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Foraging and Prehistoric Use of High Elevations in the Western Great Basin: Evidence from Seed Assemblages at Midway (CA-MNO-2196), California

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Artifacts, features, and faunal remains indicate that the use of high-elevation resources in the Great Basin increased with the establishment of alpine villages after A.D. 600. Villages are seen as part of a regional intensification resulting in more diverse diets utilizing greater amounts of low-return resources. Seeds from the Midway site in the White Mountains show that the duration of occupation increased during village times. However, there was no relative increase at Midway in low-return plant foods (small seeds), nor any change in seed assemblage diversity once sample size was controlled for. Evidence also shows that people were not primarily using local alpine plants, but were transporting ricegrass and pine nuts from lower elevations. Floral evidence, paired with faunal data, points to a population increase resulting in resource depression and falling average return rates as the reason for the establishment of alpine villages.

For many decades, archaeologists believed that high-elevation areas of the Great Basin had only been used occasionally and in a limited way. This changed in 1982, when the first description of a residential alpine village was produced, showing that people had invested substantial time and energy in creating domestic stone structures (Grayson 1993; Thomas 1982). The initial discovery of Alta Toquima, a village above the tree line in the Toquima Range in Nevada, was surprising because such areas had only been known to contain temporary hunting camps, drive blinds, and meat processing stations (Thomas 1982). Information from Alta Toquima prompted archaeologists to survey other alpine areas, resulting in the rapid discovery of more residential rock ring sites at elevations ranging from 3,130 to 3,854 m. in the White Mountains and Toiyabe Range (Bettinger 1991; Canaday 1997).

From the time alpine villages were first reported, archaeologists have been working on the task of explaining these phenomena (Bettinger 1991, 1994; Elston 1986; Grayson 1991; Thomas 1982), making this an important line of research in the Basin (Beck and Jones 1992; Bettinger 1993). Why was so much effort put into establishing permanent structures at such a high elevation? Why did the use of alpine areas increase when it did?

Ideas that have been proposed to explain the timing and nature of alpine village occupation include an ethnic spread, increasing populations, foraging conflicts, deteriorating lowland conditions, and improving alpine conditions (Bettinger 1993). A variety of lines of evidence have been presented in the literature to evaluate these explanations, including faunal remains, grinding implements, chipped stone tools, lichenometric dates, and radiocarbon dates (Bettinger 1991; Bettinger and Oglesby 1985; Grayson 1991). Plant remains offer a complementary source of information to help clarify how and why people began to use high-elevation areas so intensively about a millennium ago. This paper adds to the growing body of information by presenting and analyzing archaeobotanical evidence from seeds deposited at Midway (CA-MNO-2196), one of the alpine village sites in the White Mountains of California.

HIGH-ELEVATION SITES IN THE GREAT BASIN

The Nature of Alpine Archaeological Sites

The early "previllage" use of mountain tops in this area is characterized by hunting facilities that date back before A.D. 600. Most of these early sites consist of stacked rock features such as hunting blinds and drive lines. These early sites are known to exist in the ranges that contain later residential structures (the White Mountains, the Toquima Range, and the Toiyabe Range) as well as in several alpine areas that have no recorded domestic stone structures (the Ruby Mountains, the Snake Range, the Jarbidge Mountains, and the Deep Creek Mountains). Like the villages that follow them, hunting facilities are not evenly distributed on mountain tops, but occur in greater concentrations in smaller subareas within the White Mountains, the Toquima Range, and the Toiyabe Range (Canaday 1997). Many of the later alpine village deposits are underlain by middens containing artifacts and food refuse from this early period, but no previllage residential structures have been found.

During village times, between one and thirty-one circular dwellings—rock rings with central depressions, multi-course stone walls and evidence of footings for a superstructure—were built at each village site. Residential rock rings in the Toquima and Toiyabe ranges are associated with projectile points that post-date Elko times (Canaday 1997; Thomas 1982), as confirmed by a median radiocarbon age of A.D. 1010 from Toquima village samples (Thomas 1994). Use of the White Mountain villages also starts after Elko times; projectile point chronologies, radiocarbon dating, and lichenometry show that use of White Mountain villages begins between A.D. 600–900 and ends during the historic era (Bettinger 1991; Bettinger and Oglesby 1985; Grayson 1991).

Alpine Sites in the White Mountains

In the White Mountains, Bettinger (1991) reported that village deposits contained significantly more millingstones, typeable points, blanks, drills, unifaces, and roughouts than previllage deposits, but that early deposits contained more untypeable points, bifaces, and pressure scrap. Bettinger has also noticed a statistical association of early (pre-A.D. 600) dart points with hunting facilities, and later (post-A.D. 600) arrow points with village deposits (Bettinger 1991). This evidence has led Bettinger and others to conclude that small all-male parties used the alpine areas for short logistical forays to harvest mountain sheep during previllage times (Bettinger 1991; Grayson 1991; Delacorte 1994; Kelly 1987). In this view, the use of villages involved longer stays by more diverse groups of people (single or multiple families) who established residential bases from which they exploited a broader range of resources (Bettinger 1991; Delacorte 1994; Kelly 1987). Integral to this scenario is the assumption that village subsistence strategies were characterized by an increased emphasis on a wider array of foods, especially low-return items like small-bodied prey and small seeds (Bettinger 1991).

Critics of this interpretation of the alpine archaeological record do not doubt that there are differences in land use in the White Mountains before and after A.D. 600, but argue that the differences have been exaggerated. Basgall and Giambastiani (1995) point out that the lack of arrow points found outside village contexts could be due to collection bias, that many deposits used for analysis were chronologically mixed, and that although millingstones are relatively more abundant in later deposits, they are still common in previllage contexts. Zeanah (2000) further questions the dichotomy, demonstrating that mountain sheep could have been profitably harvested in previllage times using a residential strategy. In addition, Thomas (1994) stresses the variability in Bettinger and Oglesby's (1985) dates, showing that White Mountain alpine villages were not all established and used, simultaneously, at A.D. 600. Nonetheless, there is a consensus that villages contain evidence of occupation by larger groups who stayed for one to two months during warm summer months and used more resources than their predecessors (Bettinger 1991).

