precipitation further lend themselves to a likely explanation for the oscillating correlation between growth and PDSI during the last eight centuries. PDSI is a function of both temperature and precipitation (Palmer 1968) and annual PDSI values depend on the relative strengths of both variables. Dry years (negative values) imply above average temperatures and/or below average precipitation; the opposite is true for wet years. When growth is primarily limited by one of these variables, a chronology should correlate with PDSI in a relatively consistent manner as growth tracks a single variable through time. Because growth at High Rise Village responds to both variables, correlation varies. Each year, trees at the site respond to both temperature and precipitation and the cumulative response determines the correlation between growth and PDSI. The mixed correlation relationship could be the product of one response outweighing the other or a similar response to both variables. As the relative influences of temperature and precipitation vary through time, so do the correlations. The result is a complex
relationship between growth and PDSI at High Rise Village, with periods of positive and negative correlation throughout the last eight centuries.

The question remains why the correlations oscillate in a multidecadal manner. Significant correlation between the MWP portion of the chronology and PDO suggest that multidecadal patterns are related to Pacific Ocean teleconnections during this period. However, PDSI patterns persist during the LIA when there is no correlation with PDO. It is worth mentioning that Anderson (2010) was able to demonstrate continued influence of Pacific sea surface temperature patterns on Wind River Range snowpack during much of the LIA. Long-term influences on temperature and precipitation at the site, particularly during the LIA, bear further examination.

The MWP and LIA at High Rise Village

All tree ring analyses undertaken for this thesis indicates that climate at High Rise Village during the MWP was stable, relative to the LIA. Response function analyses indicated that both temperature and precipitation may have been stable over spans of 30–100 years, though this cannot be verified beyond the instrumental record. Coherence between the wavelet power spectrum, the correlation with PDO, and the correlation with PDSI indicates that the MWP was primarily characterized by multidecadal modes of variability. Wavelet analysis specifically demonstrates that 30-year variability is the dominant mode during this period. The positive, moderate correlation with the multidecadal PDO further bolsters these results and provides partial explanation for MWP stability. The relationship between growth and PDSI is less clear,
but also follows long-term patterning. Together, these data demonstrate climatic change operating at scales exceeding one human generation (and in several cases encompassing four to five generations) during the final centuries of the MWP at High Rise Village.

Given multidecadal variability, the High Rise Village environment was, to human foragers, relatively stable during the MWP. Because growth at the site is likely limited by both temperature and precipitation, cycling in both variables probably took several decades of mostly incremental change. Growing season lengths and conditions would have been relatively consistent for plants in the area, as well as the animals that relied on them. Abrupt change would have been infrequent, as would any resultant shift in resource population structure or productivity. Under the stable conditions identified here, resources would have been stable and minimally variable.

Climatic and resource stability would have made foraging returns relatively predictable at High Rise Village. Stability reduces foraging uncertainty by effectively lengthening the period of time in which knowledge about the environment remains useful for hunter-gatherers in the area (Winterhalder et al. 1999). Because the MWP primarily varied at a scale longer than a human generation (25 years, Dean et al. 1985), foraging, hunting and other environmental knowledge would have remained relevant for decades or more. In short, the High Rise Village environment and resources were relatively predictable during the MWP.

It is necessary to note that MWP sample size is small for this study (n = 2–4, Figure 9) and the above characterization is necessarily tentative. However, results at the
site are comparable to similar studies in the greater region, which indicate multidecadal variability in precipitation during the final centuries of the MWP (Gray et al. 2003; Herweijer et al. 2007).

In contrast to the MWP, the LIA is characterized by interannual variability and unpredictability with regard to expected resource return rates. During the early LIA, variability shifts from 30-year cycles to two- to four-year cycles, considerably shorter than a human generation.

Also, there ceases to be any correlation between climate-driven growth at High Rise Village and PDO, indicating that the multidecadal teleconnection is no longer a stabilizing factor for local climate. This is particularly interesting in light of Anderson’s (2010) determination that Pacific teleconnections likely influence climate during the LIA in the Wind River Range. At least in terms of PDO, this is not the case at High Rise Village. Correlation with PDSI indicates that some longer-term patterns persist during the LIA, but these patterns are neither strong nor significant in the wavelet power spectrum. Together these data indicate the LIA at High Rise Village was a period of rapid and frequent change, though further research into the relative influences of Pacific patterns in the Wind River Range is needed.

The LIA presented foragers with an inconsistent environment and unpredictable resources. Sheep are particularly sensitive to short-term environmental variability, particularly with regard to forage and water (Douglas 2001; Epps et al. 2004). Marmots struggle with environmental variability as well in that it disrupts hibernation and breeding cycles during the spring and fall (Inouye et al. 2000). Lastly, whitebark pine
requires two years of suitable conditions to mature more than a few cones (Tomback et al. 2001). Abrupt, frequent change at an interannual scale would have threatened many cone yields and mast years would likely have been rare. Under variable LIA conditions, resource health, reproductive success, and productivity would have been quite variable and foraging returns would likely have reflected this variability. In turn, increased variability would have reduced resource predictability for hunter-gatherers at High Rise Village.

It is assumed in the High Rise Village z-score model that the MWP and LIA offered contrasting conditions for the risk-sensitive forager at High Rise Village. The MWP climate and environment was characterized as stable and predictable, leading to longer stays and frequent use. Conversely the LIA was assumed to be relatively unpredictable due to greater environmental and resource variability, leading to infrequent, shorter-term use of the area. These assumptions have been largely corroborated by the dendroclimatological study undertaken here. Tree-ring data indicate that temperature and precipitation during the MWP were stable at the site, and it can be reasonably assumed that resources were minimally variable and predictable. In contrast, the LIA was characterized by interannual variability, likely resulting in highly variable, unpredictable foraging within the High Rise Village catchment.
CHAPTER 5

THE HIGH RISE VILLAGE ARCHAEOLOGICAL STUDY

Chronometric, subsistence, and flaked stone data were sampled and analyzed from Medieval Warm Period (MWP) components of the site. These data were compared against expected behaviors for the climate period. Infrequent use of the site during the Little Ice Age (LIA) limited data from this period to projectile points, which are discussed in comparison to MWP chronometric data. This chapter first describes the 2010 and 2011 excavations at High Rise Village which generated the data used in this project, followed by the analyses used to compare these data to model expectations. The chapter concludes with a discussion of the results in terms of the High Rise Village z-score study and regional culture histories.

Excavation

Data for this thesis were acquired during the 2010 and 2011 field seasons at High Rise Village. The methods and results of these field seasons are discussed below.

2010 Field Season

This study sampled the lithic and chronometric data from the Lodge 22, 26, 49, and W assemblages, all excavated during the 2010 field season. Obsidian and chronometric data were also sampled from Lodge SS. Methods and results from the 2010 excavation are described in Morgan, Losey, and Adams (2012) and in Morgan
(2011); excavation methods were the same for all lodges, though unit size varied (Table 7).

Table 7. 2010 Excavation Summary.

<table>
<thead>
<tr>
<th>Lodge</th>
<th>Unit No.</th>
<th>Unit Size</th>
<th>Max. Depth (cmbs*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>1</td>
<td>1-x-1 m</td>
<td>40</td>
</tr>
<tr>
<td>26</td>
<td>1</td>
<td>1-x-1 m</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1-x-.5 m</td>
<td>40</td>
</tr>
<tr>
<td>49</td>
<td>1</td>
<td>1-x-1 m</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1-x-1 m</td>
<td>40</td>
</tr>
<tr>
<td>W</td>
<td>1</td>
<td>50-x-50 cm</td>
<td>30</td>
</tr>
</tbody>
</table>

*centimeters below surface

2011 Field Season

In addition to data from the lodges above, Lodge 16 was excavated in 2011 to sample the previously unexplored above treeline portion of the site and to provide additional chronometric, groundstone, and flaked stone data.

Methods. A 1-x-1 m unit (Unit 1) was placed in roughly the center of the lodge and excavated in 5 cm levels. Each level was excavated and screened in 50-x-50 cm quadrants. Level fill was reduced by dry screening and then wet-screened, both with one-eighth inch screen. Levels were documented using unit level forms describing provenience, artifact and ecofact counts and descriptions, stratigraphy, and disturbances. All artifacts and samples were bagged by quadrant. The east wall, all level floors, and all in situ artifacts were recorded with a scale profile or sketch and photographed. All in situ groundstone were handled minimally, wrapped in aluminum
foil, and bagged to avoid contamination for residue analysis. Excavation was terminated at the end of Level 5 (20–25 cmbs) because the level was culturally sterile.

*Results.* Debitage, flaked stone tools, and groundstone were recovered throughout Levels 1 through 4. Dark charcoal staining with charcoal flecks and pieces was sampled for radiocarbon analysis in Levels 3 and 4.

One charcoal sample (FS 16.1.3–011) from Level 3 was sent to the Center for Applied Isotope Studies at the University of Georgia (Figure 13), and reported in Table 11 below as well as Table 1 (Chapter 2).

![Charcoal Staining Diagram](image)

Figure 13. Lodge 16, Unit 1 (1-x-1 m), Level 3 (10–15 cmbs) with charcoal sample (FS 16.1.3–011) provenience.
Two corner-notched and one side-notched point were recovered during excavation and one small, concave-based triangular point was recovered from a macrobotanical sample (Figure 14).

![Figure 14. Lodge 16 projectile points: (a) corner-notched; (b) corner-notched; (c) side-notched; (d) concave-based triangular.]

The corner-notched points, (a) and (b), are not typed but are considered likely contemporaneous with Rosegate and other corner-notched points in the region; 1500–900 cal B.P. on the Plains (Kornfeld et al. 2010), 1500–600 cal B.P. in the mountains (Larson and Kornfeld 1994) and 1800–900 cal B.P. in the basins of southwestern Wyoming (McNees 1992; Thompson and Pastor 1995). The points compare favorably with Late Prehistoric corner-notched points recovered from Mummy Cave (Husted and Edgar 2002, pages 202 and 204, plates 32 and 34) as well as some Rosegate examples (page 206, plate 36). Nonetheless, it must be acknowledged that the points are similar
to Pelican Lake points (approximately 3100–1500 B.P.; Frison and Walker 2007; Kornfeld et al. 2010; Wettlaufer 1955), particularly the wide base of (b). Pelican Lake points would correspond with late Archaic dates at the site (Table 1, Chapter 2). Similarly, the points also suggest Elko points, corner-notched dart points common in the Great Basin (3500–1300 B.P.; Heizer and Baumhoff 1961; Justice 2002; Thomas 1981). Elko points overlap with Rosegate points in size, can be difficult to tell apart, and also correspond with late Archaic dates at the site (Justice 2002; Thomas 1981). However, Pelican Lake points are not common south or west of the Bighorn Basin (Kornfeld et al. 2001; Smith 2005) and Elko points are rarely mentioned in the literature of southwestern Wyoming. Thus, it is considered likely that both are Late Prehistoric corner-notched points.

