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Alpine Hunting and Selective Transportation of Bighorn Sheep in the White Mountains, California

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In the White Mountains of California, a shift in the use of the alpine zone from logistical (Previllage) to residential (Village) occupation circa 1,350 B.P. is evident in the appearance of structures, dense midden sites, and an increase in diet breadth. This change in settlement-subsistence should also be apparent in the representation of skeletal parts of artiodactyls exploited in the alpine zone. Since central-place foragers minimize the costs of transporting large game by increasing field processing in order to reduce transport weight, the logistical use of the alpine zone should be marked by high levels of selective transportation of artiodactyl body parts, while minimal selective transportation to alpine residential bases is expected after c. 1,350 B.P. These predictions are tested through a comprehensive analysis of the skeletal part representation and taphonomy of the faunal assemblages from a suite of White Mountains archaeological sites. Differences in skeletal part representation between Previllage and Village assemblages generally reinforce expectations derived from the central-place foraging model, with some important deviations worth further investigation.

FIELDWORK COMPLETED IN THE LATE TWENTIETH century by Bettinger and others resulted in the identification of two discrete high-altitude adaptations present in the White Mountains (Fig. 1) that have been observed elsewhere in the Great Basin, such as in the Toquima Range in Nevada (Thomas 1982) and the Wind River Range in Wyoming (Morgan et al. 2012). Early use of the alpine zone in the White Mountains involved a limited-intensity occupation centered on the long-range logistical hunting of large game, often referred to as the “Previllage” adaptation (Bettinger 1991). Previllage sites consist of hunting blinds and sparse flake and tool scatters that are indicative of individual hunters or small hunting parties targeting large game, namely bighorn sheep (*Ovis canadensis*), and operating from lower-elevation residential bases in nearby valleys, such as the Owens Valley (Bettinger 1991:657–658). The caloric returns from large game arguably compensated for the increased costs of exploiting alpine systems from these lower valleys.

Previllage sites are common until about 1,350 B.P., after which residential bases appear at high elevations.

Excavations of over a dozen “Village” sites in the White Mountains (see Bettinger 1991), ranging in elevation from 3,130 to 3,854 m. amsl, revealed a pattern consistent with long-term, generalized hunting and gathering at odds with the Previllage adaptation. The remains of roofed dwellings, abundant milling and hunting equipment, and extensive middens with abundant charcoal and a variety of alpine plant residues (Rankin 2016; Scharf 2009) and animal remains dominated by bighorn sheep and marmot (*Marmota flaviventris*; Fisher 2015; Grayson 1991) are characteristic of extended occupations by multifamily units (Bettinger 1996:664). These two adaptations are not necessarily mutually exclusive in their location, as several Village sites have an earlier, Previllage, component.

The presence of milling equipment and a dominance of lower efficiency food remains, such as roots, grass seeds, nuts, and small game, have been interpreted as evidence of alpine resource intensification (Bettinger 1991; Grayson 1991). Grayson (1991) demonstrated that there was an increased focus on alpine-zone animal resources corresponding with the shift to Village occu-

