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Prehistoric human influence on the abundance and distribution of deadwood in alpine landscapes

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Abstract

Scientists have long inferred the locations of past treelines from the distribution of deadwood above modern tree boundaries. Although it is recognized that deadwood above treeline may have decayed, the absence of such wood is routinely taken to imply the absence of trees for periods ranging from the past few millennia to the entire Holocene. Reconstructed treeline histories are then explained in terms of such variables as slope, drainage, temperature, solar insolation, and precipitation. While these variables certainly help determine where deadwood is to be found above treeline today, we suggest that they cannot always explain where it is not to be found. In the alpine environments of the western United States, archeological work has established a human presence during nearly the entire Holocene in portions of the Rocky Mountains and for over 5000 radiocarbon years in the Great Basin and Sierra Nevada. We suggest that prehistoric occupations may have stripped deadwood from the landscape in all of these areas. To the extent that this is true, reconstructions of past treelines from deadwood may reflect the human prehistory of an area as much as it reflects treeline history itself. We encourage evaluation of this hypothesis in areas of active dendrochronological and archeological research.

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Introduction

Recent models predict that by the end of the 21st century, annual temperatures in California will have risen between 2.3 and 5.8 °C (Hayhoe et al., 2004; see also Christensen et al., 2007). In response, California's Sierra Nevada has been projected to lose 75–90% of its subalpine forests. A loss of this magnitude would dramatically alter the high elevation landscapes of the

Sierra Nevada and would have enormous implications for all subalpine forest species.

Empirical information on treeline history clashes with this prediction. Millar et al. (2006a) have documented that between about AD 900 and 1350 (the Medieval Climatic Anomaly, or MCA), some areas just east of the Sierran crest saw an increase in the extent and species richness of the subalpine forest. In the headwaters of Owens Valley, eastern California (Fig. 1), this response appears to reflect increased temperatures coupled with precipitation levels only slightly different from those of today. Given that average annual MCA temperatures here are estimated to have been about 3.2 °C greater

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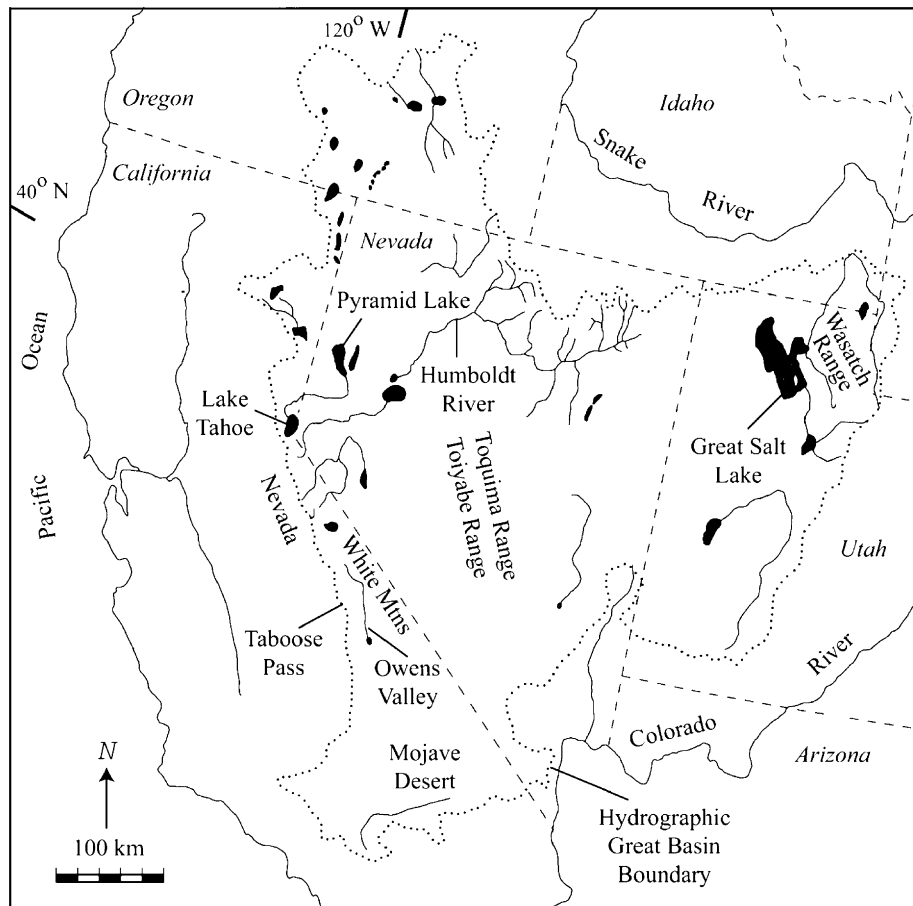