Costs, Benefits, and Explanations of the Use of Alpine Areas

The construction of facilities, such as drive lines, hunting blinds, and dwellings, raises questions about the costs and benefits of living at this altitude. One cost is the amount of labor invested in these facilities, a capital investment that clearly indicates that there was value in utilizing this high-elevation patch, and that prehistoric inhabitants of the Great Basin planned to reuse this area regularly.

An obvious drawback is the opportunity cost of using high elevations, as it precludes the use of low elevations at the same time by those who have ventured upslope. Alpine zones have a lower taxonomic richness than lowland areas (MacArthur 1972), and some plant species at high altitude tend to have low, unreliable seed sets (Spira 1986; Wiens et al. 1988). Overall, higher elevations are less productive and predictable than other parts of the landscape (Bettinger 1991; Körner 2003; Picon-Reategui 1978; Zeanah 2000), making this patch a less attractive, lower-return foraging choice than lower-elevation patches in the same area (Bettinger 1991).

Given these costs, why would populations choose to move themselves and their possessions upslope to exploit a less stable and less diverse habitat? And why would people begin to use the higher-elevation areas more intensively and create alpine villages in the White Mountains starting a little over a thousand years ago? Several competing explanations exist to account for this seemingly illogical economic choice, linked to larger subsistence-settlement system changes seen in the valleys near the White Mountains.

The Greater Context: Changes in the Record Circa A.D. 600

Evidence from archaeological sites at lower and middle elevations around the White Mountains indicates that there were significant changes taking place around A.D. 600, as people placed greater emphasis on a wider range of lower-return resources (Delacorte 1990; Elston 1986). Although a few authors cite individual exceptions, this is generally seen as a time of intensification, centralization, and population growth (Bettinger 1993; Bouey 1979; Burton 1996; Delacorte 1991; Elston 1986; Kelly 1997; Nelson 1999; Zeanah 2000). As a result, territories became more restricted, movements became more regularized as sites were reused, trade networks contracted, and previously ignored or underused resources and habitats were exploited more fully (Basgall and Giambastini 1995; Delacorte 1990, 1994; Elston 1986; Giambastiani 2004; Nelson 1999).

In Owens and Deep Springs valleys, west and south of the White Mountains, the number and use of specialized hunting camps decreased starting about A.D. 600 (Basgall and McGuire 1988; Bettinger 1977; Delacorte 1990, 1991). Resources that had previously made only minor contributions to the diet grew more important, as pinyon camps, lowland seed camps, and freshwater mussels appeared in significant numbers (Basgall and McGuire 1988; Delacorte 1990, 1991, 1994; Giambiastani 2004; Zeanah 2002). Labor investment and reuse of permanent facilities increased, as people planned to revisit locations regularly. Obsidian sourcing and hydration data reveal that obsidian distributions became more restricted as people traveled and traded less widely (Giambastiani 2004). Such trends are evident even in more marginal areas such as Fish Lake Valley, the Volcanic Tablelands, and the Coso Volcanic fields (Basgall and Giambastiani 1995; Delacorte 1990, 1991; Gilreath and Hildebrandt 1997; Nelson 1999). In Owens Valley, this trend culminated in the low mobility, high territorial circumscription, permanent lowland villages, and irrigation practices that typified Owens Valley patterns in ethnohistoric times (Bettinger 1999a, 1999b; Bouey 1979; Burton 1996; Delacorte 1990, 1991; Lawton et al. 1976; Steward 1938).

Explanations for the Establishment of Alpine Villages in the White Mountains

How do changes in the rest of the region relate to what we see in the White Mountains? One possibility is that climate was ultimately responsible, either through a favorable change that enhanced the productivity of alpine areas, or through a downturn that decreased food availability in the valleys. There is some evidence of warm, dry conditions in the Great Basin during the period from A.D. 900–1350 (Millar and Woolfenden 1999), leading some (e.g., Hughes 1994; Knack 1994) to speculate that alpine villages were founded by people compensating for growing aridity in the lowlands (Aikens and Witherspoon 1986). However, in comparing archaeological and paleo-climatological data, Delacorte (1990), Bettinger (1991, 1994), Canaday (1997), and Hughes (1994) found mixed to no support for a climatological link, indicating that some other causal factor was of greater importance.

A competing proposal is that changes at A.D. 600 in both the Owens Valley and the White Mountain villages were due to rising population densities and the development of new labor-intensive strategies for obtaining and processing low-return foods. The Numic spread model, inspired by linguistic data and analysis from Lamb (1958), attributes these changes specifically to Numic-speaking peoples (Bettinger 1994; Bettinger and Baumhoff 1982, 1983; Delacorte 1990). The same intensification was attributed by other researchers (e.g., Canaday 1997; Delacorte 1994; Giambastiani 2004; Grayson 1991, 1993) to *in situ* population growth without any connection to a particular ethnic group. There are several reasons to suppose that there may be a connection between population density and alpine village use. First, population growth could depress return rates from traditionally used patches, forcing people to add lower-ranked foods and patches (e.g., grass seeds, pine nuts, pinyon woodlands, and alpine areas) to their foraging schedule (Bettinger 1987; Charnov 1976; Charnov et al. 1976; Kaplan and Hill 1992; MacArthur and Pianka 1966; Stevens and Krebs 1986). Second, a dense packing of people on the landscape would leave little "margin for error" in years when one resource might fail. Grayson (1991) and Canaday (1997), for example, explored the possibility that alpine areas would be used for exploiting marmots and limber pine (*Pinus flexilis*) nuts in compensation for single-leaf pinyon (*Pinus monophylla*) crop failures. Third, population increases can create population pressure, which Rosenberg (1998) has linked to intensification, decreases in residential mobility, storage, increased territoriality, and increased sedentism—regional trends that are temporally associated with the use of high-elevation villages in the White Mountains. Finally, alpine villages might be used because they offer the best resolution to the twin problems of resource scheduling and balancing the costs of travel, transportation, and processing (Basgall and Giambastiani 1995; Bettinger 1994; Canaday 1997; Delacorte 1994; Zeanah 2000, 2002).