The side-notched point (c) is a Late Prehistoric side-notched point, common throughout the Plains and Wyoming Basin 900–250 B.P. (Larson and Kornfeld 1994; McNees 1992) and after 600 B.P. in the mountains (Larson and Kornfeld 1994; Scheiber and Finley 2010).

The concave-base triangular point (d) is also considered likely Late Prehistoric. Its shape and small size is comparable with Late Prehistoric triangular points at Mummy Cave, one of which exhibits a similar concave base (Husted and Edgar 2002, page 230, plate 60, “u”). Several Late Prehistoric unnotched points from the Firehole Basin site also have similar concave bases (Lubinski et al. 2007, Figure 2). Further, small, unnotched triangular points are diagnostic of the Firehole Phase (900–250 B.P.) throughout the Wind River Basin, along with small side-notched and tri-notched points (McNees 1992).
However, the shape is also suggestive of a Middle Plains Archaic McKean lanceolate point (Green 1975; Mulloy 1958), though typically McKean points are both wider and longer than the above point (e.g. Davis and Keyser 1999, Figures 3–6; Kornfeld et al. 2010, Figures 2.57 and 2.58). It is worth mentioning that Davis and Keyser (1999) suggest that small McKeans, comparable to the above, are toys. Nonetheless, the above is considered a likely Late Prehistoric triangular point, primarily due to its small size, and is considered contemporary with the side-notched point (c).

**Dating Lodges**

This project relied on radiocarbon dates and temporally diagnostic projectile points to determine whether the 2010 and 2011 lodges were occupied primarily during the MWP, LIA, or earlier.

Rosegate corner-notched projectile points (Lanning 1963; Thomas 1981) and other contemporaneous corner-notched points (Kornfeld et al. 2010) were used to date MWP lodges. Corner-notched points date from approximately 1500–900 cal B.P. on the Plains (Kornfeld et al. 2010), 1500–600 cal B.P. in the mountains (Larson and Kornfeld 1994), and 1800–900 B.P. in the Wyoming Basin (McNees 1992, 2006; Metcalf 1987; Smith 2005; Thompson and Pastor 1995).

The temporal span for Rosegate points used here is 1500–600 B.P. While this span predates the MWP by three centuries, generally “medieval” (i.e., warm and dry) climate conditions began as early as 1800 B.P. in the region (e.g. Ahlbrandt et al. 1983; Davis 1988) and pre-MWP Rosegates are likely indicative of behavior under similar
environmental conditions. Radiocarbon dates corresponding to this span are also considered MWP occupations.

Side-notched, tri-notched, and unnotched Late Prehistoric points date from 900–250 cal B.P. in the Plains and basins (Larson and Kornfeld 1994; McNees 1992; Thompson and Pastor 1995), 600–250 cal B.P. in the mountains (Larson and Kornfeld 1994). These points and corresponding radiocarbon dates are used to date LIA occupations at High Rise Village.

**Radiocarbon Dates.** All MWP and LIA radiocarbon dates from High Rise Village are presented in Table 8, the earliest dates from the site are presented as well for discussion. See Table 1, Chapter 2 for all radiocarbon data. While this project is primarily concerned with lodges excavated and dated in 2010 and 2011, Adam’s (2010) data are included for the purposes of later discussion.

The oldest dates at the site (from Lodges 16 and 49) and the youngest from Lodge CC are here rejected due to problems regarding sample context. The oldest dates are rejected as an old wood problem (Schiffer 1986; Thomas 1982) based on environmental and archaeological considerations. Very old wood is abundant across the site landscape. Whitebark pine can live for seven or more centuries (Perkins and Swetnam 1996; Tomback et al. 2001) and radiocarbon dating of above treeline remnants at the site indicates that their downed wood can persist for at least that long (872 ± 46 B.P.; above treeline remnant; WRR-WM-WBP-25; Morgan, Losey, and Adams 2012). Further, there are no temporally diagnostic artifacts from any lodges that clearly correspond to the older, mid-Archaic AMS dates (Adams 2010a; Morgan, Losey, and
Based on the paucity of corresponding projectile points and the excellent preservation of wood at the site, these dates are not considered representative of human use of the site.

Table 8. MWP and LIA Radiocarbon Dates by Lodge.

<table>
<thead>
<tr>
<th>Lodge</th>
<th>Context</th>
<th>$^{14}$C Age</th>
<th>Cal BP (1-Sigma)$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC$^b$</td>
<td>Sherd residue</td>
<td>130 ± 40</td>
<td>160 ± 100</td>
</tr>
<tr>
<td>CC$^b$</td>
<td>Structural timber</td>
<td>420 ± 50</td>
<td>450 ± 80</td>
</tr>
<tr>
<td>S$^b$</td>
<td>Hearth</td>
<td>840 ± 40</td>
<td>770 ± 50</td>
</tr>
<tr>
<td>D$^b$</td>
<td>Lodge fill</td>
<td>1070 ± 30</td>
<td>1000 ± 40</td>
</tr>
<tr>
<td>26$^c$</td>
<td>Hearth</td>
<td>1210 ± 25</td>
<td>1150 ± 50</td>
</tr>
<tr>
<td>26$^c$</td>
<td>Hearth</td>
<td>1480 ± 25</td>
<td>1380 ± 30</td>
</tr>
<tr>
<td>W$^c$</td>
<td>Charcoal lens</td>
<td>1560 ± 25</td>
<td>1470 ± 40</td>
</tr>
<tr>
<td>SS$^b$</td>
<td>Hearth</td>
<td>1570 ± 40</td>
<td>1480 ± 50</td>
</tr>
<tr>
<td>49$^b$</td>
<td>Hearth</td>
<td>3880 ± 30</td>
<td>4430 ± 60</td>
</tr>
<tr>
<td>49$^c$</td>
<td>Hearth</td>
<td>3960 ± 25</td>
<td>4450 ± 40</td>
</tr>
<tr>
<td>49$^b$</td>
<td>Lodge fill</td>
<td>4000 ± 40</td>
<td>4480 ± 40</td>
</tr>
<tr>
<td>16$^c$</td>
<td>Charcoal smear</td>
<td>4010 ± 25</td>
<td>4480 ± 40</td>
</tr>
</tbody>
</table>

$^a$ All dates calibrated using CalPal 2007 (Weninger et al. 2012) and the HULU calibration dataset (Weninger and Jöris 2008).
$^b$ Uncalibrated dates reported in Adams (2010a).
$^c$ Reported in Morgan, Losey, and Adams (2012).

The LIA dates from Lodge CC are also rejected because of the materials sampled for dating. One date was obtained from organic residue on a sherd recovered during excavation. Dating residues on sherds is highly problematic (Roper 2013), and it is unknown whether the dated residue is from food prepared in the vessel or, more likely, organic material introduced since deposition. The other date is from a part of a log found during excavation of the lodge. It is unknown whether the dated sample represents a structural timber as suggested by Adams (2010a) or naturally downed wood buried over the last four centuries.
Of the remaining lodges, Lodges 26 and W are considered MWP occupations. The dated samples were collected from discrete features in each lodge and are believed to reflect human behavior at the site. None of the lodges used here date to the LIA (post-600 B.P.).

*Projectile Points.* Counts and percentages for projectile points recovered during excavation are summarized by lodge in Table 9; counts do not include nondiagnostic fragments. No projectile points were found in subsurface contexts that clearly predate Rosegate or other corner-notched points. No projectile points were recovered from Lodge W.

<table>
<thead>
<tr>
<th>Lodge</th>
<th>Corner-notched</th>
<th>Rosegate</th>
<th>Late Prehistoric</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>4</td>
<td>4</td>
<td>100%</td>
<td>8</td>
</tr>
<tr>
<td>49</td>
<td>-</td>
<td>2</td>
<td>100%</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>-</td>
<td>50%</td>
<td>4</td>
</tr>
<tr>
<td>SS</td>
<td>-</td>
<td>3</td>
<td>100%</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>9</td>
<td>88%</td>
<td>17</td>
</tr>
</tbody>
</table>

While samples are small, the Lodge 26 and 49 assemblages are dominated by corner-notched or Rosegate points and are considered primarily MWP occupations. The Lodge 16 assemblage is split between corner-notched and later points. While the lodge’s chronometric data will be discussed further, its flaked stone assemblage cannot be considered primarily MWP or LIA and is not included in the analyses below. Lodge SS is similarly treated as it has two radiocarbon dates that predate its Rosegate assemblage.
Discussion. Lodges 26, 49, and W comprise the MWP assemblage at High Rise Village. Lodges 26 and W are included for their radiocarbon dates, which in Lodge 26 are further corroborated by eight Rosegate and corner-notched projectile points. Because this study rejects the oldest radiocarbon dates at the site, Lodge 49 is also included given its Rosegate projectile points.

No lodges date exclusively to the LIA, though triangular and side-notched points from Lodge 16 arguably indicate some use of the site during this period. It is worth mentioning that these point types can occur as early as 900 B.P. in the region and these points may predate the LIA. Which the exception of the final consideration of chronometric data from the site, the below analyses lack an LIA component and most LIA hypotheses and expectations remain unexplored.

Analyses

Macrobotanical flotation, groundstone residue analysis, flaked stone tool and debitage analyses, obsidian sourcing and hydration, and chronometric data comparison were used to characterize MWP use of the site and compare use to the behavior expected under the High Rise Village z-score model.

Macrobotanical Sampling

Methods. To reconstruct the plant resources in the High Rise Village diet, macrobotanical sampling was undertaken at Lodges 16, 22, 26, 49, and W. Sampling targeted intact cultural deposits within previously excavated lodges. Extensive
extralodge shovel and auger testing was undertaken during the 2012 field season and revealed no cultural deposits outside of lodges, in spite of particular attention paid to potential areas of discard and deposition. Forty-eight shovel/auger tests as well as six years of work entailing intensive surface inspection of the High Rise Village site indicates that lodges offer the best option to recover macrobotanical remains at the site.

The four previously excavated lodges were relocated and 25-x-50 cm soil samples were excavated immediately adjacent to previous excavation units. Lodge 16 was sampled in the same manner during excavation. One sample was taken per lodge, excavated in 5 cm levels and terminated at bedrock. Each level was approximately 4 liters in volume. Levels were assigned macrobotanical sample numbers designating lodge number, sample number, and level number (MS - ## - ## - ##) and bagged separately.

The macrobotanical samples were floated to separate lighter botanical remains from soil and gravels (Smith 1985). Each sample was floated separately and volume was recorded in liters before flotation (Wohlgemuth 1996). Once separated, light fractions were dried in fine-meshed screens and sorted to separate subsistence remains from natural debris (Smith 1985).

Results. A total of twenty-two samples were collected from Lodges 16, 22, 26, 49, and W. One sample was discarded due to limited space in packhorse panniers, bringing the total to 21. Level 5 from Lodge 16 was chosen for discard because it was from the “B” horizon, which was determined to be culturally sterile during excavation.
Eleven of the remaining 21 samples were sorted during the following year. The first two levels (10 cm) of each sample were not sorted as they were found to be primarily composed of modern forest debris. No evidence of prehistoric subsistence was found in any of the macrobotanical samples.