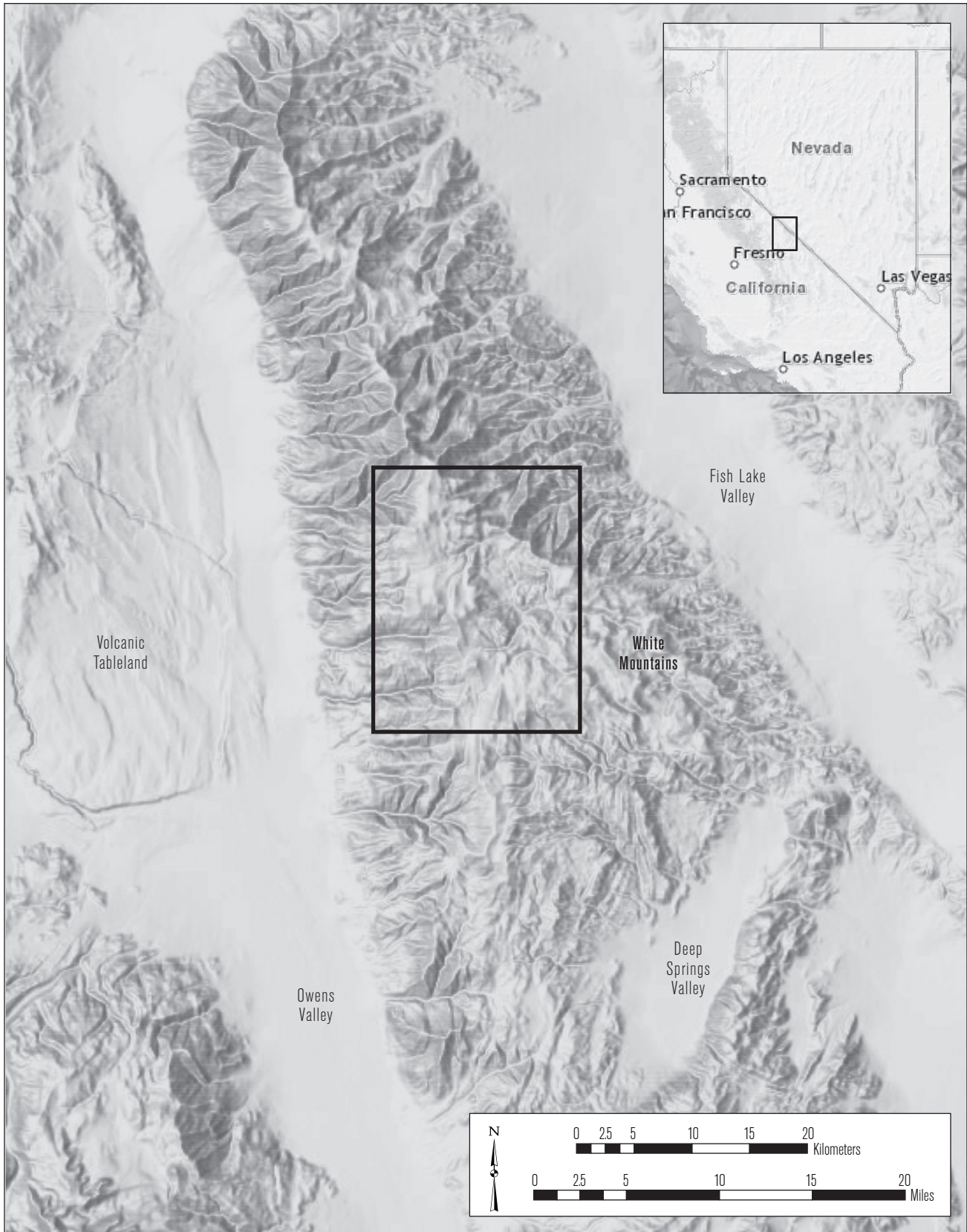


Figure 1. Vicinity map of alpine zone archaeological sites in the White Mountains, California.

pations. The relative abundance of bighorn sheep relative to other taxa, in particular marmots, declined with the appearance of alpine-zone Village sites and may represent the localized resource depression of bighorn sheep populations. Resource depression would have increased the economic risk of pursuing large game, which could be mitigated by diversifying the diet, intensifying processing (e.g., marrow and grease extraction), and shifting settlement systems. Population replacement by the *Numa* (Bettinger 1994; Bettinger and Baumhoff 1982), changes in the timing and availability of resources at lower valley residences (Zeanah 2000), shifts in climate (Ababneh 2008), and ceremonial usage (Morgan et al. 2014), have all been suggested as possible factors involved in the intensified occupation of the White Mountains.

Regardless of the underlying cause(s) for the expanded use of the alpine zone, the change from long-distance logistical Previllage to residential Village occupation is expected to have observable effects on faunal assemblages due to differences in transportation costs, processing intensity, and time spent in the alpine zone. Drawing upon the central place foraging model, we expect that Previllage hunters responded to the greater costs of transporting bighorn sheep from the alpine zone to lower elevation residences by reducing transportation loads through increased field processing. Conversely, extensive processing is expected to decrease with intensified, long-term use of the alpine zone. These predictions are tested here using a comprehensive analysis of skeletal part representation and taphonomy of nine White Mountains faunal assemblages.

CENTRAL PLACE FORAGING AND TRANSPORT

We use central place foraging theory (Orians and Pearson 1979) to lay the logical foundation for examining bighorn transportation in the White Mountains. The model predicts foraging decisions regarding which resources should be exploited, the extent of field processing, the

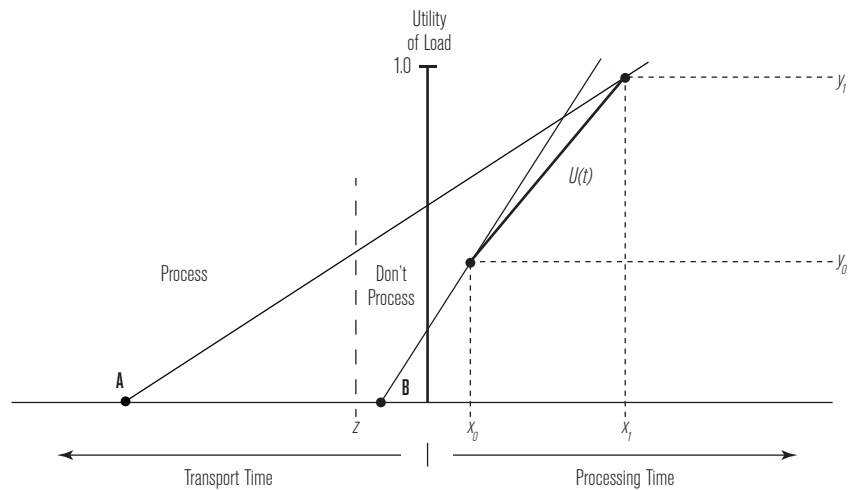


Figure 2. Graphic example of the central place foraging model (adapted from Metcalfe and Barlow 1992).