Zeanah (2000) explored these trade-offs mathematically by modeling competing alpine costs and benefits in central place models, relying on the growing literature from Great Basin researchers on processing, return rates, and transport costs (e.g., Barlow and Metcalfe 1996; Brannan 1992; Jones and Madsen 1989; Metcalfe and Barlow 1992; Rhode 1990; Simms 1985b, 1987). Comparing returns of mountain sheep and tansymustard at an alpine and a lower-elevation base camp, Zeanah (2000) demonstrated that the residential use of high-elevation areas should occur during times of low human population density (previllage times) if high-ranked alpine resources (i.e., mountain sheep) were abundant. He also showed that in times of high population density (village times), people would have a wide breadth of diet and would map onto high elevations residentially in the White Mountains because better central place locations at lower elevations were already in use (Zeanah 2000). Likewise, Zeanah (2002) argued that residential camps in the pinyon woodlands on the slopes of the White Mountains were established around A.D. 650, when rising populations filled the low-elevation base camps below the pinyon zone that had previously been used for profitable logistical pine nut exploitation.

Alpine Archaeofaunas from the White Mountain Sites

When alpine villages were originally discovered, many believed they showed support for a spread of Numic-speaking peoples, as originally proposed by Bettinger and Baumhoff (1982). This idea explained changes in the archaeological record about a thousand years ago as the outcome of the switch from a "traveler" strategy (targeting high-return resources) to a "processor" strategy (targeting a wider range of low-return resources). Since this idea received much attention and discussion (e.g., Bettinger 1991, 1994; Grayson 1991; Madsen and Rhode 1994; Simms 1983), it was addressed by Grayson (1991) when the faunal assemblages from the White Mountain villages were analyzed and published. Grayson assumed that previllage groups pursuing a small number of easily available high-return resources would leave less diverse archaeofaunas than later Numic "processors," who supposedly gained a competitive advantage through using a broader and more diverse range of lower-return foods (Bettinger and Baumhoff 1982; Broughton and Grayson 1993; Grayson 1991).

Using faunal assemblages, Grayson (1991) found that there were no statistically significant differences in assemblage diversity between previllage and village faunas. Differences in NTAXA (richness, as measured by the number of taxa) were not as clear, but showed that the range of taxa being taken was primarily related to elevation, not sample age. Grayson also demonstrated that highly-ranked, large-bodied taxa were overrepresented in previllage contexts, while village deposits contained relatively more small-bodied prey. Specifically, previllage faunas contained more high-return mountain sheep remains, while village faunas had a higher proportion of marmots. These last results, related to resource ranking, were the only ones Grayson thought to be consistent with the Numic spread model. This led Grayson (1991) to conclude that his findings were unlikely to be explained by the Numic expansion model and most likely to be explained by growth in the regional human population.

Both Madsen (1993) and Bettinger (1991, 1994) criticized Grayson's analysis, arguing that assemblage richness and diversity are not appropriate measures of diet breadth. Bettinger (1994) stressed that the change was not a simple increase in NTAXA, but an increase in the proportion of low-return items being taken. Key resources were identified in the original model as small seeds (Bettinger and Baumhoff 1982, 1983). Madsen (1993) likewise pointed out that the use of small seeds in village times was pivotal to the postulated differences in traveler and processor strategies.

Plant use is important in competing explanations as well. Many of those who focus on increasing regional populations and intensification specify that changes in pinyon harvests were an important factor in the establishment of alpine villages (Bettinger 1994; Canaday 1997; Grayson 1991; Zeanah 2002). Others focus on the appeal of alpine plant resources (e.g., bitter root) as a possible attractive stimulus for residential mapping onto high-elevation resources (Bettinger 1991; Delacorte 1994). This makes floral assemblages critically important in understanding and evaluating changes in the prehistoric use of high-elevation areas.

MIDWAY SEED ASSEMBLAGES

Botanical Samples from the Midway site

Of all the villages in the White Mountains, Midway, at an elevation of 3,440 m., stands to reveal the most about plant use. One reason for this is that Midway contains the greatest number of millingstones of all the White Mountain sites, and milling equipment is argued to be indicative of plant processing activities here and elsewhere (Bettinger 1991; Bright et al. 2002; Jackson 1991; McGuire and Hildebrandt 1994; Zeanah 2000). Midway is also advantageous because it contains distinct previllage and village age deposits, allowing for the direct comparison of earlier and later assemblages. Additionally, the use of this single site guarantees that observed differences in taxonomic diversity will be due to human behavior and not to differences in geographic or biotic settings. The analysis of a single site controls for elevation, location, aspect, and slope—all of which are known to affect the species richness of plant communities (Körner 2003).

Yet another benefit of Midway is its unique chronology. Midway was the first village among the White Mountain sites to be occupied; it has the earliest rock ring date (A.D. 660) and it is the only site in which all structures predate A.D. 1285 (Bettinger and Oglesby 1985). Since materials from Midway date back to the beginning of village times, this site stands the best chance of revealing the reasons behind the initial establishment of villages. Midway is also an appropriate choice because many bulk sediment samples were taken and set aside for botanical analysis when the site was originally excavated, providing ample, well-preserved sediments from clearly defined temporal and functional contexts.

Midway was one of the sites chosen for faunal analysis by Grayson (1991), and was excavated by Bettinger, who also dated and analyzed the lithic artifacts and features from the site (Bettinger 1991; Bettinger and Oglesby 1985). Out of all the archived sediment samples from Midway, eleven samples were chosen for analysis because they came from a single set of comparable functional contexts (hearths and hearth-like features). These samples were also clearly assignable to either previllage or village times; none of the samples were derived from "mixed" deposits. Four of the eleven samples come from the lower, previllage, deposits that fall within the Cowhorn phase (1,200 B.C. to A.D. 600). The remaining seven sediment samples come from the upper, or village, deposits (i.e., the Klondike and Baker phases, post A.D. 600).

Samples were dry sieved and seed recovery was assessed for all samples using the "poppy seed test" (Scharf 1992; Wagner 1988). Recovery rates for these samples were high, varying from 92% to 96%. Preservation, likewise, was good, although grass seeds often lacked glumes. The results are summarized in Table 1, which includes the excavator's field sample number, the age of the sample, the sample size (NISP, the number of identified specimens), and measures of the two components of diversity—taxonomic richness (NTAXA) and taxonomic dominance (Simpson's D).