The absence of subsistence remains may reflect sampling problems, human behavior, or poor preservation at the site. As mentioned previously, all 2011 macrobotanical sampling took place within lodges and subsistence remains may be elsewhere at the site. However, this is unlikely based on extensive testing in 2012.

There is also the possibility that the lack of subsistence data represents limited or no plant processing at High Rise Village. The moderate abundance of groundstone at the site suggests this is unlikely.

Without successful flotation or residue analysis (below) it is difficult to determine whether the lack of macrobotanical remains represents human behavior or poor preservation due to the site’s steep slope and shallow, acidic soils. However, given the quantity of groundstone and its importance for plant processing in the region (Kornfeld et al. 2010), it appears most likely that macrobotanical preservation is very poor at the site.

**Groundstone Analysis**

*Methods.* One groundstone fragment from Lodge 16 was sent to the Laboratory of Archaeological Science at California State University, Bakersfield for residue analysis using a wide variety of antisera (Table 10).
<table>
<thead>
<tr>
<th>Animal Antisera</th>
<th>Identifies</th>
<th>Source</th>
<th>Plant Antisera</th>
<th>Identifies</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alligator</td>
<td>Alligator, crocodile</td>
<td>CR(^a)</td>
<td>Agave</td>
<td>Agave, yucca</td>
<td>UC(^c)</td>
</tr>
<tr>
<td>Bear</td>
<td>Black, grizzly, etc.</td>
<td>CR</td>
<td>Amaranth</td>
<td>Amaranth, pigweed, quelite, etc.</td>
<td>“</td>
</tr>
<tr>
<td>Bovine</td>
<td>Bison, cow, musk ox</td>
<td>CR</td>
<td>Aster</td>
<td>Camas, wild hyacinth</td>
<td>“</td>
</tr>
<tr>
<td>Camel</td>
<td>All camelids</td>
<td>LB(^b)</td>
<td>Bitterroot</td>
<td>Beeplant, bladderpod, stinkweed, etc.</td>
<td>“</td>
</tr>
<tr>
<td>Cat</td>
<td>Bobcat, cougar, Lynx, etc.</td>
<td>CR</td>
<td>Camas</td>
<td>Cedar, cypress, juniper</td>
<td>“</td>
</tr>
<tr>
<td>Chicken</td>
<td>Quail, grouse, other gallinaceous fowl</td>
<td>“</td>
<td>Capparidaceae</td>
<td>Goosefoot, greasewood, pickleweed saltbush, etc.</td>
<td>“</td>
</tr>
<tr>
<td>Deer</td>
<td>Deer, elk, moose</td>
<td>“</td>
<td>Cedar</td>
<td>Mallows</td>
<td>“</td>
</tr>
<tr>
<td>Dog</td>
<td>Coyote, dog, wolf</td>
<td>“</td>
<td>Chenopod</td>
<td>Mesquite, Palo verde, other legumes</td>
<td>“</td>
</tr>
<tr>
<td>Elephant</td>
<td>Elephant, mammoth</td>
<td>LB</td>
<td>Lomatium</td>
<td></td>
<td>“</td>
</tr>
<tr>
<td>Guinea-Pig</td>
<td>Beaver, guinea-pig, porcupine, squirrel</td>
<td>“</td>
<td>Mallow</td>
<td></td>
<td>“</td>
</tr>
<tr>
<td>Horse</td>
<td>Horse, donkey, etc.</td>
<td>“</td>
<td>Mesquite</td>
<td></td>
<td>“</td>
</tr>
<tr>
<td>Human</td>
<td>Human</td>
<td>CR</td>
<td></td>
<td></td>
<td>“</td>
</tr>
<tr>
<td>Rabbit</td>
<td>Rabbit, hare, pika</td>
<td>“</td>
<td></td>
<td></td>
<td>“</td>
</tr>
<tr>
<td>Rat</td>
<td>All rat &amp; mouse species</td>
<td>“</td>
<td></td>
<td></td>
<td>“</td>
</tr>
<tr>
<td>Sheep</td>
<td>Bighorn &amp; other sheep</td>
<td>“</td>
<td></td>
<td></td>
<td>“</td>
</tr>
<tr>
<td>Swine</td>
<td>Pig, possibly Javelina</td>
<td>“</td>
<td></td>
<td></td>
<td>“</td>
</tr>
<tr>
<td>Trout/Salmon</td>
<td>All species</td>
<td>LB</td>
<td></td>
<td></td>
<td>“</td>
</tr>
</tbody>
</table>

\(^a\) Cappel Research. \(^b\) Lampire Biomedical. \(^c\) University of Calgary.
Results. All tests were negative and no other groundstone was submitted. It is worth noting that previous blood residue analysis on flaked stone tools (n = 2) also failed (Morgan, Losey, and Adams 2012). The failure of all residue analyses likely indicates poor preservation or perhaps laboratory error.

Flaked Stone Analysis

Methods. As a means to investigate mobility and gauge the diversity of foraging and processing activities at High Rise Village, flaked stone tools from each MWP lodge were separated into two categories: bifacial and informal tools. Bifacial tools were defined as tools that were reduced and shaped to form two “faces” which joined at a single edge around the circumference of the artifact (Andrefsky 2005; Kelly 1988; Kooyman 2000). Both faces had to show evidence of flake removal, the size and shape of which vary depended on the stage of reduction (Andrefsky 2005; Callahan 1990). All stages of reduction, from the early removal of large flakes and rough shaping to finished tools (e.g., projectile points) were considered bifacial tools.

Informal tools were defined as unmodified or minimally modified flakes (Andrefsky 2005; Kooyman 2000; Nelson 1991). Unmodified flake tools were identified by use wear on at least one flake margin. Minimally modified flake tools could also show use wear in addition to at least one retouched edge. Counts and proportions of formal and informal tools were calculated for each MWP lodge.

In conjunction with tool analysis, debitage from one quadrant of one level was analyzed for all lodges (Table 11). The exception was the 50-x-50 cm unit from Lodge W
which was not subdivided into quadrants; all debitage from one level were analyzed. 

Quadrants were originally limited to those with greater than 100 flakes. This was not possible with Lodges 49 and W, in which case the quadrant/level with the most flakes was chosen instead.

<table>
<thead>
<tr>
<th>Lodge</th>
<th>Unit</th>
<th>Level (cmbs)</th>
<th>Quad</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>1</td>
<td>0–5</td>
<td>SW</td>
<td>258</td>
</tr>
<tr>
<td>22</td>
<td>1</td>
<td>0–5</td>
<td>NW</td>
<td>239</td>
</tr>
<tr>
<td>49</td>
<td>2</td>
<td>5–10</td>
<td>SW</td>
<td>67</td>
</tr>
<tr>
<td>W</td>
<td>1</td>
<td>0–5</td>
<td></td>
<td>41</td>
</tr>
</tbody>
</table>

Flakes were sorted according to type of reduction. Flake types included primary decortication, secondary decortication, early interior percussion, late interior percussion, biface thinning, pressure, shatter, and indeterminate. This analysis adhered strictly to a conservative classification of flake types; see Table 12 for the diagnostic attributes of each flake type. Shatter is defined an angular piece of toolstone that lacks flake characteristics (Andrefsky 2005). Indeterminate flakes are flake fragments that do not have sufficient diagnostic features to classify the fragment into one of the above categories.

The z-test for two proportions was used to determine whether differences in tool and debitage proportions were significant between MWP and LIA components. Though tests were limited by sample sizes; the test requires at least five, preferably 10, samples to make up each proportion (Utts and Heckard 2011). The resulting z-score and
Table 12. Debitage Analysis Flake Type Attributes.

<table>
<thead>
<tr>
<th>Attributes:</th>
<th>Core Reduction</th>
<th>Bifacial Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size/Shape</td>
<td>&gt;3 cm</td>
<td>Symmetrical</td>
</tr>
<tr>
<td>Thickness</td>
<td>≤3 cm</td>
<td>Uniform</td>
</tr>
<tr>
<td>Cortex</td>
<td>&gt;70%</td>
<td>&lt;5 mm</td>
</tr>
<tr>
<td>Platform</td>
<td>&quot;U&quot;-shaped</td>
<td>Uniform below bulb</td>
</tr>
<tr>
<td>shape</td>
<td></td>
<td>below bulb</td>
</tr>
<tr>
<td>Platform</td>
<td>&quot;U&quot;-shaped</td>
<td>Thinning</td>
</tr>
<tr>
<td>Condition</td>
<td></td>
<td>flake scars</td>
</tr>
<tr>
<td>Bulb of</td>
<td>Yes</td>
<td>Grinding,</td>
</tr>
<tr>
<td>Percussion</td>
<td>Yes</td>
<td>crushing</td>
</tr>
<tr>
<td>Flake Scars</td>
<td>≤2</td>
<td></td>
</tr>
<tr>
<td>Dorsal</td>
<td>≥3</td>
<td></td>
</tr>
<tr>
<td>curvature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventral</td>
<td>Yes</td>
<td>Reduced concave</td>
</tr>
<tr>
<td>curvature</td>
<td>Less</td>
<td>or convex</td>
</tr>
<tr>
<td></td>
<td>pronounced</td>
<td></td>
</tr>
</tbody>
</table>

corresponding p-value indicate the likelihood that that the differences in observed probabilities are due to the vagaries of sampling.

Results. Flaked stone tools recovered from Lodges 26 and 49 are summarized in Table 12 below; no tools were recovered from Lodge W. Only Lodge 26 met the minimum criteria of the z-test (n ≥ 10).

While bifacial tools appear to make up the majority of the Lodge 26 assemblage, these proportions are not statistically significant (z = .6412, p = .2607). The proportions
observed in Lodge 49 are similarly evenly split, though with a slight majority of informal tools.

Table 13. MWP Tool Assemblage.

<table>
<thead>
<tr>
<th>Lodge</th>
<th>Bifacial Tools</th>
<th>Informal Tools</th>
<th>Total</th>
<th>z-score</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>13</td>
<td>10</td>
<td>23</td>
<td>.6412</td>
<td>.2607</td>
</tr>
<tr>
<td>49</td>
<td>4</td>
<td>5</td>
<td>9</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Debitage. A total of 117 flakes was analyzed from Lodge 26 once indeterminate flakes and shatter (n = 141) were removed from the sample (Table 13). Similarly, 25 of 67 flakes from Lodge 49, and 27 of 41 flakes from Lodge W were analyzed.

The Lodge 26 debitage sample is clearly dominated by debris from bifacial reduction but with a moderate proportion from core reduction. The observed proportions are significant (z = 2.5771; p = .0050). Flake proportions do not differ significantly in Lodges 49 (z = .1918, p = .4239) or W (z = .6000, p = .2743).