weight of transport loads, and the location of central places (see Lupo 2007 and references therein). Central to this theory is the implication that the costs, measured as caloric intake, of transporting a resource to a residential base is ultimately offset by field processing. Since the goal of the forager is to maximize the utility of the load being transported, the degree to which a resource is field processed is directly correlated with the travel distance required to return the load to the central base (e.g., Bettinger et al. 1997; Metcalfe and Barlow 1992; Metcalfe and Jones 1988).

The trade-off between transporting an unprocessed versus a processed resource is modeled in Figure 2. As described by Metcalfe and Barlow (1992), the time required to field process is depicted on the right side of the x-axis, while the time required to transport the resource is on the left side of the axis. The y-axis represents the utility of the load; the function $U(t)$ shows the relationship between the utility of the load and processing time—as processing time increases, the utility of the load does as well. Central to this model is determining the length of time to process a resource given a particular transportation time. On the left side of the x-axis, z marks the point at which field processing becomes economically profitable. When transport time is high (A), foragers are expected to process more extensively (x_1) to increase the utility of the load (y_1). However, if the transport time to a central base is below the z threshold (B), then no processing is expected (x_0, y_0). Nevertheless, despite the higher utility load returned from (A), foraging efficiency

is always greater for minimal processing of a resource obtained closer to a residential base than it is for heavy processing of a resource acquired at a far distance from the base (Cannon 2003).

Applying the model is complicated by situational variations in human behavior that have been identified in ethnographic contexts (see Bartram 1993; Lupo 2006; O'Connell et al. 1990), such as the distance between kill sites, secondary processing sites, and residential sites; the number of individuals in a hunting party; and the size and condition of the carcass involved. This is reflected in a recent debate regarding the profitability of long-distance large-game hunting in western North America, and ultimately, whether large-game hunting was motivated by costly signaling behaviors (Broughton and Bayham 2003; Byers and Broughton 2004; Codding and Jones 2007; Fisher 2010, 2015; Grimstead 2010, 2012a; Hildebrandt and McGuire 2002; McGuire and Hildebrandt 2005; McGuire et al., 2007; Whitaker and Carpenter 2012). Grimstead (2010) modeled the travel and transport costs for black-tailed deer (*Odocoileus hemionus*), antelope jackrabbit (*Lepus alleni*), and desert cottontail (*Sylvilagus audubonii*) obtained between 0 and 200 km. from a central place to demonstrate that the long-distance hunting of large game follows the expectations derived from optimal foraging theory. Instead of depending simply on travel time, Grimstead used a larger number of variables based on bioenergetics to evaluate the travel cost to a resource, as well as the costs of transporting a load back to the central place. She concluded that large game remains a high-return prey item even with greater travel distances; a 141 kg. artiodactyl procured within 200 km. would produce the equivalent return of 31 jackrabbits acquired within 1 km. This finding runs contrary to arguments made by McGuire and colleagues (2007), who used least-cost pathway analysis to argue that the costs of upland sheep hunting exceeded the return rates for locally-acquired small game, and therefore foragers might not have been motivated by energy-maximizing goals. Among a number of critiques of Grimstead's approach, Whitaker and Carpenter (2012) make the important point that she does not consider load size as a limitation to foragers transporting meat long distances. Instead of considering the return rates for a single forager traveling with 74 kg. of meat, an unrealistic load for an average human, they use a more modest estimate—but, as they note, still likely

an overestimate when considering terrain—of 36 kg. derived from actualistic research. By changing this single variable, Whitaker and Carpenter found that the roundtrip net-zero distance is reduced by almost half. However, load capacity likely varied considerably between individuals, as exemplified by Jack Stewart, an Owens Valley Paiute who took pride in his ability to transport heavy loads:

The deer and mountain sheep were a heavy load, for I had packed them both at once down to the valley. But when I was a young man nothing was too heavy for me. I enjoyed carrying a large, heavy load. Didn't my power come from the mountain upon whose back are rocks which never hurt it? It is this way with me [Jack Stewart, in Julian Steward 1934:428].