Table 1

SAMPLE CONTEXT, SIZE, RICHNESS, AND DOMINANCE FOR MIDWAY SEED ASSEMBLAGES

Field Sample	Archaeological Phase(s)	Sample Size NISP	Taxonomic Richness NTAXA	Taxonomic Dominance (Unevenness) Simpson index (*D*)
11129	Cowhorn	11	3	0.53
11130	Cowhorn	19	8	0.25
11131	Cowhorn	6	3	0.40
11102	Cowhorn	15	5	0.52
7069/7070	Klondike/Baker	207	24	0.24
7071	Klondike/Baker	67	8	0.63
7072	Klondike/Baker	145	17	0.28
7073	Klondike/Baker	78	10	0.26
7214	Klondike/Baker	20	4	0.34
10656	Klondike/Baker	206	21	0.26
10989	Klondike/Baker	6	4	0.13

Adapted from Scharf (1992:27–28)

Seed counts include burnt and unburnt, as well as whole and fragmented seeds, as all were likely to be cultural in origin (Scharf 1992).

The Simpson index, *D*, ranges from 0 to 1, and is the probability that any two observations, taken at random from an assemblage, will come from the same taxon. If p^i is the proportion of all observed individuals that belong to a given taxon, and *s* is the number of taxa present in the assemblage, then *D* can be calculated using the following formula:

$$D = \sum_{i=1}^{s} (p^i)^2$$

(See Magurran [1988, 2004] or Hurlbert [1971] for further details.)

Table 2 lists seed counts, broken down to the lowest possible taxonomic level, for each Midway sample. Some seeds could be securely assigned to a particular species, whereas others could only be identified to the generic or family level. Some seeds in the grass (Poaceae) and aster (Asteraceae) families could not be assigned to a named genus, but clearly fell into several distinct morphological types. Each grass morphotype, for example, was represented by seeds with a distinctive size and shape, but as glumes and other features were lacking, positive identifications could not be assigned to each type. For this analysis, morphotypes were given letter designations and treated as roughly equivalent to genus-level designations. Taxonomic designations presented in the text and tables reflect a series of recent changes and are drawn from the nomenclature currently in use by the United States Department of Agriculture (2008).

Sample Size and Richness in Midway Seed Assemblages

A quick scan of Table 1 shows that the total number of seeds and the absolute number of taxa in previllage samples are lower than those of village samples. From the differences in NTAXA, it would seem that later

Table 2

SEED COUNTS BY TAXON FROM MIDWAY SAMPLES

	Midway Cowhorn Phase Samples (by sample number)					Midway Klonkide/Baker Phase Samples (by sample number)							
Taxon	11129	11130	11131	11102	Total	7069/7070	7071	7072	7073	7214	10656	10989	Total
Asteraceae:													
Morphotype A	0	0	0	0	**0**	0	0	0	0	0	1	0	**1**
Morphotype B	0	0	0	0	**0**	0	1	0	0	0	0	0	**1**
Morphotype C	0	0	0	0	**0**	0	0	0	0	0	0	1	**1**
Brassicaceae:													
Descurainia sp.[2]	0	0	0	0	**0**	1	0	4	0	0	4	0	**9**
Caprifoliaceae:													
Sambucus sp.[1]	0	0	0	0	**0**	1	0	1	0	0	1	0	**3**
Caryophyllaceae:													
Cerastium sp.[1]	0	0	0	0	**0**	4	0	0	0	0	0	0	**4**
Sagina sp.[2]	0	0	0	0	**0**	0	1	0	0	0	1	0	**2**
Chenopodiaceae:													
Chenopodium sp.[2]	8	9	4	11	**32**	27	4	28	8	3	23	2	**95**
Atriplex sp.[2]	0	1	0	1	**2**	0	2	1	0	3	3	0	**9**
Crossosomataceae:													
cf. Glossopetalon sp.[2]	0	0	0	0	**0**	0	0	0	0	0	0	2	**2**
Cyperaceae:													
Carex sp.[2]	1	1	0	0	**2**	0	0	1	0	0	0	0	**1**
Eleocharis sp.[2]	0	0	0	0	**0**	0	0	0	0	0	0	1	**1**

Table 2 (continued)

	Midway Cowhorn Phase Samples (by sample number)					Midway Klonkide/Baker Phase Samples (by sample number)							
Taxon	11129	11130	11131	11102	Total	7069/7070	7071	7072	7073	7214	10656	10989	Total
Ericaceae:													
cf. *Ledum*[1]	0	0	0	0	**0**	0	1	0	0	0	0	0	**1**
Fabaceae:													
Astragalus sp.[2]	0	0	0	0	**0**	3	0	1	2	0	2	0	**8**
Grossulariaceae:													
cf. *Ribes* sp.[2]	0	0	0	0	**0**	19	0	0	0	0	0	0	**19**
Juncaceae:													
Juncus sp.[2]	0	0	0	1	**1**	2	0	1	0	3	0	0	**6**
Pinaceae:													
Pinus monophylla[2]	0	0	0	0	**0**	23	20	30	11	0	14	0	**98**
Pinus cf. *monophylla*[2]	2	4	0	1	**7**	71	33	39	23	11	61	0	**238**
Poaceae:													
Achnatherum hymenoides[2]	0	0	0	0	**0**	6	0	3	3	0	71	0	**83**
Morphotype A	0	0	0	0	**0**	1	0	0	0	0	0	0	**1**
Morphotype B	0	0	0	0	**0**	2	0	1	1	0	1	0	**5**
Morphotype C	0	0	0	0	**0**	6	0	3	0	0	2	0	**11**
Morphotype D	0	0	0	0	**0**	1	0	0	0	0	0	0	**1**
Morphotype E	0	0	0	0	**0**	6	4	21	3	0	5	0	**39**
Morphotype F	0	1	0	0	**1**	5	0	1	0	0	0	0	**6**
Morphotype G	0	0	0	0	**0**	0	0	1	0	0	0	0	**1**
Morphotype H	0	0	0	0	**0**	0	0	0	0	0	1	0	**1**
Morphotype I	0	0	0	0	**0**	0	0	0	0	0	6	0	**6**
Morphotype J	0	1	0	0	**1**	0	0	0	0	0	2	0	**2**
Morphotype K	0	0	0	0	**0**	1	0	0	0	0	0	0	**1**
Morphotype L	0	0	0	0	**0**	1	0	0	0	0	0	0	**1**
Morphotype M	0	0	0	0	**0**	1	0	0	0	0	0	0	**1**
Morphotype N	0	0	0	0	**0**	0	0	0	0	0	1	0	**1**
Polygonaceae:													
Rumex sp.[2]	0	0	1	0	**1**	0	0	0	0	0	0	0	**0**
Polygonum sp.[2]	0	1	0	0	**1**	3	0	1	1	0	1	0	**6**
Eriogonum sp.[2]	0	0	0	1	**1**	0	0	0	0	0	0	0	**0**
Portulaceae:													
Lewisia sp.[1]	0	0	0	0	**0**	3	0	3	2	0	1	0	**9**
Claytonia sp.[2]	0	1	0	0	**1**	0	0	0	0	0	0	0	**0**
Cistanthe sp.[2]	0	0	0	0	**0**	3	0	0	0	0	1	0	**4**
Rosaceae:													
Amelanchier cf. *pallida*[1]	0	0	0	0	**0**	1	0	0	5	0	0	0	**6**
Solanaceae:													
Lycium sp.[2]	0	0	1	0	**1**	14	1	5	19	0	3	0	**42**
Oryctes sp.[1]	0	0	0	0	**0**	2	0	0	0	0	1	0	**3**