Fig. 1. The Great Basin with selected place names, including those mentioned in the text.

than modern, and thus within the temperature range predicted by the models discussed by Hayhoe et al. (2004), the results of Millar et al. (2006a) suggest that the model-based predictions for the future of western North America's alpine forests may contain significant inaccuracies. Similarly, while Lloyd and Graumlich (1997) have shown that treeline elevation and tree abundance declined along the Sierran Crest in Sequoia National Park and the Inyo National Forest during the MCA, that decline seems to have been a response to drought alone, treelines having expanded upslope during the early MCA when water stress was low.

If the empirical data are correct, the modeled predictions for the future of Sierran subalpine forest may be wrong. But may the empirical data themselves be wrong? How accurate are the indicators that have been used to reconstruct past treeline altitudes?

Deadwood and ancient treelines

For at least the past 70 years, scientists have inferred the locations of past treelines and upper montane forest conditions from the distribution of deadwood above contemporary treelines and from within the forests that

form them (e.g., Griggs, 1937, 1938). During the past 40 years, treeline studies based on the distribution of deadwood have been conducted throughout the world to address a range of climatic and ecological questions (e.g., Richmond, 1962; McCulloch and Hopkins, 1966; LaMarche and Mooney, 1967, 1972; La Marche, 1973; Kearney and Luckman, 1983; Grant, 1984; Scuderi, 1987; Clague and Mathewes, 1989; Payette et al., 1989; Hughes and Funkhouser, 1999; Kullman and Kjällgren, 2000; Cuevas, 2002).

The logic behind these studies is simple. The presence of deadwood in alpine landscapes and in the upper live tree zone is assumed to indicate the presence of living trees in the past, since few natural mechanisms exist that can transport such wood significantly beyond treeline and those that are known (for instance, volcanic events) are generally easy to detect (e.g., Millar et al., 2006a). The deadwood can be dated either by dendrochronology or radiocarbon dating and the results used to reconstruct a chronology of past treeline movements. Similarly, dendroclimatological methods can be used to reconstruct past climates directly from the deadwood itself (e.g., LaMarche and Mooney, 1972; Hughes and Funkhouser, 1999), or climate inferred from the overlapping climatic requirements of the species represented

by that deadwood (climate-envelope methods, e.g., Millar et al., 2006a).

From the beginning of these analyses, it has been recognized that deadwood above treeline may have decayed and that the highest known deadwood is best seen as providing a minimum estimate of ancient treeline elevation (e.g., La Marche, 1973). On the other hand, it is often reasonably assumed that on mountain slopes capable of supporting forest growth in the arid western United States, the higher the elevation, the better preserved ancient deadwood might be. This rests on the argument that the higher the elevation, the less fuel there is to support wood-consuming fires at the same time as colder temperatures would inhibit the action of decay organisms. Further, many high elevation and tree-line forming conifer species of western North America (especially genus *Pinus*) produce abundant resins that permeate and preserve dead wood. The absence of deadwood above treeline is thus routinely taken to imply the absence of trees in the recent past (e.g., Cuevas, 2002) and important research has been done to determine the variables that differentiate settings that contain deadwood at and above treeline from those that do not (e.g., Lloyd, 1997; Bunn et al., 2004).