Clearly, simple foraging models involve variables that are difficult to estimate in archaeological applications, such as travel distance, load capacity, and number of travelers. Despite such limitations, central place foraging theory allows us to develop a set of generic expectations for the faunal record. Our concern here is not the profitability of hunting medium-bodied artiodactyls within a certain distance or the underlying motivations; the empirical record is clear that foragers were traveling to the alpine zone of the White Mountains for millennia, at least in part to hunt bighorn sheep. Instead, the question at hand is how the intensified use of the alpine zone circa 1,350 B.P. may have altered long-distance selective transportation decisions.

Over the past few decades, zooarchaeologists have explored a range of analytical methods for identifying the selective transportation of carcasses that can be combined with central place foraging models to predict how foragers should optimally forage with respect to a carcass. Two such analyses, (1) Relative Skeletal Abundance (RSA) and (2) the mean food utility index (e.g., Broughton 1994)—a derivative of Metcalfe and Jones's (1988) food utility index (FUI)—have been employed to infer variations in carcass butchery and transportation, ultimately allowing researchers to better understand site functions and settlement systems. These analyses effectively measure the utility of the transported load to a central base, with the expectation that as transport time increases, low quality portions of the carcass should be discarded at kill sites to increase utility load. As such, use of distant foraging patches may be inferred from the greater representation of high-utility

body parts at central bases (Bartram 1993; Binford 1978, 1981; Broughton 1994; Faith and Gordon 2007; Lupo 2006; Metcalfe and Barlow 1992; O'Connell et al. 1990).

Applying this logic to the White Mountains, it is anticipated that Previllage faunal assemblages will reflect secondary processing bases where mostly complete sheep carcasses were brought and processed for transportation to lower elevation residential sites. The faunal assemblages should be characterized by a general absence of high-utility artiodactyl body parts.

When foragers begin to occupy the White Mountains more intensively for greater periods of time, we expect to find reduced sheep-carcass transportation compared with that occurring during the logistical Previllage use of the alpine zone. In addition, we expect to find an increase in processing and consumption to occur at Village residences. Increased processing is expected to result in higher bone fragmentation rates, particularly for those skeletal parts with greater fat content, which could result from the limited availability of sheep due to localized population depression and/or dietary stress (see Outram 2002). For example, foragers are expected to ignore parts yielding limited nutrients (e.g., phalanges) during more plentiful times, but during dietary stress these elements may have been processed and consumed for marrow and fat. Therefore, Village assemblages should have a greater overall representation of artiodactyl body parts (excepting the low-utility portions potentially left at kill sites). The expected increase in high-utility body parts should be reflected in greater mean FUI values. We also expect to see greater fragmentation rates as foragers processed prey more intensively.

MATERIAL AND METHODS

We evaluated large-game skeletal part transportation using raw faunal analysis data collected by Grayson (see 1991) from the White Mountains. These data are supplemented by faunal data from an additional Previllage assemblage from the Coldwater site that was not analyzed by Grayson (Fisher 2015). This broad regional analysis includes all faunal data that have been ascribed to the Previllage or Village adaptations. As outlined by Bettinger (1991:662), deposits were classified as Previllage or Village components using temporally-diagnostic artifacts and radiocarbon assays. Faunal

Table 1

SITES IN THE WHITE MOUNTAINS INCLUDED IN ANALYSES, THEIR ELEVATION, AND NUMBER OF IDENTIFIED ARTIODACTYL SPECIMENS FROM PREVILLAGE AND VILLAGE CONTEXTS

Site Name	Trinomial	Elevation m. (amsl)	Previllage Artiodactyl NISP	Village Artiodactyl NISP
Coldwater	CA-MNO-3736	3,097	695	–
Corral North	CA-MNO-2195	3,350	–	28
Corral South	CA-MNO-2194	3,350	–	147
Crooked Forks	CA-MNO-2191	3,150	32	259
Enfield	CA-MNO-2192	3,170	–	83
Midway	CA-MNO-2196	3,440	72	125
Rancho Deluxe	CA-MNO-2198	3,560	251	106
Raven Camp	CA-MNO-2193	3,460	578	–
Shortstop	–	3,390	215	–
Total			1,843	748

remains from contexts assigned to the Clyde phase (2,500–1,200 B.C.) and Cowhorn phase (1,200 B.C.–A.D. 600) are considered Previllage assemblages. The Village faunal assemblages include remains recovered from Baker phase (A.D. 600–1300) and Klondike phase (A.D. 1300–A.D. 1850) deposits. Nine sites that contained faunal assemblages with more than 20 artiodactyl specimens have been used to identify trends in skeletal part diversity in greater detail (Table 1). The vast majority of the artiodactyl specimens recovered from the alpine zone represents bighorn sheep (*O. canadensis*); only 2.1% of the artiodactyl species-level identifications represent pronghorn (*Antilocapra americana*) and mule deer (*Odocoileus hemionus*). For the purposes of our analyses, all artiodactyl specimens are included here, with the understanding that they most likely represent alpine-zone bighorn sheep hunting and transportation.