1 = uniquely high-elevation (only found above 3,100 m. elevation)
2 = low or widely-ranging taxa (taxa with ranges wholly or partially below 3,100 m. elevation)

assemblages contain a greater relative range of taxa than earlier ones. However, the number of seeds recovered and identified for these samples varies widely, from 6 to 207, with early deposits being underrepresented. This poses a considerable obstacle, as sample size affects taxonomical richness and diversity in samples (Grayson 1984; Rhode 1988), introducing a systematic bias unrelated to human behavior, inherently resulting in larger NTAXA for larger assemblages. For seeds at Midway, sample size and generic richness values are highly correlated (Pearson's $r = .98$, $p < 0.001$), showing that NTAXA is primarily a function of assemblage size (Scharf 1992) and that a comparison of raw values would constitute an unfair test of any model.

One method for compensating for the sample size effect is to use rarefaction, a means of recalculating richness values used in the biological sciences (Hurlbert 1971; Magurran 1988, 2004). Using a critical value of $\alpha = 0.05$, rarefied values submitted to an ANOVA show that there is no statistically significant difference between the two sets of samples, as the analysis produced an $F(1,9) = 1.19$, $p = 0.304$. As archaeologists more commonly use linear regression to identify, control for, and remove the bias that sample size imposes on richness (Grayson 1984; Rhode 1988), this method was also used by regressing NTAXA on NISP. The resulting residual values, representing that portion of the variability in NTAXA not explained by sample size alone, were entered into a one-way ANOVA that produced an $F(1,9) = 0.68$, $p = 0.431$. Linear regression, like rarefaction, showed that no matter what method is used to control for sample size, the results are the same—there is no significant difference between previllage and village samples in terms of taxonomic richness (Scharf 1992, 2000).

Taxonomic Dominance in Midway Seed Assemblages

Sample diversity can be characterized by taxonomic dominance (unevenness) as well as by richness (Magurran 1988). For Midway seed assemblages, the Simpson index was used to measure this aspect of sample diversity, as the index is less sensitive to sample size bias than other measures (Magurran 1988). A correlation run on Midway assemblages confirms that the Simpson index is statistically unrelated to sample size (Pearson's $r = .31$, $p = 0.177$) and therefore can be meaningfully used in further statistical analyses. Used in an ANOVA between earlier and later samples, the Simpson index fails to show a significant difference between Cowhorn and Klondike/Baker samples (Scharf 1992, 2000), with an $F(1,9) = 1.65$ and $p = 0.231$.

Presence, Absence, and Abundance of Taxa in Midway Seed Samples

Table 2 contains the seed counts on which sample size and diversity were based. The most abundant taxa at Midway identifiable to a generic level are (in descending order) pinyon (*Pinus monophylla* and *Pinus* cf. *monophylla*), goosefoot (*Chenopodium*), ricegrass (*Achnatherum hymenoides*), desert-thorn (*Lycium*), currant (*Ribes*), saltbush (*Atriplex*), bitter root (*Lewisia*) in a tie with tansymustard (*Descurainia*), and milkvetch (*Astragalus*). Also present are elderberry (*Sambucus*), chickweed (*Cerastium*), pearlwort (*Sagina*), greasebush (*Glossopetalon*), sedge (*Carex*), spikerush (*Eleocharis*), Labrador tea (*Ledum*), rush (*Juncus*), dock (*Rumex*), knotweed (*Polygonum*), buckwheat (*Eriogonum*), springbeauty (*Claytonia*), pussypaws (*Cistanthe*), serviceberry (*Amelanchier*), and oryctes (*Oryctes*). Two of the three most common taxa, pinyon and ricegrass, currently grow at elevations well below Midway and must have been brought upslope to the site. Many other taxa found at Midway can also be found at lower elevations and in valley sites, while stereotypical alpine taxa (e.g., bitter root) are low in abundance. Conspicuously absent are limber pine nuts, and some taxa that are common in lower sites such as blazing star (*Mentzelia*), cattail (*Typha*), bulrush (*Schoenoplectus*), and iodinebush (*Allenrolfea*, commonly referred to in the archaeological literature as "pickleweed") (Barlow and Metcalfe 1996; Basgall and McGuire 1988; Delacorte 1990; Fowler 1986; Gilreath and Hildebrandt 1997; Nelson 1999).

Uniquely Alpine Taxa in Midway Seed Samples

Elevation ranges for taxa found at Midway are footnoted in Table 2. If people are being "pulled" upslope by increasingly productive alpine resources, samples should contain a high proportion of alpine resources (Canaday 1997; Scharf 1992). Conversely, if lowered returns in lowland areas are "pushing" people up into higher elevations, then resources available at low elevations would be used at a relatively higher rate.