Under the High Rise Village z-score model, foragers during the MWP are expected to have relied on both bifacial and core technologies given varied foraging activities and longer residential stays associated with a diverse diet. This expected assemblage heterogeneity is observed in tool and debitage assemblages. No one tool type dominates any lodge and debitage indicates use of both biface and core technologies. Bifacial reduction has a small majority in Lodges 26, likely from the repair and repurposing of formal tools. Because bifacial tools have long use lives, unlike most informal tools, it is expected that there be correspondingly more associated debitage,
Table 14. MWP Debitage Samples.

<table>
<thead>
<tr>
<th>Lodge</th>
<th>Core Reduction</th>
<th>Bifacial Reduction</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Early Int.</td>
<td>Late Int.</td>
<td>Total</td>
</tr>
<tr>
<td>26</td>
<td>6</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>49</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>W</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

even when both tool types make up similar proportions of an assemblage (Cowan 1999; Kelly 1988).

The diversity of the flaked stone assemblage indicates that during this period, High Rise Village was used as a residential site. A heterogeneous assemblage is expected at a residential base given the diversity of activities centered there, including most resource processing and the manufacture and maintenance of many material goods, such as flaked stone tools (Binford 1980; Kelly 1988). At this type of site, bifacial versatility is important, but expedient tools are effective for many activities, hence the heterogeneity (Cowan 1999; Kelly 1988). Residential use and diverse activities are also indicated by the presence of groundstone at every lodge and Koenig's (2010) intralodge analysis of artifact and feature distributions.

**Obsidian Analysis**

**Methods.** Thirty obsidian samples from Lodges 22, 26, 49, W and SS were sent to the Geochemical Research Laboratory, Portola Valley, California for X-ray fluorescence
spectrometry (XRF) sourcing. The samples were also sent to Archaeometrics, Woodland, California for obsidian hydration analysis. However, the utility of hydration data was limited because obsidian studies in the region rarely include hydration analyses and hydration rates remain poorly understood (Scheiber and Finley 2011b; Smith 1999). Analyses predated the Lodge 16 excavation and no Lodge 16 obsidian was sent for analysis.

Results. Thirty obsidian samples from Lodges 22, 26, 49, W and SS underwent X-ray fluorescence spectrometry (XRF) sourcing and obsidian hydration analysis. Of the 30 samples, 26 were sourced to seven known sources and one unknown source and hydration rim measurements were possible on 16 artifacts. Results for both analyses are presented in Table 15.

The sources represented at the site fall in to three distinct groups (Figure 15). The Teton Pass and Crescent H sources are in the vicinity of Jackson Hole, Wyoming, approximately 100 km to the west of High Rise Village. Huckleberry Tuff, Lava Creek Tuff, and Obsidian Cliff are at the northern end of Yellowstone, all approximately 170–190 km away. The Malad and Bear Gulch sources in Idaho are both more than 200 km from High Rise Village.

While the above obsidian sources have been studied (e.g., Connor and Kunselman 1995; Scheiber and Finley 2011b; Schoen 1997) there are no hydration rates developed in the region. Rim measurements cannot be assigned an approximate age and it is unknown how hydration rates compare between sources. Without a means to determine artifact age, the above measurements and sources cannot be used to discuss
### Table 15. XRF and Obsidian Hydration Results by Lodge.

<table>
<thead>
<tr>
<th>Lodge</th>
<th>Artifact Type</th>
<th>Source</th>
<th>µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Debitage</td>
<td>Bear Gulch, ID</td>
<td>2.36</td>
</tr>
<tr>
<td>26</td>
<td>Biface</td>
<td>Huckleberry Tuff, WY</td>
<td>2.63</td>
</tr>
<tr>
<td>26</td>
<td>Debitage</td>
<td>Unknown</td>
<td>-</td>
</tr>
<tr>
<td>49</td>
<td>Flake Tool</td>
<td>Bear Gulch, ID</td>
<td>1.92</td>
</tr>
<tr>
<td>49</td>
<td>Debitage</td>
<td>Teton Pass, WY</td>
<td>.99</td>
</tr>
<tr>
<td>49</td>
<td>Debitage</td>
<td>Teton Pass, WY</td>
<td>1.02</td>
</tr>
<tr>
<td>W</td>
<td>Debitage</td>
<td>Lava Cliff, WY</td>
<td>-</td>
</tr>
<tr>
<td>SS</td>
<td>Debitage</td>
<td>Crescent H, WY</td>
<td>-</td>
</tr>
<tr>
<td>SS</td>
<td>Debitage</td>
<td>Crescent H, WY</td>
<td>-</td>
</tr>
<tr>
<td>SS</td>
<td>Debitage</td>
<td>Crescent H, WY</td>
<td>-</td>
</tr>
<tr>
<td>SS</td>
<td>Debitage</td>
<td>Teton Pass, WY</td>
<td>-</td>
</tr>
<tr>
<td>SS</td>
<td>Debitage</td>
<td>Teton Pass, WY</td>
<td>-</td>
</tr>
<tr>
<td>SS</td>
<td>Debitage</td>
<td>Teton Pass, WY</td>
<td>1.05</td>
</tr>
<tr>
<td>SS</td>
<td>Debitage</td>
<td>Teton Pass, WY</td>
<td>1.06</td>
</tr>
<tr>
<td>SS</td>
<td>Debitage</td>
<td>Obsidian Cliff, WY</td>
<td>2.46</td>
</tr>
<tr>
<td>22</td>
<td>Debitage</td>
<td>Bear Gulch, ID</td>
<td>-</td>
</tr>
<tr>
<td>22</td>
<td>Debitage</td>
<td>Bear Gulch, ID</td>
<td>2.95</td>
</tr>
<tr>
<td>22</td>
<td>Debitage</td>
<td>Bear Gulch, ID</td>
<td>2.97</td>
</tr>
<tr>
<td>22</td>
<td>Debitage</td>
<td>Crescent H, WY</td>
<td>-</td>
</tr>
<tr>
<td>22</td>
<td>Debitage</td>
<td>Crescent H, WY</td>
<td>-</td>
</tr>
<tr>
<td>22</td>
<td>Debitage</td>
<td>Crescent H, WY</td>
<td>.99</td>
</tr>
<tr>
<td>22</td>
<td>Debitage</td>
<td>Crescent H, WY</td>
<td>.97</td>
</tr>
<tr>
<td>22</td>
<td>Debitage</td>
<td>Crescent H, WY</td>
<td>.99</td>
</tr>
<tr>
<td>22</td>
<td>Debitage</td>
<td>Crescent H, WY</td>
<td>.96</td>
</tr>
<tr>
<td>22</td>
<td>Debitage</td>
<td>Crescent H, WY</td>
<td>1.4</td>
</tr>
<tr>
<td>22</td>
<td>Debitage</td>
<td>Malad, ID</td>
<td>1.36</td>
</tr>
</tbody>
</table>

MWP and LIA obsidian use and mobility. However, the data do lend themselves to an exploratory discussion of changes in source use through time at High Rise Village.

Without hydration curves, the current discussion is limited to a comparison of obsidian use from different points in the site’s history.
For the purposes of this discussion, so-called “early” artifacts are those with rim measurements that are ≥ 1.5 µm, while “late” artifacts are those with rims < 1.5 µm (Table 15). It is assumed that early artifacts represent obsidian use patterns some time prior to late artifacts.

While sample sizes are extremely small, there are some cautiously drawn distinctions to be made between the two data sets. The six early artifacts are
Table 16. Early and Late Obsidian Assemblages.

<table>
<thead>
<tr>
<th>Lodge</th>
<th>Source</th>
<th>µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>Bear Gulch, ID</td>
<td>2.97</td>
</tr>
<tr>
<td>22</td>
<td>Bear Gulch, ID</td>
<td>2.95</td>
</tr>
<tr>
<td>26</td>
<td>Huckleberry Tuff, WY</td>
<td>2.63</td>
</tr>
<tr>
<td>SS</td>
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</tr>
<tr>
<td>26</td>
<td>Bear Gulch, ID</td>
<td>2.36</td>
</tr>
<tr>
<td>49</td>
<td>Bear Gulch, ID</td>
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</tr>
<tr>
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<tr>
<td>22</td>
<td>Crescent H, WY</td>
<td>1.4</td>
</tr>
<tr>
<td>22</td>
<td>Malad, ID</td>
<td>1.36</td>
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<td>SS</td>
<td>Teton Pass, WY</td>
<td>1.06</td>
</tr>
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</tr>
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<td>49</td>
<td>Teton Pass, WY</td>
<td>.99</td>
</tr>
<tr>
<td>22</td>
<td>Crescent H, WY</td>
<td>.99</td>
</tr>
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</tr>
<tr>
<td>22</td>
<td>Crescent H, WY</td>
<td>.96</td>
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exclusively from sources furthest from High Rise Village: Huckleberry Tuff and Obsidian Cliff in Yellowstone and Bear Gulch from eastern Idaho. In contrast, the 10 later artifacts are nearly all from the closest sources in Jackson Hole, Teton Pass and Crescent H. The one exception is a late artifact from Malad in southeastern Idaho, more than 200 km away.

The hint of two distinct obsidian use patterns is intriguing and may suggest changing mobility patterns in the region, probably during the Late Prehistoric given thin hydration rims. In terms of the current study, this change could represent changing mountain use patterns related to resource unpredictability during LIA. Changing obsidian use patterns and mobility could also be related to the arrival of the Shoshone
in the region during the last 2000 years (Francis and Loendorf 2004; Loendorf and Stone 2006; Wright 1978; but see Husted 1995; Husted and Edgar 2002), or changing land use patterns between the Uinta Phase and the Firehole Phase in the Wyoming Basin (Thompson and Pastor 1995; McNees 1992; Metcalf 1987). Needless to say, more work and data are needed to fully explore obsidian use at High Rise Village, particularly the development of hydration rates for the sources of the region.

**Frequency of Site Use**

*Methods.* The final analysis is to determine whether chronometric data match model expectations of the frequencies of site use during the MWP and LIA. Due to resource predictability associated with stable conditions, it is expected that there would be more Rosegate and corner-notched projectile points (1,500–600 B.P.) and corresponding radiocarbon dates than Late Prehistoric points and dates (post–600 B.P.).

Totals of MWP radiocarbon dates and Rosegate and corner-notched projectile points were compared to Late Prehistoric totals to determine whether the frequency of site use was greater during the MWP than during the LIA. Chronometric data frequencies were so small as to prevent any statistical tests of significance.

*Results.* The raw projectile point counts (Table 8) are not directly comparable because the 15 Rosegate and likely Late Prehistoric corner-notched points from the 2010 and 2011 field seasons span approximately 900 years while the two Late Prehistoric points span 450 years. To account for this, the time span of each point type
was divided by its frequency in the assemblage to determine a comparable estimate of deposition intervals.

During the MWP, there is approximately one point deposited every 60 years (Figure 16) and there are six MWP radiocarbon dates (Table 10). During the LIA, there is one point per 225 years and two radiocarbon dates.