Bone Survivorship

Density-mediated attrition analysis is a necessary first step before evaluating relative skeletal part abundances in an assemblage, due to issues of equifinality (Fisher 2018; Grayson 1989; Lam et al. 2003; Lam and Pearson 2005; Lyman 1985, 1994; Marean et al. 1992). While the absence of some skeletal parts may be due to transportation decisions made by hunters in the past, other taphonomic forces may selectively remove portions of the skeleton in ways that mirror foraging predictions.

For example, carnivore ravaging, weathering, mechanical breakdown, and trampling (Behrensmeyer 1978; Behrensmeyer et al. 1986; Marean and Spencer 1991; Marean et al. 1992; Munson and Garniewicz 2003; Olsen and Shipman 1988; Phoca-Cosmetatou 2005) often destroy the least dense portion of the skeleton, effectively biasing faunal assemblages towards high-density elements only. The potential influence of these forces is evaluated by comparing the volume density values at specific sites on skeletal elements—scanned using photon densitometry, computed tomography, and a variety of other techniques—with the frequency that these parts were recovered from an archaeological site. If a significantly positive relationship exists between volume density values and frequency of occurrence in an assemblage, it is assumed that density-mediated destruction has played a major role in structuring the faunal assemblage, and transportation inferences cannot be made using low-density skeletal parts.

The density values for bighorn sheep provided by Lyman (1984), and updated values for limb bones provided by Lam et al. (1998), are used when evaluating bone survivorship. Since some skeletal parts of sheep were not included by Lyman (1984) or Lam et al. (1998), values for deer (Lyman 1984) are used to supplement the missing values. The standardized number of identified specimens (NNISP) is used as the measure of skeletal abundance for comparison against density values (e.g., Grayson and Frey 2004). This measure is computed by dividing the number of identified specimens (NISP) of elements containing a particular scan site by the number of times the element is represented in a body (e.g., the NISP of paired elements are divided by two; phalanges by eight, lumbar vertebrae by seven, etc.).

Bone Fragmentation

Fragmentation can have two opposing effects on skeletal part abundances; moderate rates of fragmentation may increase the NISP if each reduced portion can still be identified to taxon and element, while higher rates are expected to decrease the NISP as fragments are reduced down to a size that hinders identification (Grayson 1991; Grayson and Delpech 1998). The fragmentation of artiodactyl assemblages was reviewed to determine whether fragmentation rates have an effect on measures of relative skeletal part abundance, as well as to test

whether processing intensity increased with greater residential stays in the alpine zone. While there is a healthy debate regarding how bone fragmentation should be measured (see Cannon 2013), the methods available to us were restricted due to the use of a legacy dataset. For example, mean weight, mean area, and maximum length were not available approaches as these data were not collected during the original analyses. Grayson (1991) previously reported fragmentation rates for the White Mountains assemblages by comparing the number of specimens (NSP) with the NISP of all faunas as an examination of variation in taxonomic identification. Here we selected a similar ratio-based measure that compares the NISP of high marrow-yielding long bones (femur, humerus, radius, tibia, and metapodials) with the minimum number of elements (MNE) estimated using the most redundant articular portion when considering element side. We use this measure instead of Grayson's NSP:NISP values since we are less interested in the rate of taxonomic identification than in the cultural processes that reduce marrow-yielding bones.

Relative Skeletal Part Abundance

Relative skeletal part completeness is measured using the reciprocal of Simpson's diversity index ($1/D$), which is less prone to sample size effects than other similar measures (Magurran 1988, 2004). The equation used to calculate Simpson's D is:

$$D = \sum \frac{(n_i(n_i-1))}{(N(N-1))}$$

where n_i is the NNISP of the i th skeletal part, and N is the total NNISP of all skeletal parts.

This measure evaluates the degree to which an assemblage is dominated by a single item, in this case body parts. Greater Simpson's $1/D$ values indicate that skeletal parts are more evenly represented in an assemblage (Faith and Gordon 2007). To avoid issues related to density mediated destruction, only high-survival skeletal parts are included in the RSA analyses; these elements are the femur, tibia, humerus, radius, mandible, skull, and metapodials (Faith and Gordon 2007; Faith and Thompson 2018). Although these skeletal parts may contain low-density components, such as trabecular bone at epiphyseal ends, each should be well represented by high-density portions if the entire element

Table 2
NUMBER OF HIGH SURVIVAL SKELETAL PARTS, RECIPROCAL OF SIMPSON'S INDEX AND MEAN FUI
FOR EACH ASSEMBLAGE AND COMBINED PREVILLAGE AND VILLAGE ASSEMBLAGES