For this analysis, uniquely high-elevation plants were assumed to be those found only above the minimum elevation at which the alpine villages are found (3,100 m.). Information on plant ranges was obtained from the published floras that cover the White Mountains (i.e., DeDecker 1991; Elliot-Fisk and Peterson 1991; Lloyd and Mitchell 1973; Morefield 1988), with the result that only six taxa could be identified as uniquely alpine in availability. Table 3 shows the number of seeds from alpine plants in previllage and village assemblages at Midway. Most of the seeds from both previllage (94.7%) and village (97.1%) contexts are derived either from low-elevation areas or plants that are widely distributed, rather than those that are unique to the alpine environment. A chi-square test done on Table 3 indicates that the difference between village and previllage floras is not statistically significant, with a χ^2 (1, N = 698) = 0.84,

Table 3

SEEDS FORAGED FROM UNIQUELY HIGH-ELEVATION SETTINGS VS. THOSE NOT NECESSARILY FROM HIGH ELEVATIONS

	Cowhorn (previllage) NISP	Klondike/Baker (village) NISP	Total
Uniquely higher-elevation	1 (1.40)	19 (18.60)	20
Uniquely lower-elevation and those with large altitudinal range	48 (47.96)	630 (630.40)	678
Total:	**49**	**649**	**698**

Expected values are listed, above, in parentheses.
Pearson's chi-square for this table is χ^2 (1, N = 698) = 0.84, $p < .359$
Some seeds had to be dropped from the analysis, as they were not able to be identified at a low-enough taxonomic resolution to allow for their origins to be determined. Hence, the NISP values in this table will be lower than those reported in Tables 1 and 2.

$p < .359$. There is no difference in the proportion of alpine plants taken during earlier and later occupations, indicating there was no change in the attractiveness of high-elevation plant resources over time. Critics might point out that the results from Midway come only from seeds and from a single site, whereas other plant materials and sites might reveal that alpine tubers (such as bitter root) played a dominant role in the diet and land use strategies at alpine sites. However, the analysis of seeds and other plant parts at other alpine sites shows that a surprising number of botanical remains from other alpine sites are obtained from lower elevations (Canaday 1997; Rhode 2007).

Low- and High-Return Taxa in Previllage and Village Seed Assemblages

Although early and late assemblages have equal diversity and percent abundances of lowland resources, early people could be focusing on a different combination of taxa than later residents. For this analysis, all the samples from the Cowhorn (previllage) phase were lumped together, and all Klondike/Baker (village) samples were summed together into a single unit. All low-return small seeds were totaled for each time period. Totals for larger, high-return seeds (nuts) were also created and both are presented in Table 4. Berries were not included in the totals as they were not specifically mentioned in explanations for the establishment of alpine villages. A chi-square test done on Table 4 indicates that the difference between village and previllage floras is statistically significant,

Table 4

TYPES OF RESOURCES BY TIME PERIOD

	Cowhorn (previllage) NISP	Klondike/Baker (village) NISP	Total
Small seeds	43 (25.71)	320 (337.29)	363
Large seeds (nuts)	7 (24.29)	336 (318.71)	343
Total:	**50**	**656**	**706**

Expected values are listed, above, in parentheses.
For this table, the Pearson's chi-square statistic χ^2 (1, N = 706) = 25.80, $p < 0.0001$

with a χ^2 (1, N = 706) = 25.80, $p < 0.0001$. A comparison of observed and expected values shows that small seeds are relatively overrepresented in early contexts and large seeds are overrepresented in later contexts. Counts from Table 2 indicate that these relationships are being primarily driven by pinyon pine nuts (the only large seeds in the site) in village samples, and small seeds of *Chenopodium* in previllage assemblages (Scharf 1992). It is interesting that although small seeds are statistically more abundant in previllage contexts, village samples contain a greater amount of grass seeds, with ricegrass being especially abundant.

DISCUSSION

Occupation and the Use of Alpine Seeds

Results from Midway conform well to some hypotheses regarding alpine villages. Village samples contain greater numbers of seeds than previllage samples, supporting the consensus view that Midway was used by larger groups for longer periods of time during village times than it was before A.D. 600. Proportions of alpine plants in previllage and village assemblages also confirm the conclusion that climatic change is not responsible for the establishment of villages. If environmental influences had raised alpine productivity during village times, the increased returns would have resulted in a narrower focus on a restricted range of high-return items (Bettinger 1987; Emlen 1966; Kaplan and Hill 1992; MacArthur and Pianka 1966) and the proportion of alpine seeds would be highest in village samples. Statistical analyses clearly show that there is no significant difference in either the proportion of uniquely alpine taxa being taken over time, or a constriction in the range of items being taken. Thus, there is no evidence for an increased attractiveness of alpine resources due to favorable environmental changes. In fact, over 94% of all seeds are from low-elevation or widely distributed plants, indicating that local alpine plants were never an important part of the diet.

Sample Diversity, Resource Returns, and Intensification

The taxonomic richness and dominance data conflict with other expectations about changing high altitude land use. As diversity does not vary at Midway, it can not be said that previllage peoples took a narrower set of taxa than later people. If Grayson (1991) is correct about the relationship between assemblage diversity and diet breadth, then this contradicts the predictions of the original Numic expansion idea (Scharf 1992, 2000). Seed assemblages, likewise, do not demonstrate a simple expansion in the number of plant food resources that might be expected from *in situ* population growth and a regional trend towards resource intensification.