Based on an admittedly small dataset, there appears to be substantially more use of the site during the MWP than the LIA, as expected under the High Rise Village z-score model. In terms of both radiocarbon dates and projectile points, MWP components constitute a considerable majority when compared against LIA components.

Figure 16. Projectile point deposition intervals (years) by climate period.
Summary

The High Rise Village z-score model predicted that during the stable MWP, High Rise Village was used by moderately mobile foragers with a diverse diet based on roots and pine nuts as well as large and small game. Tool and debitage assemblages were expected to be relatively diverse, reflecting longer stays at the site and more varied activities. Further, with diverse, predictable resources, the site was expected to have been used more frequently during the MWP than the later, more unpredictable LIA. LIA foragers were expected to have frequently avoided the site and any use was considerably more transient and focused on more secure animal resources. Greater mobility and a hunting focus would have led to greater investment in bifacial tools.

There was some success and some failure in testing these expectations (summarized in Tables 16 and 17). While there is some small uncertainty in projectile point types, chronometric data indicate that Lodges 26 and 49 date exclusively to between 1500 and 600 B.P., and the remaining lodges had strong MWP components. No lodges dated exclusively to the LIA, post–600 B.P. Unfortunately, no subsistence data were recovered from the site and key diet diversity expectations remain untested. However, all lodges produced flaked stone. Heterogeneous flaked stone assemblages superficially corroborated model expectations with regard to the diversity of activities and longer stays at High Rise Village given diverse diets during the MWP. These data further indicate that the site was used residentially during this period. Though sample sizes are very small, obsidian data arguably hint that obsidian use patterns, and perhaps mobility patterns, changed during the High Rise Village occupation, though it is
unknown exactly when. Lastly, as expected there is considerably more evidence of occupation of High Rise Village during the MWP than during the LIA. Rosegate and likely Late Prehistoric corner-notched points and MWP radiocarbon dates considerably outnumber their LIA counterparts.

Table 17. Summary of MWP Results.

<table>
<thead>
<tr>
<th>Data</th>
<th>Expectation</th>
<th>Verified?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macrobotanical</td>
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</tr>
<tr>
<td>Residue</td>
<td>Pine Nuts and Roots</td>
<td>-</td>
</tr>
<tr>
<td>Flaked Stone Tools</td>
<td>Formal and Informal Tools</td>
<td>Yes</td>
</tr>
<tr>
<td>Debitage</td>
<td>Core and Bifacial Reduction</td>
<td>Yes</td>
</tr>
<tr>
<td>Obsidian</td>
<td>Decreased Diversity</td>
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</tr>
<tr>
<td></td>
<td>Jackson Hole Sources</td>
<td>-</td>
</tr>
<tr>
<td>Dating</td>
<td>Primarily MWP Occupation</td>
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</tr>
</tbody>
</table>

Table 18. Summary of LIA Results.

<table>
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<th>Data</th>
<th>Expectation</th>
<th>Verified?</th>
</tr>
</thead>
<tbody>
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<td>Residue</td>
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<tr>
<td>Flaked Stone Tools</td>
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<tr>
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<td></td>
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<td>-</td>
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<tr>
<td>Dating</td>
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</table>

Discussion

A clear pattern emerges from these analyses with regard to the occupational history of High Rise Village during the Late Prehistoric. Chronometric data indicate that
the site was used primarily between 1500–600 B.P. and the flaked stone assemblage suggests that occupation during this period was residential. Use then drops off dramatically by the beginning of the LIA. While the limited success of this study precludes a complete (or full) analysis of risk-sensitive foraging at High Rise Village as initially envisioned, discussion of the above pattern is possible in a broader context. The following considers the High Rise Village occupational history in terms of both climatic variability and regional settlement and subsistence patterns.

As a means to better visualize the High Rise Village occupational history, compilation of the 1-sigma calibrated summed probability distributions of the site’s radiocarbon dates is presented below (Steele 2010; but see Williams 2012). Figure 17 was generated from the dates reported in Table 1 (Chapter 2) using Cal Pal (Weninger et al. 2007) and the Hulu calibration dataset (Weninger and Jöris 2008). Rejected dates (i.e., those older than 4000 RCY B.P. and those younger than 500 B.P.) are included in gray.

The High Rise Village occupation can be divided into three periods of use. Between approximately 3000–1500 B.P., the earliest occupation is sporadic. Most of the dates fall between 1500–600 B.P., here broadly defined by Rosegate and other Late Prehistoric corner-notched projectile points and the MWP. The number of dates decreases during the LIA, post-600 B.P., as do temporally diagnostic artifacts. Each of these periods is discussed below in terms of regional subsistence and mobility patterns and the possible role of climate-driven environmental variability in the site’s occupation.
Early Occupation

The earliest use of High Rise Village appears to be very intermittent residential use of the site, represented by Lodges 22 and SS. While Lodge SS is a mixed early and MWP assemblage, Lodge 22 is a clearer representative of this early occupation with a single radiocarbon date from a burned floor and one untyped (but likely Late Prehistoric) corner-notched projectile point. The lodge had a heterogeneous distribution of debitage ($n = 96$, 31 percent core reduction, 69 percent bifacial reduction; Morgan, Losey, and Adams 2012) similar to Lodge 26 (Table 13). Lodge 22 assemblage heterogeneity is consistent with residential use, as discussed above. The lodge is associated with groundstone likely associated with plant or seed processing and...
also contains an anomalously (for High Rise Village) high amount of crushed mammal bone (Morgan, Losey, and Adams 2012), suggesting a broad spectrum diet. While considered somewhat unlikely given poor specimen quality, it is worth mentioning that some larger corner-notched points and point fragments (arguably either Pelican Lake or Elko points) may correspond to this earlier occupation.

Without clear diagnostic artifacts, the association between the early occupation of High Rise Village and regional culture histories remains unclear. Based solely on residential mobility and evidence of a diverse diet, there is little to differentiate between affiliation with the Deadman Wash Phase of the Wyoming Basin (2900–1800 B.P.; McNees 1992; Metcalf 1987; Smith 2005) or Frison’s (1991) Late Plains Archaic Period (approximately 3000–1500 B.P.). Both periods are defined by a hunting focus, though many residential components have groundstone, including the Deadman Wash type site (Armitage et al. 1982) and the Lookingbill site (Frison 1983; Kornfeld et al. 2001). Further, Northwestern Plains and Wyoming Basin affiliated groups both used the Wind River Basin and the adjacent uplands during this period (Bliss 1950; Frison 1983; Smith 2005).

Without high resolution, local proxies, it is difficult to assess more than broad notions of climate variability at High Rise Village during this period. However, regional climate and environment appear relatively stable. Moderate soil development in the Wind River Range (Dahms 1994) suggests stability, as do long pulses of glacial activity and inactivity (Dahms 2002). Soil development and minimal dune activity in the Wyoming Basin (Ahlbrandt et al. 1983; Eckerle 1997) indicate similar conditions.
Based on data from Lodges 22 and SS, it is apparent that residential use of High Rise Village is not unique to the MWP and began approximately 2800 B.P. Between 2800–1500 B.P., use was extremely intermittent as people with either Plains affiliation, Wyoming Basin affiliation, or perhaps both, occasionally took advantage of resources in the area. Given very sporadic use of the site in spite of likely environmental stability, it seems unlikely that climate-driven resource predictability played a key role in structuring High Rise Village use patterns during this period.

**MWP–Rosegate Occupation**

While residential occupation and broad spectrum foraging are not unique to the MWP, it is clear that this pattern of use peaked between 1500–600 B.P. and that High Rise Village is primarily an MWP occupation. As clearly indicated in Figure 17, the majority of radiocarbon dates from the site fall between 1500–600 B.P. Further, the projectile point assemblage is dominated by Rosegate and similar Late Prehistoric corner-notched points.

It appears that Uinta Phase foragers took advantage of High Rise Village during the MWP. The Uinta Phase (1800–900 cal B.P.) is a distinctive phase in the Wyoming Basin (McNees 2006; Metcalf 1987) and several key features of the phase are present at High Rise Village. First, Rosegate projectile points make up a considerable portion of the assemblage, and are considered diagnostic of the phase (McNees 1992; Metcalf 1987). Second, is a focus on plant resource procurement and processing (McNees 1992; Metcalf 1987), as suggested by the groundstone associated with all lodges. Finally, both
High Rise Village and many Uinta Phase residential sites have small, circular residential features with repeated but not necessarily frequent reuse (McNees 1992; Smith 2005) and access to stable, predictable plant resources (Smith et al. 2001; Smith and McNees 1999, 2000, 2005). Together these characteristics suggest that during the MWP, High Rise Village was a Uinta Phase upland residential camp not entirely dissimilar when compared those found in lower elevations of the Wind River Basin.

The question remains as to why High Rise Village was used more frequently during the MWP than during earlier and later periods. Population trends, local environmental stability, and resource availability and predictability together offer some explanation and suggest that climatic and resource stability were important elements of the site’s MWP peak in occupation.

Population trends compiled from 3,277 radiocarbon dates from across Wyoming indicate that population growth was gradual until 2000 cal B.P., followed by rapid growth into the Late Prehistoric (Kornfeld et al. 2010). Growth peaks around 1300 cal B.P., followed by a dramatic decline to prepeak levels by 800 cal B.P. Data from the Wyoming Basin indicate that this pattern holds true in the immediate vicinity of the Wind River Range (Smith 2005). Kornfeld et al. (2010) caution that radiocarbon date frequencies may reflect changing hearth functions or the high volume cultural resource management work in the region rather than population trends. However, if radiocarbon dates are a reasonable representation of population through time, then it is apparent that population peaks in the region during the High Rise Village MWP occupation.
As discussed by Bettinger (1991a) for the White Mountains, lowland population pressure and resource depression can make the higher cost of living at high elevation sites acceptable. If this is the case for local Uinta Phase foragers, High Rise Village offers an ideal upland residential location for foragers concerned with resource access and stability. First, the site is readily accessible from the Wind River Basin with less than eight kilometers of moderate hiking. Second, the site provides excellent access to resources, both locally abundant plants and small game and the alpine/subalpine summer ranges of large game. Third, the dendroclimatological portion of this thesis demonstrates that climate was stable at High Rise Village during at least the latter portion of the MWP and that whitebark pine, geophytes, and game were likely stable and predictable. As with many Uinta Phase sites, it seems that these conditions were repeatedly taken advantage of throughout this period.

Under the combined influences of regional population growth, a redundant land use pattern, and a locally stable environment, High Rise Village was used more during the MWP than before and after. While perhaps not directly driven by MWP conditions, the resource stability demonstrated at High Rise Village was likely a key feature in the site’s repeated use by Uinta Phase foragers during this period.

**LIA Occupation**

Following the increase of site use during the MWP, occupation at High Rise Village decreased considerably after 800 cal B.P. and continued to be minimal throughout the remaining Late Prehistoric. Late Prehistoric artifacts are rare in lodges
and there are no sound radiocarbon dates postdating 770 cal B.P. (Figure 17). Site use was sporadic, though groundstone and Intermountain Grayware sherds (Mulloy 1958) suggest use was still mainly residential.