Skeletal Part	Previllage						Village						Previllage	Village
	CW	CF	MW	RD	RC	SS	CF	CN	CS	EN	MW	RD		
Cranium	27	1	-	4	7	10	4	1	9	3	1	2	49	20
Mandible	24	-	1	7	15	7	6	-	10	6	5	3	54	30
Humerus	25	-	3	17	28	3	7	-	3	1	4	5	76	20
Radius-Ulna	30	1	4	13	52	16	17	1	12	5	7	8	116	50
Femur	14	-	1	9	11	3	10	-	6	-	6	4	38	26
Tibia	38	2	1	23	37	11	8	2	6	3	5	3	113	27
Metapodial	138	3	16	33	46	38	26	3	16	8	22	3	276	81
Total	296	7	26	106	196	88	78	7	62	26	50	28	722	254
1/D	4.67	12.07^a	4.67	5.57	5.70	5.10	7.00^a	5.09	7.49^a	7.16^a	6.79^a	10.79^a	5.21	6.20
Mean FUI	1,935	2,744	2,008	2,307	2,105	1,800	2,447	2,138	1,995	1,356	2,413	2,411	2,039	2,212

^aValue outside 95% confidence interval.

Key: CW=Coldwater, CF=Crooked Forks, CN=Corral North, CS=Corral South, EN=Enfield, MW=Midway, RD=Rancho Deluxe, RC=Raven Camp, SS=Shortstop.

was transported to the site. The expectation is that Village assemblages will have greater body-part diversity than Previllage assemblages—reflecting more complete deposition of entire carcasses—and thus should have larger Simpson’s values.

Food Utility Index

Following Broughton (1994), mean FUI values are computed using the set of high-survival skeletal parts included in the RSA analyses. Food utility index values provided by Metcalfe and Jones (1988) for deer are multiplied by the NNISP of the skeletal parts and divided by the total NNISP for the assemblage. We also checked for correlation between the FUI values and NNISP values using Spearman’s rank order coefficient. It is expected that Previllage assemblages, consisting of low-utility body parts, should exhibit lesser mean FUI values and a negative correlation between NNISP and FUI. In contrast, Village assemblages should have greater mean FUI values and no correlation between NNISP and the FUI due to the increased deposition of high-utility body parts.

RESULTS

Previllage versus Village Assemblages

It was predicted that Village assemblages would have higher fragmentation rates due to a longer, more intensified occupation of the alpine zone. While the fragmen-

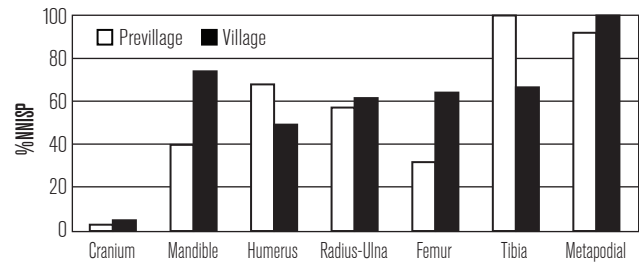


Figure 3. Relative skeletal part abundances for Previllage and Village assemblages using high-survival skeletal parts.

tation rate for combined Previllage assemblages (NISP/MNE=3.02) is marginally smaller than that computed for the Village assemblages (NISP/MNE=3.24), the difference is not significant ($\chi^2=3.274, p=0.07$). Likewise, density-mediated attrition played a significant role in alpine assemblages, regardless of temporal designation (Previllage $r_s=0.591, p<0.01$; Village $r_s=0.526, p<0.01$). The lack of significant difference in fragmentation and survivorship rates demonstrates that the two sets of assemblages have undergone similar taphonomic processes. Regardless of the underlying cause, these findings indicate that the absence of low-density body parts cannot be attributed to selective transportation decisions.

The attrition findings justify the use of only high-survival skeletal parts when examining relative skeletal part abundances. As predicted, the Village assemblages have