Another anticipated outcome of resource intensification (whether due to Numic-speaking peoples or not) is that low-return taxa should increase at the expense of high-return taxa over time. It has been argued that return rates for individual plant species can not be used on an interval or even ordinal level, due to complex interactions of factors such as differential transport and processing costs (Barlow and Metcalfe 1996; Brannan 1992; Grayson and Cannon 1999; Jones and Madsen 1989; Metcalfe and Barlow 1992; Rhode 1990), and that many traditional assumptions about return rates and resource types are faulty (Madsen and Schmitt 1998). Even so, Simms (1985a, 1985b, 1987) and others (Bettinger and Baumhoff 1982, 1983) have argued that relative return rates for broad categories of plant resources are robust measures for analysis and comparison between spatial and temporal contexts. Following this reasoning, resource intensification should result in a higher abundance of large seeds in early contexts, and small seeds in later contexts (Bettinger and Baumhoff 1982, 1983; Madsen 1993). The opposite trend is seen at Midway, as there is a proportionately greater emphasis on small, low-return seeds in previllage samples and a relative overabundance of large, high-return seeds in village samples. This could be because the expectations need revision, as Basgall and Giambastiani (1995) implied when they reported that they were surprised to find evidence of occupation and plant use in the marginal Volcanic Tablelands predating 1,360 B.P. As Midway is only one site, resolution of this issue will require a wider set of archaeobotanical data (including roots) from a number of other alpine sites.

Pinyon and Ricegrass

In revisiting the Numic spread hypothesis, Bettinger (1994) argued that it was more than a simple increase in the use of small seeds that allowed later populations to gain a competitive advantage. In a review of data from Midway, he focused on new green phase methods of harvesting as a key Numic innovation, as these allowed for the mass collection and storage of ricegrass and pinyon after A.D. 600 (Bettinger 1994; Basgall and Giambastiani 1995; Delacorte 1990, 1994), changing the relative costs and benefits of these resources relative to others (Madsen and Schmitt 1998). As Bettinger has pointed out, two of the three most abundant taxa at Midway are ricegrass and pinyon, with pinyon remains being more numerous in village contexts and ricegrass present only in village contexts. Bettinger (1999a, 1999b, 2001) later linked these changes to the introduction of the bow and arrow into the Great Basin. (See Eerkens et al. 2002 for a different explanation of green-cone processing and storage). According to Bettinger, this technological change affected hunting in such a way that it became permissible for individuals to stockpile private reserves of plant foods, socially allowing for storage and rewarding individuals for their increased foraging efforts. Once storage was an acceptable practice, people focused on "back-loaded" resources (pine nuts and seeds) that could be gathered and cached with little energy, but that required significant processing for consumption (Bettinger 1999a, 1999b). Storage, in turn, allowed for restricted territories and lowered residential mobility (Bettinger 2001; Rosenberg 1998).

Evidence from outside the alpine zone supports this idea. Significant numbers of pinyon camps appear at this time, as do seed camps and threshing floors used for the mass production of grass seeds (Basgall and Giambastiani 1995; Bettinger 1994). One of the lower-elevation sites with clear evidence for combined pinyon and ricegrass use is Fish Cave Slough in the Volcanic Tablelands. The two foods co-occur in human coprolites at Fish Cave Slough, showing that they were eaten together (Nelson 1999). Ricegrass was locally available and harvested in late spring or early summer, while pinyon was a distant resource available only in the fall. This led Nelson (1999) to conclude that the pinyon had to have been stored and brought down to Fish Cave Slough to supplement local foodstuffs.

Likewise, pinyon and ricegrass are not local to Midway, and were transported to the site from lower elevations. This means that they were either logistically procured through round trips from alpine village base camps, or carried on a one-way trip upslope at the beginning of the season to provision people on their journey to the alpine meadows. Since Midway could only be occupied during the snow-free months of summer, and pinyon is harvested in the fall, these pine nuts had to be taken from stores from a previous year's harvest.

The transport of pinyon to Midway makes economic sense, even though the site is located over 500 m. in elevation above the modern upper limits of pinyon (Lloyd and Mitchell 1973), and it is costly to transport items up a slope (Brannan 1992). Pinyon has large, calorically rich seeds that are high in carbohydrates and provide a significant source of minerals and amino acids (Farris 1980; Sutton 1984), making it a high-ranking food (Simms 1985a, 1987) likely to be transported to remote base camps (Barlow and Metcalfe 1996; Jones and Madsen 1989; Rhode and Madsen 1998). It has been estimated that pinyon can be potentially carried 100 km. from where it is procured and still provide a return on the investment (Jones and Madsen 1989). Low-return items, in contrast, from both the local area and beyond, should be ignored (Jones and Madsen 1989; Rhode 1990). *Allenrolfea* is one such low-ranked lowland resource that is much less profitable to transport than pinyon (Barlow and Metcalfe 1996; Jones and Madsen 1989), and it is understandably absent at Midway. Even stands of limber pine, that grow closer to Midway than pinyons do today, were ignored and are absent in the assemblages.

Other researchers have predicted that transportation costs for pinyon would be held down by processing at the procurement site (Barlow and Metcalfe 1996; Metcalfe and Barlow 1992), with the highest return on investment derived from drying the cones and removing the nuts (Barlow and Metcalfe 1996). As expected, Midway samples contain hulls but no cones or pine needles, showing that the labor for initial processing was invested in advance, in order to provision trips to the alpine villages. Although pine nuts could have been further processed at the collection site, the resulting weight reduction would not have saved enough on transport costs to justify the effort. Also, because nuts were stored for many months, keeping nutmeats in the hull protected the nutmeats and reduced potential losses due to pests and decomposition.

Similar patterns are seen at Danger Cave in the northeastern Great Basin, where people also processed pinyon at the procurement area so that hulls, but few cone fragments, were found at the cave (Rhode and Madsen 1998). As at Midway, more distant stands of pinyon were preferred over closer stands of limber pine. In their analysis of Danger Cave materials, Rhode and Madsen (1998) showed that pinyon was only brought to the site when people were moving to the patch, to fund trips to the new base camp. Once at the cave, people concentrated on using local, productive marsh resources.

The presence of pinyon at Midway raises other issues as well. Although village samples contain a greater number of pine nuts at Midway than earlier samples, pinyon still has a substantial presence in previllage samples. Pinyon is the second most abundant taxon in previllage assemblages, and occurs in three of four early samples. Along with CA-INY-30, this makes Midway one of only two sites in the Owens Valley area containing pinyon that predates A.D. 600 (Zeanah 2002). CA-INY-30 is a lowland village site on Lubkin Creek that contains substantial amounts of early milling equipment and plant remains (including both pinyon and ricegrass) from Newberry deposits (Basgall and McGuire 1988). This indicates that plant processing did not suddenly start after Newberry times. Basgall and McGuire (1988) have suggested that the apparent lack of plant processing evidence predating A.D. 600 is due to a bias in site visibility and archaeological methods, and not due to a lack of prehistoric plant use. If groundstone is linked with seed processing, this conclusion is supported by an abundance of milling equipment in early contexts at Midway. Even earlier evidence comes from Danger Cave, where the substantial use of small seeds extends back to the early Holocene (Rhode et al. 2006).