Based on diagnostic artifacts, High Rise Village can be broadly linked to residentially mobile peoples found throughout the basins, plains, and mountains of the region during the Late Prehistoric. Tri-notched/side-notched/triangular unnotched projectile points and Intermountain Grayware are common across the much of western Wyoming (Kornfeld et al. 2010; McNees 1992). Peoples were primarily residentially mobile and subsistence was focused on large game hunting (Kornfeld et al. 2010; Smith 2005).

It is apparent from the High Rise Village dates that increasing climatic variability and decreasing resource predictability during the LIA did not initiate a decrease in site use as predicted by the High Rise Village z-score model. Radiocarbon dates and projectile points indicate that use decreased between 800–600 cal B.P., while the High Rise Village dendroclimatological study indicates that stable conditions persisted until 500 B.P.

The decrease in site use is more likely related to regional-wide reductions in human population by 800 cal B.P. (Kornfeld et al. 2010) and an increase in lowland game abundance (Byers et al. 2005), with a minor role played by the increasingly difficult foraging conditions at High Rise Village during the LIA. Without lowland population pressure to equalize the cost of residentially using high elevation environments, High Rise Village occupations would likely have decreased dramatically as foragers favored
the more accessible lowlands. Further, Byers et al. (2005) suggest that large game abundances increased in the Wyoming Basin throughout the Late Holocene. In contrast, the High Rise Village model and data indicate that high elevation hunting became increasingly less predictable during this period. With less costly opportunities in the Wyoming Basin, High Rise Village was likely avoided in favor of more predictable and productive lowland environments.

Many High Rise Village z-score model expectations remain untested; however, the site was undoubtedly used more frequently during the MWP than before or after. A broader consideration of the data suggests that climate-driven resource predictability in conjunction with regional population growth structured site use during the MWP. Resource predictability at High Rise Village likely encouraged infrequent but consistent reuse of the site by Uinta Phase foragers seeking opportunities at the peripheries of the crowded Wyoming Basin. However, in opposition to model expectations, the Late Prehistoric decrease in site occupation clearly predates the LIA. Region-wide population decline and increasing lowland game abundances likely lead Late Prehistoric foragers to take advantage of lowland foraging opportunities considerably less costly than High Rise Village.
CHAPTER 6

CONCLUSION

Using the z-score model, this thesis sought to answer the question: How did changes in climate-driven resource predictability and associated foraging risk affect subsistence strategies and site use patterns at High Rise Village during the last millennium? Regional paleoenvironmental studies informed assumptions about likely climate-driven changes in resource return rates between the Medieval Warm Period (MWP; 1500–600 B.P.) and the Little Ice Age (LIA; post-600 B.P.; Bradley et al. 2001; Bradley and Jones 1992; Herweijer et al. 2007; Hughes and Diaz 1994a; Mann 2002a, b). Based on these assumptions, the z-score model was used to predict a risk-sensitive diet under each climate regime and develop corresponding archaeological expectations with regard to diet, mobility, and technology.

Assuming environmental stability, the MWP occupation was predicted to be residential (per Binford 1980) with a diverse diet, as the majority of resources were highly likely to satisfy the required minimum. Given environmental stability and resource predictability, the site was expected to be used more frequently during this period. Conversely, due to increased environmental variability, little use of the site was expected during the LIA. Any use was expected to be short-term and focused on high-return animal resources in an effort to avoid caloric shortfall.

As a means to obtain paleoclimate data specific to the site and verify the model’s baseline environmental assumptions, this project developed an 835-year whitebark pine
(Pinus albicaulis) chronology from samples obtained from the immediate vicinity of the site. Wavelet analysis and correlation with Pacific Decadal Oscillation data corroborated model assumptions. The MWP was primarily characterized by multidecadal modes of variability, indicating long-term environmental stability. Under these conditions, resources would have been predictable at High Rise Village, at least at temporal scales equal to or greater than one human generation. Conversely, the LIA was a period of rapid and frequent temperature and precipitation change, with change occurring at temporal scales of as little as two years. Interannual variability is challenging for foragers and resources alike, and High Rise Village was likely avoided in favor of more predictable foraging and hunting environments.

Unfortunately, a test of the model’s archaeological expectations was equivocal, this largely due to poor preservation of residues and macrobotanical debris in the site’s shallow, acidic soils. Further, small sample sizes and poorly understood hydration rates hindered the utility using obsidian data to understand the site’s chronology and affiliated toolstone conveyance and mobility patterns. However, a regional consideration of the High Rise Village chronometric and flaked stone data offers some insight into the influences of the MWP and LIA at High Rise Village.

While residential occupation and a broad spectrum diet predate the MWP at High Rise Village, it is clear that this pattern of use peaked under MWP conditions. As populations grew in the region, the energetic cost of using high elevation environments became comparable to (or less than) the cost of living in the increasingly crowded lowlands. Under these conditions, High Rise Village offered excellent access to
productive, predictable resources for Uinta Phase foragers. The site was consequently used more intensively during this period than before or after.

It is worth noting that the conditions here labeled as MWP likely extend back to 1800 cal B.P. at High Rise Village and in western Wyoming. Warm, dry conditions began around 1800 cal B.P. in the region (Ahlbrandt et al. 1983; Eckerle 1997), and it is possible that long-term stability did as well. With this in mind, it is apparent that the MWP is likely too narrow a climatic–temporal bracket for comparison to cultural change in western Wyoming. While this thesis took a rather extended view of the MWP (beginning around 1500 cal B.P. rather than the more typical 1200 or 1100 cal B.P. (Hughes and Diaz 1994a, b; Mann 2002a), the argument could be made for warm–dry conditions (and perhaps more stable conditions) developing as early as 1800 cal B.P. Further paleoclimatic work is needed to continue to characterize this period to better relate it to culture change in the region. In particular, finer resolution climate records could offer further insight into the intriguing correlation between the beginning of this climate pattern and the Uinta Phase (1800–900 cal B.P.).

After 800 cal B.P., the frequency of High Rise Village occupations decreases considerably. LIA interannual variability and likely subsequent decreases in resource predictability do not begin until 500 cal B.P. and thus do not initiate the decline in site use. Instead, region-wide population decline and increasing lowland game abundances likely increased returns on lowland foraging. In comparison, LIA foraging at High Rise Village was unpredictable and more costly due to the site’s high elevation setting. With
less costly opportunities in the Wyoming Basin, High Rise Village was likely avoided in favor of lowland environments.

Under the High Rise Village z-score model, the nature of MWP and LIA occupations were expected to be heavily influenced by climate-driven resource variability. Perhaps unsurprisingly, the relationship between variability and site use patterns is not as clear-cut as initially hypothesized. However, there is some indication that resource predictability may have helped structure Late Prehistoric site use patterns. The above discussions remain broadly comparative, but suggest a pattern worth further consideration both at High Rise Village and regionally.

There are three elements of this thesis that warrant further discussion. First are my final thoughts on the advantages of integrating dendroclimatological studies with archaeological studies. This is followed by a discussion of the regional implications for the characterization of High Rise Village as a likely high elevation Uinta Phase component. Lastly, I offer a consideration of the utility of the z-score model to archaeological research.

**Dendroclimatology in Archaeology**

Despite over a century of tree-ring research in the American West and more than four decades of tree-ring based climate studies across the globe, dendroclimatology is still underutilized in the investigation of the dynamics between humans and the natural environment. The hope is that the exercise and data presented
here will encourage greater integration of tree-ring and archaeological data in the northern Rockies.

Climate is considerably more complex than implied by commonly used subjective notions like “favorable versus unfavorable” or by broad generalizations like “warm/cool” and “wet/dry.” Instead, climate is a complicated, multivariate phenomenon with localized effects on the environments people exploited. Tree-ring studies offer archaeologists a means by which to obtain high resolution, local paleoclimate data relevant to understanding specific human behavior, particularly those that relate directly to resources affected by changes in temperature and precipitation at multiple scales.

An integrated dendroclimatological study produces temperature, precipitation, and/or drought data specific to the area of interest. Because the effects of climate to resources are always local (Dean et al. 1985; Mann 2002c; Mayewski et al. 2004; Stenseth et al. 2002), an integrated study allows for the realistic extrapolation of environmental variables directly relevant to human behavior within the study area. The High Rise Village study considered food resource variability and predictability, but other options include climate-driven effects to water availability, environmental productivity and arability, and resource abundance and distribution.

As partially demonstrated here, dendroclimatology also offers the means to explore behavioral responses to temporal and spatial trends in local environmental variability. As discussed by (Dean et al. 1985) and others (Anderson et al. 2011; Goland 1991a; Minc and Smith 1986), temporal and spatial variability in resource availability are
key elements conditioning how people respond to changing environmental conditions.

Given the annual resolution of tree-ring data, spectral analysis can be used to identify a broad spectrum of frequencies of past climate change. This includes potentially challenging periods of interannual variability invisible in lower resolution proxies. The spatial heterogeneity of environmental change can also affect the nature and scale of behavioral responses. Multiple dendroclimatological studies or a large project area lend themselves to understanding behavior in relation to the spatial characteristics of changing conditions.

Unfortunately, dendroclimatology–archaeology studies are limited by location. The archaeological sites under study have to be situated in environments in which climate variables are the limiting factors of annual tree growth, typically at the edges of a species’ range (Tranquillini 1979). Further, the characterization of past conditions is restricted to the climate variable(s) limiting growth within the area.

While not applicable everywhere, integrated dendroclimatological studies offer archaeologists excellent paleoclimate data with which to study the interaction between climate and human behavior. High elevation environments are particularly well suited for these types of studies. The well dated, spatially relevant, fine-grained data readily lend themselves to the development of a wide variety of area specific models of behavior. This study took full advantage of its location to integrate these data and the hope is that more studies recognize this potential as well.
High Rise Village and the Wyoming Basin

Based on Rosegate projectile points, radiocarbon dates, site use patterns, and setting, High Rise Village appears to be a mainly Uinta Phase residential site. In addition, two similar but smaller sites within a few kilometers of High Rise Village also have apparent Uinta Phase components, based on reported Rosegate points (Adams 2010a). Like High Rise Village, these sites are above 3000 m in elevation and have groundstone and comparable (though far fewer) lodge pads. Together, these sites indicate an alpine/subalpine element of the Uinta Phase subsistence and mobility pattern.

A high elevation component is a previously unexplored aspect of the Uinta Phase landscape use pattern. While basin and foothill sites are common throughout the Wyoming Basin (e.g., (McNees 2006; Smith 2005; Thompson and Pastor 1995), high elevation sites are absent from the literature and some propose that basin peoples made little use of mountain resources (McNees 2006). The Wind River Range sites indicate that Uinta Phase subsistence and mobility patterns at least occasionally incorporated high elevation environment and resources.