Those variables are assumed to include such things as slope, drainage, temperature, solar insolation, and precipitation (Lloyd and Graumlich, 1997; Cuevas, 2002; Bunn et al., 2004; Millar et al., 2004, 2006b). However, while there is every reason to believe that such variables help determine where deadwood is to be found above treeline today, there are also reasons to believe that they cannot always explain where it is not to be found. Although it is widely recognized that modern human collecting activities can alter the distribution of high elevation deadwood, no study of ancient treelines based on deadwood has taken into account the fact that alpine areas have often been the focus of prehistoric human activity and that these activities may have significantly altered the distribution and abundance of deadwood. Here, we use the alpine archeology of the western United States to suggest that reconstructed locations of past treelines may well reflect both treeline and human history. In this essay, we encourage evaluation of this hypothesis in areas of active dendrochronological and archeological research.

Archeology above treeline in the western United States

Great Basin

During the late 1970s and early 1980s, a series of small village sites was discovered in the alpine tundra of the Toquima Range of central Nevada and the White

Mountains of southeastern California (Thomas, 1982, 1994; Bettinger, 1991a, b; see Fig. 1). More recently, a third set was reported from the Toiyabe Range, just west of the Toquima Range (Canaday, 1997). Ranging from ca. 3170 to 3855 m in elevation, these villages are defined by the presence of circular houses, each marked by a stone ring that provided the footing for a superstructure, presumably of wood, which was not present at the time of discovery. Each structure had a central fireplace and each contained stone tools, including projectile points and grinding stones, associated with hunting and plant gathering. Because plant gathering is strongly associated with women, and hunting with men, among hunter-gatherers, the presence of such tools suggests that these villages were occupied by family groups. Analyses of the food remains from these sites suggest occupations between spring and fall (Grayson, 1991), while radiocarbon dates and artifacts of known age show that the sites were established sometime after about 1800 radiocarbon years ago (AD ~200) and that their use continued into, or very close to, historic times (Thomas, 1982, 1994; Bettinger, 1991a, b).

The villages do not mark the earliest known human use of the above-treeline landscape in the Great Basin. That use appears to have begun between 4500 and 5000 radiocarbon years ago, and to have involved small groups using the alpine tundra for hunting. These sites consist of specialized hunting facilities – rock walls, stacked-rock cairns, and hunting blinds – that were apparently used to pursue large mammals, particularly mountain sheep (McGuire and Hatoff, 1991) and perhaps birds (Thomas, 1988). While these features continued to be used into latest prehistoric times, the intensity of that use seems to have declined around 1000 years ago or so (Pendleton and Thomas, 1983; Bettinger, 1991a, b; Canaday, 1997).

Rocky Mountains

The Great Basin was not unique in the degree to which the alpine tundra was the focus of prehistoric human occupation in western North America. In fact, the highest density of above-treeline sites in this region may be represented by the more than 50 game-drive systems known from the Front Range of Colorado's Rocky Mountains (Benedict, 1996, 2005; Cassells, 2000). As in the Great Basin, these facilities consist of constructed rock walls, lines of stone cairns, and hunting blinds. As an indication of the abundance of such features, Benedict (2005) notes that one Front Range alpine-tundra ridge contains at least 174 hunting blinds and over 10 km of drive lines. Unlike the situation in the Great Basin, the earliest use of the alpine tundra in the Rocky Mountains began between 10,000 and 8000 radiocarbon years ago (Benedict, 1992; Pitblado,

2000). However, small alpine villages of the sort known from the Great Basin are not known from this region.

Sierra Nevada

Compared to our knowledge of the alpine archeology of the Great Basin and Rocky Mountains, our knowledge of the prehistoric use of the above-treeline landscape in the Sierra Nevada is weak. Nonetheless, the little we do know suggests that this area is archeologically rich.