Zeanah (2002) made an analogous argument for the seemingly instantaneous and relatively late appearance of pinyon exploitation in the Owens Valley archaeological record some 1,350 years ago (Bettinger 1989; Simms 1985a). He argued that pinyon use did not start at this time—it merely became more archaeologically visible. Both INY-30 and Midway, he reasoned, were part of a system that utilized pinyon through a logistical strategy. Both sites lie outside the pinyon woodlands, and predate the rapid and remarkable establishment of residential pinyon camps. After A.D. 650, dense packing of people in the lowest parts of the valley meant that less favorable locations had to be used, and residential bases had to be established in the once-marginal pinyon woodlands. Whereas others have viewed the appearance of abundant milling equipment in the pinyon zone at A.D. 650 as signaling the onset of pine nut use, Zeanah has interpreted this as evidence of a shift in existing exploitation behaviors. For him, A.D. 650 marked the inception of a new strategy of bulk processing of pinyon at residential sites, specifically in preparation for storage and transport (Zeanah 2002).

Evaluating Explanations for Alpine Villages

People were bringing pinyon to Midway during both previllage and village times, preferring to pay the costs of processing and transporting seeds to Midway rather than using locally available plant taxa. This was part of a greater trend at the site in which uniquely alpine seeds were ignored, and it implies that alpine plants were not "pulling" people upslope. Nor did alpine plants increase in attractiveness—there are no significant changes in the contribution of alpine seeds to the diet over time. This lack of change over time indicates that climate was not the cause for the establishment of alpine villages, as favorable changes would have raised the productivity at high elevations, resulting in an increased use of special plant foods that could only be gathered at high altitudes.

If alpine patches were not increasing in returns, were lower-elevation patches decreasing in returns? An increase in the number of seeds being deposited at Midway shows that people were staying for longer periods during village times, which could be due to decreasing returns in the valley and lower mountain slopes. If lowland resources were being stressed, resource depression and lowered average return rates should have resulted in the addition of new resources and patches to the itinerary (Bettinger 1987; Charnov et al. 1976). Within the alpine patch, the diversity of resources being taken should have increased; later seed assemblages should demonstrate greater taxonomic richness and lower dominance than earlier samples. However, after controlling for differences in sample size, taxonomic richness and unevenness in seed samples do not change over time. Seed assemblage diversity does not follow the trends expected, given a regional trend towards either resource depression or resource intensification. Sample diversity results from Midway, along with statistically higher rates of small seed deposition in early samples, also argue against the original expectations for a Numic expansion as put forth by Bettinger and Baumhoff (1982). However, increased amounts of ricegrass and pinyon are found in later contexts, providing support for one of the later (Bettinger 1994) restatements that linked a Numic spread to the success of new green phase plant collection strategies.

It could be that diversity measures of seed assemblages, taken in isolation, are not representative of the greater suite of foraging decisions being made in alpine areas. If roots (like *Lewisia*) or animal foods were more important to the diet, then the taxonomic representation of seeds could remain unchanged over time while new strategies for obtaining mammals and/or roots were being used to meet the new challenges presented by lowland resource depression (Charnov et al. 1976). In fact, faunal evidence does support the notion of overall depression on the landscape, as more low-ranked taxa (marmots) are being taken in village times (Grayson 2001). Thus, the greater body of evidence shows most support for a drop in foraging returns at lower elevations as the impetus for an increased use of mountain tops in the Great Basin. When compared to the seed assemblages at Midway, the relatively large faunal assemblages indicate that animal foods were more important than seeds. Certainly, alpine animals are better represented than alpine seeds.

Given the assumption that prehistoric inhabitants of the Great Basin followed a sexual division of labor in which men focused on hunting high-return mammals and women took primarily low-return plant foods (Bettinger 1999a, 1999b; Elston and Zeanah 2002; Zeanah 2004), alpine villages pose a problem. In various parts of California and the Great Basin, there was a shift over time that resulted in residential site locations that favored women's work over men's (Elston and Zeanah 2002; Jackson 1991; Zeanah 2004) by the middle to late Holocene. If alpine villages were being established to obtain alpine faunal resources, either villages are the exception to this trend, or women were participating in marmot harvesting.

Before seed assemblages were analyzed at Midway, the expectation was that alpine plants and small seeds played a pivotal role here, and this idea was based at least in part on the profusion of milling equipment found at this site. Grinding stones are important for removing the hulls from pinyon and for grinding other seeds (such as ricegrass). These artifacts do not have to be used solely for plant processing, as small mammal blood has been found on groundstone artifacts elsewhere in California (Yohe et al. 1991). Grayson (1991) has pointed out that marmots may have been attractive, especially during village times, because they contained fat that could not be obtained profitably from other resources during times of depressed overall returns. Animal bones at alpine villages in the White Mountains are highly fragmented and burnt, indicating that animals were being processed more fully for food and/or fuel (Grayson and Millar 2008). Faunal materials in lowland sites near Manzanar are also extremely fragmented, showing that each individual animal was being utilized to a greater extent than before, possibly for maximizing access to fats (Burton 1996). Again, the faunal data support a scenario in which regional resource intensification resulted in a more complete, expanded use of all resources and patches.

Thus, results from Midway do not provide support for a causative climatic change. The presence of ricegrass and pinyon provides support for one expectation related to a Numic expansion. Taken in isolation, trends in seed diversity and small-seed use are more difficult to interpret, as they do not lead to a clear, simple conclusion regarding resource intensification. Paired with the faunal data, however, the combined results indicate that alpine villages were established at a time when returns at all elevations were diminishing due to resource depression. In the absence of climatic change, the most likely cause for resource depression and the establishment of alpine villages would be population growth, which resulted in increased population pressure and lowered average foraging returns.

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