While the aforementioned sites are suggestive of an intriguing high-altitude residential pattern, they are a small sample and further work is necessary to ascertain whether they represent a local phenomenon or a previously unknown component of the greater Uinta Phase landscape use pattern. Both upland and lowland environments offer means to explore Uinta Phase use of alpine/subalpine resources. While preservation is likely to be poor at many high elevation sites, diagnostic artifacts, flaked
stone, and obsidian studies offer the means identify sites and understand mobility. More in depth lithic studies, including use-wear analyses, could offer some insight into subsistence and other activities at these sites. Further, better preservation at lowland sites may offer a means to characterize high elevation contributions to the Wyoming Basin economy. Only with more research, survey, and excavation in the understudied high elevation areas of the western Wyoming will we begin to see the spatial extent of and any variation in the upland pattern noted at High Rise Village.

**The Z-score Model in Archaeology**

Most foraging models assume risk indifference and do not account for resource variability and the associated risk of caloric shortfall (Kacelnik and Bateson 2000). While this assumption may be appropriate in some cases, it has been shown that humans sometimes actively manage risk while foraging, particularly as the likelihood of caloric shortfall increases (Winterhalder et al. 1999). Models that account for risk provide an alternative to popular rate-maximization models when investigating these types of conditions, such as periods of increased environmental variability (e.g., Pinson 1999) or poor or unpredictable productivity (e.g., Goland 1991a; Winterhalder and Goland 1997). These models offer the means to better understand factors driving human foraging decision making and the role of environmental variability.

Of the risk-sensitive foraging models, the z-score model offers a first step with which to begin exploring risk. The model reduces risk-sensitive foraging to a few simple variables: a minimum caloric requirement and several foraging options, each with a
mean return rate and standard deviation. Given these variables, the model provides readily testable predictions (especially at sites with robust faunal and macrofloral remains) as to whether foragers should behave in risk-averse or risk-prone manner, and what that behavior should look like in terms of preferred resources and their frequency in archaeological components. By testing these predictions, it is possible to determine whether the risk of caloric shortfall is motivating foraging decision making and appropriately focus future research.

However, archaeological applications of the z-score model are clearly difficult to implement and the model remains little used. This is likely due to the difficulty in identifying appropriate archaeological applications of the model, and more importantly, the difficulty of quantifying the necessary variables. The problem of determining archaeologically plausible applications largely lies partly in the temporal resolution of the archaeological record. With often only coarse means of dating, it can be difficult to identify discrete events and periods of risk-sensitive behaviors within the aggregate archaeological record. For risk-averse behavior, this requires identifying periods of increased risk of caloric shortfall and determining the archaeological components specific to these periods. Further difficulty lies in identifying periods of risk-prone behavior. Due to the high likelihood of caloric shortfall, risk-prone foraging is not a sustainable strategy and is unlikely to last more than a season before people find a means to adjust or, more likely, leave the area (Pinson 1999). The level of temporal resolution necessary to identify very short periods of extreme variability and the
corresponding behavior is rare and these discrete periods remain indiscernible in the archaeological record.

The greater challenge lies in generating the necessary numerical data for the foraging options in question, namely return rate standard deviations and fully quantifying resource variability. As demonstrated by the current study, while mean return rates are readily calculable from published return rate data, standard deviations are not. There are too few published data points to generate meaningful standard deviations. Needless to say, more return rate data are needed to fully resolve this problem, whether derived experimentally or using Geographic Information Systems (GIS) simulations to model foraging returns (e.g., Zeanah 1999).

Finally, the single biggest problem for an archaeological application of the z-score model lies in fully quantifying resource variability. Three means of approaching this problem are discussed here. The first option is to not fully quantify variability. The High Rise Village study focused on only one element of resource variability: variability in resource package size as quantified by post-encounter return rates. However, while readily obtainable, post-encounter return rates do not account for resource abundance. Rather, these rates only account for prey package size and handling time, the amount of time it then takes to obtain and process the prey item after it was encountered. Arguably, most variability in foraging success is related to resource abundance and the possibility of not encountering prey (Winterhalder 1986). This study’s approach does not capture this crucial variable.
Fully quantifying variability requires accounting for abundance and the original z-score model literature does so (Stephens and Charnov 1982; Winterhalder 1986). As described by Winterhalder (1986), this approach uses overall foraging return rates, rather than post-encounter return rates, and includes search time as a measure of abundance; search time is the amount of time it takes to locate a prey item. Foraging return rates are calculated by dividing the prey package (in calories) by the total time it takes to find, acquire, and process said package (search time + handling time). By using a predetermined minimum and maximum for each variable, the resulting minimum and maximum return rates fully captures variability in terms of both package size and abundance. The foraging return rates could then be used to predict the expected risk-averse or risk-prone diet.

However, the above approach is extremely difficult to apply archaeologically. While minimum and maximum package sizes and handling times are available for many resources from (Simms 1987) and others (e.g., Smith et al. 2001), modeling realistic, locally relevant resource search times is at best difficult and time consuming to estimate. Search times must be representative of the abundance and distribution of resources in the study area. If modern conditions are representative of the time period in question, then GIS foraging simulations offer means to determine search times using digitized modern resource density and distribution data. When the modern environment differs from the prehistoric environment in question, paleoenvironmental modeling would be necessary to reconstruct the appropriate foraging landscape. This requires local paleoenvironmental data to reconstruct local habitat types and
distributions before a GIS foraging simulation can then be used to generate search times or foraging rates (e.g., Zeanah 1999), no mean task. Obviously, there are several variables, each with potential sources of error that could confound an archaeological application of the z-score model that includes abundance/search time.

Pinson (1999) offers a final, questionable option to account for resource variability in her application of the z-score model to foraging the Great Basin during the climatically variable Late Pleistocene/Early Holocene. Rather than a mathematical application, Pinson assumed that prey size can be used as a proxy indicator of variance in foraging return rates, thus sidestepping the issues raised above. Large game was assumed to be high variance while small game and plant resources were low variance resources. Risk-averse foragers were expected to prefer low variance options while risk-prone foragers were expected to prefer high variance large game.

However, the High Rise Village z-score study demonstrates that while highly variable, animal resources are not necessarily high risk. In the z-score model, variability in a resource is inconsequential to the forager if the return rate is sufficiently high so as never to threaten the possibility of caloric shortfall. The current study demonstrates that the high mean return rate in sheep (*Ovis canadensis*) and marmots (*Marmota flaviventris*) do just this, effectively countering their high variability (Chapter 3, Figures 4 and 6). However, because this application of the model was limited to post-encounter return rates, it remains to be seen whether this pattern is upheld when search time is accounted for.
It is with good reason that the High Rise Village z-score study was limited to resource package size variability and post-encounter return rates and only half applies the z-score model. It takes a remarkable amount of time, data, and modeling to generate accurate resource search times relevant to a study area. Given these limitations, this thesis is not alone in avoiding modeling abundance. The vast majority of archaeological applications of optimal foraging models rely on post-encounter return rates to rank resources and do not directly account for resource search times (e.g., (Byers and Broughton 2004; Byers et al. 2005; Kornfeld 2003). Until such time as the necessary foraging metrics are more readily obtainable, post-encounter return rates as well as proxy standard deviations offer a feasible option when using the z-score model to determine whether people are foraging in a risk-sensitive manner.

While clearly difficult to implement archaeologically, the z-score model offers an alternative to rate-maximization models that may have equal or greater predictive power when foragers are faced with an increasing likelihood of caloric shortfall. Further, this application of the model demonstrates the utility of quantitatively modeling risk and using local paleoenvironmental datasets alongside archaeological data to reconstruct occupational histories in light of environmental change and risk sensitivity.
REFERENCES CITED

Adams, Richard


Adams, Richard, John Lund, Tory Taylor, and Ruth Shepard


Adams, Richard, Bryon Schroeder, Orrin Koenig, and Matt Stirn


Ahlbrandt, Thomas S., James B. Swinehart, and David G. Maroney


Aldenderfer, Mark


Anderson, David G., Kirk Maasch, and Daniel H. Sandweiss


Anderson, SallyRose


Andrefsky, William

2005 *Lithics: Macroscopic Approaches to Analysis*. Cambridge University Press, United Kingdom.

Armitage, C. Lawrence, Steven D. Creaseman, and J.D. Mackey


Arno, Stephen F., and Ramona P. Hammerly


Arno, Stephen F., and Raymond J. Hoff

Baker, Richard G.


Baksh, Michael, and Allen Johnson


Barash, David P.


Beiswenger, Jane M.


Bender, Susan J., and Gary A. Wright


Benedict, James B.


Bettinger, Robert L.


Bettinger, Robert L., and Martin A. Baumhoff


Binford, Lewis R.


Biondi, Franco, Alexander Gershunov, and Daniel R. Cayan


Biondi, Franco, and Kishor Waikul


Black, Kevin D.


Bliss, Wesley L.


Bradley, Raymond S., Keith R. Briffa, Thomas J. Crowley, Malcolm Kenneth Hughes, Phillip D. Jones, and Michael E. Mann


Bradley, Raymond S., and Phillip D. Jones

Broughton, Jack M.


Broughton, Jack M., and Donald K. Grayson


Brunstein, F. Craig


Byers, David A., and Jack M. Broughton


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


Byers, David A., and Andrew Ugan


Callahan, Errett

Canaday, Timothy W.


Caraco, Thomas, Steven Martindale, and Thomas S. Whittam


Carbone, Victor A., and Bennie C. Keel


Charnov, Eric L.


Collopy, Michael W.


Colson, Elizabeth


Connor, Melissa, and Raymond Kunselman


Cook, Edward R.

Cook, Edward R., and Richard L. Holmes


Cook, Edward R., and Leonadas A. Kairiukstis


Cook, Edward R., and Paul J. Krusic


Cook, Edward R., Richard Seager, Richard R. Heim, Russell S. Vose, Celine Herweijer, and Connie Woodhouse


Cook, Edward R., Connie A. Woodhouse, C. Mark Eakin, David M. Meko, and David W. Stahle


Cowan, Frank L.


Dahms, Dennis E


Dai, Aiguo, Kevin E. Trenberth, and Taotao Qian

Daly, Christopher, G.H. Taylor, and W.P. Gibson

Davies, Nigel

Davis, Carl M., and James D. Keyser

Davis, P. Thompson

Davis, P. Thompson, John C. Gosse, Mel A. Reasoner, and Gregory Zielinski
Dean, Jeffrey S., Robert C. Euler, George J. Gumerman, Fred Plog, Richard H. Hevly, and Thor N. V. Karlstrom


Douglas, Charles L.


Draper, Patricia


Dunbar, Robert B.


Dunwiddie, Peter W.

1977  Recent Tree Invasion of Subalpine Meadows in the Wind River Mountains, Wyoming.

*Arctic and Alpine Research* 9(4): 393–399.

Eakin, Daniel H.


Eckerle, William P.