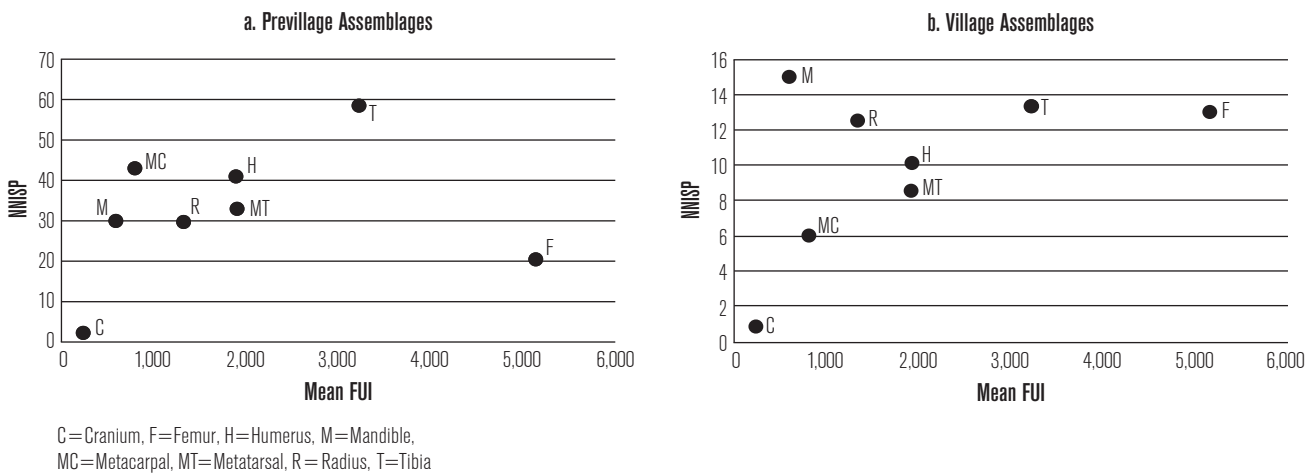


Figure 4. Relationship between food utility index (FUI) values and normed number of identified specimens (NNISP).

greater body-part diversity than Previllage assemblages (Table 2; Fig. 3). We computed confidence limits for the Simpson's 1/D values using a jackknife operation that removed individual site assemblages one at a time (Magurran 2004). This statistical analysis produced 95% confidence limits for Simpson's 1/D of 4.65 to 6.27. As seen in Table 2, all but one of the Village assemblages fall outside the confidence limits. In contrast, Previllage assemblages fall within the range with only one exception. The two anomalies, the Crooked Forks Previllage and Corral North Village assemblages, both have exceedingly small sample sizes when limited to high-survivorship skeletal parts. When these two assemblages are removed, the Previllage body-part diversity values range from 4.67 to 5.70 and Village diversity values range from 7.00 to 10.79. The greater evenness in skeletal part values observed among the Village assemblages indicates that a greater portion of the carcass was transported to these sites.

We predicted that since Previllage assemblages should be dominated by low-utility body parts, mean FUI values would be relatively small and there would be a negative correlation between the NNISP and FUI. Conversely, since Village assemblages should have a mix of both high- and low-utility skeletal parts, mean FUI values would be relatively large and there would be no correlation between the NNISP and FUI. However, the results of the food utility analyses reveal that mean FUI values from Previllage to Village assemblages are not significantly different when evaluated using a *t*-test ($t_{(0.05[df=336])} = -0.986$, $p = 0.325$; Table 2). Further,

Previllage assemblages exhibit a moderate but highly significant positive correlation between the FUI and NNISP ($r_s = 0.233$, $p < .001$; Fig. 4a) instead of a negative correlation, indicating that high-utility body parts are more common than anticipated in these assemblages. This finding corresponds with the lower Simpson 1/D values, which collectively indicate that Previllage assemblages are dominated by high-utility body parts. As shown in Figure 4a, the one exception to this is the femur; despite its high utility, it is less common than expected in Previllage assemblages. As expected, there is no relationship between skeletal part representation and FUI values for the combined Village assemblages ($r_s = -0.070$, $p = 0.54$; Fig. 4b), aligning well with the greater Simpson's 1/D values observed.

DISCUSSION

Utilizing the logic of the central-place foraging model, we developed a set of rather simple predictions regarding how large-game skeletal part representation should change with the development of long-term residential stays in the alpine zone of the White Mountains. Longer residential stays in the alpine zone were projected to result in greater skeletal part diversity, due to the deposition of both high- and low-utility body parts, in contrast to long-distance logistical assemblages that would develop when high-utility body parts were transported to and deposited at sites at lower elevations. With an increase in the deposition of high-utility body parts, mean food utility values were also predicted to increase in Village

assemblages. While Previllage assemblages were expected to show a negative correlation between food utility index values and skeletal part representation, no such relationship was expected for Village assemblages.

Our expectations are largely supported by the faunal data, with some important exceptions. Skeletal part diversity consistently increases in the Village deposits, supporting our argument that a greater portion of artiodactyl carcasses was transported to the alpine zone central bases. Further, there is no correlation between skeletal part representation and FUI for Village assemblages, providing additional support for our prediction that a greater portion of the carcass was transported to alpine residential bases.

Contrary to our expectations, the mean FUI values do not significantly differ between Previllage and Villages assemblages. There is also no difference in the fragmentation rates between the assemblages. Although a lack of difference in fragmentation rates does not support an increase in marrow or grease extraction in Village assemblages, this could be due to analytical limitations when using a legacy dataset; further work should evaluate fragmentation using more direct measures, such as mean specimen area (Cannon 2013).