Stevens (2005), for instance, has documented the presence of some 50 sites above treeline in the vicinity of Taboose Pass (c. 3355 m; see Fig. 1) in Kings Canyon National Park west of Owens Valley near the crest of the Sierra Nevada. Some of these sites contain stone tools suggestive of both hunting and gathering activities and a few also include rock rings that may indicate the presence of houses similar to those known from alpine settings in the Great Basin. The earliest occupations in the Taboose Pass area may be as much as 5500 radiocarbon years old and are marked by sites that seem related to hunting. The latest sites, which include those that might contain houses, date to within the past 1500 years or so (Stevens, 2005). This sequence mirrors that developed by Roper Wickstrom (1993) for nearby areas in Sequoia and Kings Canyon National Park. Both sequences are very similar to those known from the Great Basin to the east. The Sierra Nevada was also traversed by numerous prehistoric trails, parts of which were above treeline, that facilitated human travel into and across these massive mountains (e.g., Davis, 1965; Liljeblad and Fowler, 1986; Stevens, 2005).

In short, substantial evidence now documents some 5000 years of human use of the above-treeline landscape in the Sierra Nevada and Great Basin, and a longer, and

perhaps more intense, history of such use in the Rocky Mountains.

Staying warm above treeline

Archeologists have dedicated significant effort to understanding the prehistoric human use of the alpine tundra landscapes of the western United States. They have constructed chronologies of that use (e.g., Bettinger, 1991a; Benedict, 1996; Canaday, 1997; Stevens, 2005), identified the plant and animal remains from some of the sites involved (e.g., Grayson, 1991; Scharf, 1992; D. Rhode, pers. comm., 2006), described the stone tools from these sites (e.g., Bettinger, 1991a; Canaday, 1997), mapped the features that they display (e.g., Thomas, 1982; Benedict, 1996; Canaday, 1997), and constructed sophisticated models to explore the nature of the subsistence and settlement systems in which these sites may have been embedded (e.g., Bettinger, 1999; Zeanah, 2000). There is, however, one intriguing question that no archeologist has addressed in detail. Even during summer, temperatures at these elevations routinely fall below freezing. Even allowing possible warmer conditions during the times some of these sites were occupied, subfreezing temperatures in summer seem likely to have been common at high elevations throughout the Holocene. Given that people would have needed fuel for both cooking and warmth, where did that fuel come from?

That fuel was a significant issue for the occupants of at least some of these sites is indicated by the fact that between 50% and 74% of the very large samples of bones from the White Mountains sites are burned (Grayson, 1991; Table 1). Of these, between 10% and 68% had been burned to the point where they had become calcined (burning stages 4–6 of Stiner et al.,

Table 1. The percentage of bone that has been burned in the village and previllage occupations in the White Mountains (see Grayson, 1991 for specimen counts); distance to trees refers to the distance from the site to the nearest live trees, as measured digitally from topographic maps (see Grayson, 2005 for measuring protocol; distance to live trees rounded to nearest 5 m)

	Elevation (m)	Distance to live trees (m)	% Burned: village occupations	% Burned: previllage occupations
Crooked Forks	3150	365	60.0	64.0
Enfield	3170	1135	61.8	–
Corral North	3350	95	68.4	–
Corral South	3350	25	61.8	–
Shortstop	3390	640	–	50.6
Midway	3440	985	54.1	68.6
Pressure Drop	3460	1065	50.3	–
Raven Camp	3460	540	–	56.4
Rancho Deluxe	3560	2090	64.0	51.1
Shooting Star	3620	1260	52.4	–
12640	3850	910	74.1	–

1995), suggesting that they had been heated to at least 700 °C (Lyman, 1994).