1997  Eolian Geoarchaeology of the Wyoming Basin. In *Changing Perspectives of the Archaic*
Elston, Robert G., and P. Jeffrey Brantingham  

Elston, Robert G., and David W. Zeanah  

Epps, Clinton W., Dale R. McCullough, John D. Wehausen, Vernon C. Bleich, and Jennifer L. Rechel  

Fall, Patricia L., P. Thompson Davis, and Gregory A. Zielinski  

Finley, Judson, and Chris C. Finley  

Fitzhugh, Ben  
Francis, Julie E.


Francis, Julie, and Lawrence L. Loendorf


Frison, George


Frison, George C., and Danny N. Walker (editors).

Frison, George, and Michael Wilson


Fritts, Harold C.


Gershunov, Alexander, and Tim P. Barnett


Goland, Carol A.


Graumlich, Lisa J., Michael F. J. Pisaric, Lindsey A. Waggoner, Jeremy S. Littell, and John C. King


Gray, Stephen T., Julio L. Betancourt, Christopher L. Fastie, and Stephen T. Jackson

Gray, Stephen T., Christopher L. Fastie, Stephen T. Jackson, and Julio L. Betancourt


Grayson, Donald K.


Green, James P.


Grissino-Mayer, Henri D.


Grissino-Mayer, Henri D., and Harold C. Fritts


Grove, Jean M.


Hadley, E.A.


Halstead, Paul, and John O’Shea

Harding, William M., and James A. Lowe


Harris, David R.


Hawkes, Kristen, James F. O’Connell, and N.G. Blurton Jones


Heizer, Robert F., and Martin A. Baumhoff


Herweijer, Celine, Richard Seager, Edward R. Cook, and Julien Emile-Geay


Hildebrandt, Tod W.


Hill, Jane H.

Holmer, Richard

Holmes, R. L.

Housley, Lucile A.

Hughes, Malcolm K., and Henry F. Diaz

Hultkrantz, Ake

Husted, Wilfred M.
Husted, Wilfred, and Robert Edgar


Inouye, David W., Billy Barr, Kenneth B. Armitage, and Brian D. Inouye


Jackson, Stephen T., Mark E. Lyford, and Julio L. Betancourt


Janetski, Joel

1985 Archaeological Investigations at Sparrow Hawk (42TO261): A High Altitude Prehistoric Hunting Camp in the Southern Oquirrh Mountains, Tooele County, Utah. Cultural Resource Management Services, Brigham Young University, Provo, Utah. Utah Division of State History, Salt Lake City.


Johnson, Clay, and Byron Loosle

2010 *Archaeology and Native American History at Fish Lake, Central Utah*. Occasional Paper, Museum of Peoples and Cultures, Brigham Young University, Provo, Utah.

Jones, George T., Charlotte Beck, Eric E. Jones, and Richard E. Hughes


Justice, Noel D.


Kacelnik, Alex, and Melissa Bateson


Kaestle, Frederika A., and David Glenn Smith


Kaplan, Hillard, Kim Hill, A. Magdalena Hurtado, and Elizabeth Cashdan


Kearney, Michael S.


Kelly, Robert L.


Kipfmueller, Kurt F., and Matthew W. Salzer


Knoll, Michelle K.


Kobashi, Takuro, Jeffrey P. Severinghaus, Jean-Marc Barnola, Kenji Kawamura, Tara Carter, and Toshiyuki Nakaegawa


Koenig, Orrin


Koenig, Orrin, and Richard Adams


Kohler, Timothy A., and Carla R. Van West

Bagley Tainter, pp. 169–196. Addison-Wesley, Reading, Massachusetts.

Kooymans, Brian P.


Kornfeld, Marcel


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

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

Kornfeld, Marcel, Mary Lou Larson, David J. Rapson, and George C. Frison


Kroeber, Alfred Louis


LaMarche, Valmore C.


LaMarche, Valmore C., and Charles W. Stockton


Lamb, Hubert H.

Lamb, Sydney M.


Lanning, Edward P.


Larson, Mary Lou


Larson, Mary L., and Marcel Kornfeld


Lloyd, Andrea H., and Lisa J. Graumlich


Loendorf, Lawrence L., and Nancy Medaris Stone

Losey, Ashley


Lubinski, Patrick M.


Lubinski, Patrick M., Lowell T. Evans, and Michael D. Metcalf


Luckman, Bryan H.


Luckman, Bryan H., and Michael S. Kearney

Lyford, Mark E., Julio L. Betancourt, and Stephen T. Jackson


Lyford, Mark E., Stephen T. Jackson, Julio L. Betancourt, and Stephen T. Gray


Lynch, Elizabeth A.


MacArthur, Robert H., and Eric R. Pianka


McCracken, Harold


MacDonald, Glenn M., and Roslyn A. Case


McKern, Scott T.


McNees, Lance M.

1992  Implications of the Current Investigations of the Culture Historic Chronology of Southwest Wyoming. In *Data Recovery Investigations at the Black Butte and Leucite Hills*


Madsen, David B.


Madsen, David B., and Michael D. Metcalf


Madsen, David B., and David Rhode

Mann, Michael


Mensing, Scott, John Korfmacher, Thomas Minckley, and Robert Musselman

2012 A 15,000 Year Record of Vegetation and Climate Change from a Treeline Lake in the Rocky Mountains, Wyoming, USA. *The Holocene* 22(7): 739–748.

Metcalf, Michael D.


Metcalf, Michael D., and E.K. MacDonald

Minc, Leah D., and Kevin P. Smith


Moerman, Daniel E.


Morgan, Christopher

2006  Late Prehistoric Territorial Expansion and Maintenance in the South-central Sierra Nevada, California. Unpublished Ph.D. dissertation, Department of Anthropology, University of California, Davis.


Morgan, Christopher, Richard Adams, Kenneth Cannon, and Robert Pack


Morgan, Christopher, Jacob L. Fisher, and Monique Pomerleau

Morgan, Christopher, Ashley Losey, and Richard Adams


Morgan, Christopher, Robert Pack, Richard Adams, and Kenneth Cannon


Mulloy, William


Munroe, Jeffrey S.


Nabokov, Peter, and Lawrence L. Loendorf


Nelson, Margaret C.


Owens, John N., Thanong Kittirat, and Mary F. Mahalovich


Palmer, Wayne C.


Perkins, Dana Lee

2001  *Ecology of Treeline Whitebark Pine (Pinus Albicaulis) Populations in Central Idaho: Successional Status, Recruitment and Mortality, and a Spring Temperature Reconstruction from Whitebark Pine Tree Rings*. Department of Forest Resources, Utah State University, Logan.

Perkins, Dana L., and Thomas W. Swetnam


Pinson, Ariane O.


Plager, Sharon R., and Richard N. Holmer

2004  Vegetation Change in the Upper Snake, Yellowstone, and Green River Drainages: The Last 14,000 Years. In *Wildfire Effects on Rangeland Ecosystems and Livestock Grazing in*

Poage, Michael A., Derek J. Sjostrom, Judd Goldberg, C. Page Chamberlain, and George Furniss


Raven, Christopher, and Robert G. Elston


Reed, Robert M.


Rhode, David


Rhode, David, and David B. Madsen


Richmond, Gerald M.

Rochefort, Regina M., Ronda L. Little, Andrea Woodward, and David L. Peterson


Roper, Donna


RSI


Scharf, E.A.


Scheiber, Laura, and Judson Finley


Schiffer, Michael B.

Schoen, Jamie


Schuster, Paul F., David E. White, David L. Naftz, and L. DeWayne Cecil


Scuderi, Louis A.


Shimkin, Demitri B.


Simms, Steven R.

1979  *High Altitude Archaeology in Utah: A Cultural Resource Inventory of 11 Projects and a Test Excavation (42SV1357) in the Fishlake National Forest*. Reports of Investigations. Archaeological Center, Department of Anthropology, University of Utah, Salt Lake City.


Smith, C. Earle Jr.


Smith, Craig S.


Smith, Craig S., William Martin, and Kristine A. Johansen


Smith, Craig S., and Lance M. McNees


Smith, Eric Alden, Robert L. Bettinger, Charles A. Bishop, Valda Blundell, Elizabeth Cashdan, Michael J. Casimir, Andrew L. Christenson, Bruce Cox, Rada Dyson-Hudson, Brian Hayden, Peter
J. Richerson, Eric Abella Roth, Steven R. Simms, and W. A. Stini


Smith, Felisa A., Hillary Browning, and Ursula L. Shepherd


Speer, James H.


Steele, James


Stenseth, Nils C., Atle Mysterud, Geir Ottersen, James W. Hurrell, Kung-Sik Chan, and Mauricio Lima


Stephens, David W.


Stephens, David W., and Eric L. Charnov


Steward, Julian Haynes


1940  *Native cultures of the Intermontane (Great Basin) area*. Smithsonian Institution, Washington, D. C.

Stirn, Matt


Stokes, Marvin A.

1968  *An Introduction to Tree Ring Dating*. University of Arizona Press, Tucson.

Stubbendieck, James L., Stephan L. Hatch, and L. M. Landholt


Sutton, Mark


Sutton, Mark, and David Rhode


Thomas, David Hurst


Thompson, Kevin W., and Jana V. Pastor


Thorne, Tom


Tomback, Diana F., Stephen F. Arno, and Robert E. Keane


Tomback, Diana F., and Yan B. Linhart


Torrence, Christopher, and Gilbert P. Compo


Tranquillini, Walter


Trout, Luke

Conference, Stateline, Nevada.


USDA


Utts, Jessica M., and Robert F. Heckard


VoorTech


Walsh, Kevin, Suzi Richer, and J. L. de Beaulieu


Wang, Shih-Yu, Robert R. Gillies, Jiming Jin, and Lawrence E. Hipps


Watkins, Renee


Watson, Thomas A., F. Anthony Barnett, Stephen T. Gray, and Glenn A. Tootle

Weninger, Bernhard, and Olaf Jöris


Weninger, Bernhard, Olaf Jöris, and Uwe Danzeglocke


Western Regional Climate Center

2012  Westmap Climate Analysis Toolbox - Time Series. Western Regional Climate Center, Desert Research Institute, Reno, Nevada.

Wettlaufer, Boyd N.


Whitlock, Cathy


Whitlock, Cathy, and Patrick J. Bartlein


Whitlock, Cathy, Mel A. Reasoner, and Carl H. Key

Whitlock, Cathy, Sarah L. Shafer, and Jennifer Marlon


Wigley, Thomas M. L., Keith R. Briffa, and Phillip D. Jones


Williams, Alan N.


Winterhalder, Bruce


Winterhalder, Bruce, and Carol Goland


Winterhalder, Bruce, Flora Lu, and Bram Tucker


Wohlgemuth, Eric

Wright, Gary A.


Wright, Gary A., Susan Bender, and Stuart Reeve


Yamaguchi, David K.


Zeanah, David W.


1999 *Archaeological Predictive Model, Management Plan and Treatment Plans for Northern Railroad Valley, Nevada*. Intermountain Research, Silver City, Nevada.


Zielinski, Gregory A., and P. Thompson Davis