Significantly, there is a positive correlation between skeletal part representation and FUI for Previllage assemblages. This is particularly interesting as it runs directly opposite of our expectation that low-utility body parts should be more abundant. This raises the question then of where the low-utility portions of the skeleton are located. The positive relationship just mentioned is worth further exploration, as it would seem to indicate that either Previllage foragers were maximizing transport loads to alpine-zone central bases by discarding the low-utility parts at kill sites (which may be less likely to survive due to their ephemeral nature), or these parts were transported from the alpine-zone to lower elevations.

It is also possible that the absence of low-utility parts is related to unexplored culinary processing techniques. In particular, one benefit of high altitude foraging is the unique opportunity to reduce transport weight by drying meat using methods reminiscent of those found in the Andes, where camelid meat is freeze-dried into *ch'arki* (e.g., Miller and Burger 1995; Valdez 2000). At the White Mountains Research Station in Crooked Forks Valley (3,094 m. amsl), the 30-year average July temperature is

51.7°F, with maximum lows and highs of 22° and 79°F, respectively (Powell and Klieforth 1991). Such conditions could have allowed for freeze-drying, which may have had lower processing costs than meat smoking due to the added transport costs of fuel, which is scarce in the alpine zone. Steward (1933:255) noted that small strips of meat were dried, possibly over a fire, but that the smoking of meat was unknown. Regardless of the drying method used, the process would effectively decrease the transport load weight while producing a storable resource. Previllage foragers may have discarded low-utility body parts at kill sites and transported only the meaty portions of the carcass to temporary central bases in the alpine zone in order to prepare jerky for long-distance transport to lower elevation localities. This would have resulted in the greater abundance of high-utility body parts observed in the Previllage assemblages.

One approach to testing the argument for dried meat production is through the analysis of cutmark data (*sensu* Valdez 2000:570). Using actualistic research, Binford (1978) classified cutmarks into the broad categories of skinning, dismemberment, and filleting marks based on their location and form on skeletal parts. Our expectation is that there should be a greater abundance of filleting marks, as a result of removing meat from bone, in assemblages where freeze-drying occurred frequently. Comparisons are limited, as Grayson did not classify cutmarks using Binford's categories, but at Coldwater 62.5% of the cutmarks correspond with filleting activities. Future work should further evaluate cutmark locations in the remaining assemblages from the White Mountains.

The transportation of dried meat may explain the relatively limited occurrence of bighorn remains at lower elevations. In Holanda and Delacorte's (1999) regional faunal dataset, fewer than one hundred sheep bones have been recovered from non-alpine sites in Inyo and Mono counties. Whether these remains represent sheep acquired in the summer from high altitudes or during cooler months from lower altitudes remains unknown, but the question may be addressed using skeletal part analysis, and stable isotope and trace element analyses, to determine whether foragers were transporting large game from the alpine zone to lower elevations (e.g., Fisher and Valentine 2013; Grimstead 2012b); seasonality inferred from age profiles could also be employed. To fully understand the range of subsistence patterns,

including bighorn sheep processing and long-distance transportation, a stronger faunal dataset from the valleys is necessary.

As an alternative to the dried meat hypothesis, bone elements of some low-utility body parts may have been curated and transported elsewhere to fashion into various implements. We see two problems with this argument. First, we find it unlikely that the rate at which skeletal parts were removed for curation would correlate with FUI values. For example, metacarpals and metatarsals, which are arguably the most versatile elements for producing tools due to their straight, grooved shafts, should be removed at the same rate if curated, yet their relative abundance corresponds with the food utility index. Second, this explanation would require that the curation of skeletal parts for bone occurred much more frequently during Previllage times than after the shift in settlement patterns ca. 1,350 B.P., an argument that we find difficult to justify. This is not to deny that skeletal parts were used for bone tool production, but that curation is not likely to have had a measurable impact on skeletal part abundances.

CONCLUSIONS

Regardless of why high-utility skeletal parts are more abundant than expected in Previllage assemblages, the compendium of artiodactyl skeletal part data supports the prediction that foragers were transporting and depositing a greater portion of artiodactyl carcasses at high elevation sites after ca. 1,350 B.P. This observation backs the general argument that foragers were using the alpine zone in novel ways in response to regional demographic and resource intensification trends.

A significant challenge zooarchaeologists face when addressing resource intensification is resolving differences in the taphonomic histories among temporally disparate faunal assemblages. The cultural processes addressed in this paper can have substantial influences on the relative abundance of taxa present in an assemblage (Fisher 2018; Ugan 2005), as greater transportation of body parts from a single carcass will increase the NISP in an assemblage. Previous observations of a decline in the relative abundance of artiodactyls in White Mountains Village assemblages (Grayson 1991) are likely underestimated, considering the shift in transportation decisions identified here.

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