Bone is far inferior to wood for generating long-lasting heat (Théry-Parisot et al., 2005). However, experiments conducted by Théry-Parisot (2002) and Théry-Parisot et al. (2005) have shown that great benefits are to be had from fires that are composed of both wood and bone since the higher the proportion of bone to wood, the longer the fire lasts. For instance, in the experimental fires created by Théry-Parisot and her colleagues, the duration of combustion doubled as the proportion of bone increased from 20% to 80% (Théry-Parisot, 2002).

This suggests that bone was being intensively burned in the White Mountains sites in order to maximize the utility of wood that was being burned along with it. But what was this wood and where did it come from? The Midway site (985 m from the nearest stand of live trees; see Table 1) contained significant amounts of sagebrush (*Artemisia* sp.) charcoal (Scharf, 1992) but other White Mountains sites for which we have information also contained pine charcoal, presumably from either limber (*Pinus flexilis*) or bristlecone (*P. longaeva*) pine (D. Rhode, pers. comm., 2006).

It is conceivable that the tree wood burned in these sites was transported from areas in which trees still occur. However, given that the archeological sites are up to 2090 m from live trees today (Table 1), it is also possible that much of this fuel was provided by deadwood collected from above-treeline contexts in settings far closer to these sites than it now occurs. Deadwood lying close to habitation sites would not only reduce fuel transport costs but, by virtue of being dry, would also be easier to collect than greenwood at greater distance (Fig. 2). This latter issue was likely quite important in areas like the Great Basin, where axes did not exist and wood was split with wood, stone, and antler wedges driven by hammerstones (Lowie, 1909; Kelly, 1932; Steward, 1941; Stewart, 1941; Fowler, 1992). High-elevation pine deadwood in the Great Basin is frequently far more resinous than live trees, so much so that the resin can foul both saws and borers. While it is not clear why this is the case, the resinous and often dense nature of this wood makes it a superb fuel.

There is no reason to think that the White Mountains posed more severe energy-based challenges than other high-elevation zones in western North America or elsewhere. Indeed, while our examples have been drawn from North America, there is a rich above-treeline archeological record in other parts of the world as well, including Europe (e.g., Fedele, 1990; Indrelid, 1990) and Middle and South America (e.g., Iwaniszewski, 1995; Parsons et al, 2000). In all of these areas, fuel would have been needed for cooking and heating. Local deadwood – the remnants of prior



Fig. 2. A bristlecone pine (*Pinus longaeva*) deadwood stand in the White Mountains, California (elevation = 3570 m). The arrows illustrate potentially harvestable deadwood. Photograph by C.I. Millar.

treeline advances – would have served those purposes well.

Conclusions

If our speculations are correct, the distribution of deadwood above and within upper treeline forests has in part been determined by prehistoric human behavior, much as the distribution of driftwood along arctic coastlines is in part determined by human behavior today (Dyke and Savelle, 2000; Alix, 2005). If so, reconstructions of past treelines and inferences based on the distribution, abundance, and age classes of deadwood in treeline forests, and the climatic predictions that follow from them, may reflect the human prehistory of a given area at least as much as it reflects treeline history itself.

This possibility suggests that future studies of treeline history should include an archeological component to determine the degree to which deadwood abundance and distribution may have been determined by prehistoric human behavior. There are multiple possible ways of doing this. For instance, a negative relationship between the abundance of deadwood and archeological sites across an alpine landscape may suggest that prehistoric human activities removed such wood from the landscapes involved. Radiocarbon or tree-ring dates of archeological fuelwood that are significantly older than other indicators of the age of the occupation of alpine sites – for instance, those derived from artifacts of known age, from luminescence dating, or from short-lived plants – would support such an inference. If this latter approach is taken, one would, of course, have to

exclude the possibility that the ancient dated wood simply came from the internal section of a long-lived species that may have been felled during the time of the occupation itself (e.g., Schiffer, 1986; Taylor, 1987). No matter how it is accomplished, however, we suggest that possible prehistoric human impacts on the distribution of deadwood and abundance at and above treeline be evaluated in association with analyses of the histories of those treelines.

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