Journal of Archaeological Science (1998) **25,** 1199–1210
Article No. as980290

Pine Nut Use in the Early Holocene and Beyond: The Danger Cave Archaeobotanical Record

David Rhode

Quaternary Sciences Center, Desert Research Institute, Reno, NV 89512, U.S.A.

David B. Madsen

Environmental Sciences, Utah Geological Survey, Salt Lake City, UT 84114, U.S.A.

(*Received 2 December 1997, revised manuscript accepted 21 February 1998*)

Nuts of limber pine (*Pinus flexilis*) from Early Holocene strata in Danger Cave, Utah, are distinguishable by seed-coat sculpturing from pine nuts of single-needled pinyon (*Pinus monophylla*), which occur in strata dating <7000 years BP. Owls and other taphonomic agents may deposit pine nuts in archaeological sites, but the morphology of the pine nuts in Danger Cave strongly indicate they were deposited by human foragers who brought small quantities with them for food for at least the last 7500 years. Large-scale transport of pine nuts to Danger Cave from distant hinterlands is unlikely, however. The seamless transition from limber pine to pinyon pine nuts in the Danger Cave record suggests that foragers who had utilized limber pine as a food resource easily switched to using pinyon pine nuts when pinyon pine migrated into the region at the close of the Early Holocene.

Keywords: LIMBER PINE, PINYON PINE, DANGER CAVE, BIOGEOGRAPHY, TAPHONOMY, FORAGING THEORY.

Introduction

For millennia, people inhabiting the mountains of western North America have valued the seeds of various species of pines as a nutritious and often abundant food. The single-needled pinyon pine (*Pinus monophylla*) was a major resource for Great Basin foraging societies (Steward, 1938; Thomas, 1973, 1983; Fowler, 1986; Madsen, 1986). Limber pine (*Pinus flexilis*), common in the northern Rocky Mountains and scattered across the higher elevations of the intermountain ranges, provided a similar nut crop, but one that was harder to collect and process than pinyon (Steward, 1938: 28). Whitebark pine (*Pinus albicaulis*) was also used prehistorically in the northern Great Basin and central Rocky Mountains (Steward, 1938: 28; Munger, 1997). Gray and sugar pines (*Pinus sabiniana* and *P. lambertiana*) provided seed crops for generations of the original Californians (Muir, 1917; Farris, 1982), while four-needled pinyon (*Pinus quadrifolia*) was used by the inhabitants of adjacent northern Baja California (Aschmann, 1959). On the Colorado Plateau, two-needled pinyon (*Pinus edulis*) was a key supplement to the diet of southwestern horticulturalists, as were several pine species (*Pinus ayacahuite, P. cembroides, P. engelmannii, P. leiophylla, P. reflexa*) in the cordillera to the south (Pennington, 1969). Little is known, however, about the origins and early history of pine nut use in western North America. George Frison (1992) suggested that palaeoindian groups in the Rocky Mountain region may have included limber pine nuts as part of their diets, but this speculation has never been seriously investigated.

Recent excavations at Danger Cave, western Utah (Figure 1), were conducted in part to investigate the early history of pine nut use in the eastern Great Basin. Remains of pine nuts occur throughout the deep, well-dated stratified deposits of Danger Cave, and these remains provide insights into the dietary use of two pine species during the Early to Middle Holocene in the intermountain West. They were all initially identified and reported as single-needled pinyon pine (Madsen & Rhode, 1990), but continuing research into plant biogeography of the Bonneville Basin (Rhode & Madsen, 1995) and refined methods of identification of pine nut remains suggest that the oldest pine nut remains from Danger Cave are predominantly limber pine, rather than pinyon. The finding and distribution of pine nut remains from both taxa in Danger Cave has a number of implications for hunter-gatherer adaptations in western North America.

In this paper, we discuss the criteria used to distinguish limber pine and single-needled pinyon pine nut remains and the temporal distribution of these

0305–4403/98/121199+12 $30.00/0

Figure 1. Map showing the location of Danger Cave within the Great Basin of western North America.

Figure 2. View of excavation profiles exposed during the major excavation in the early 1950s. Note the discontinuous nature of many depositional layers.

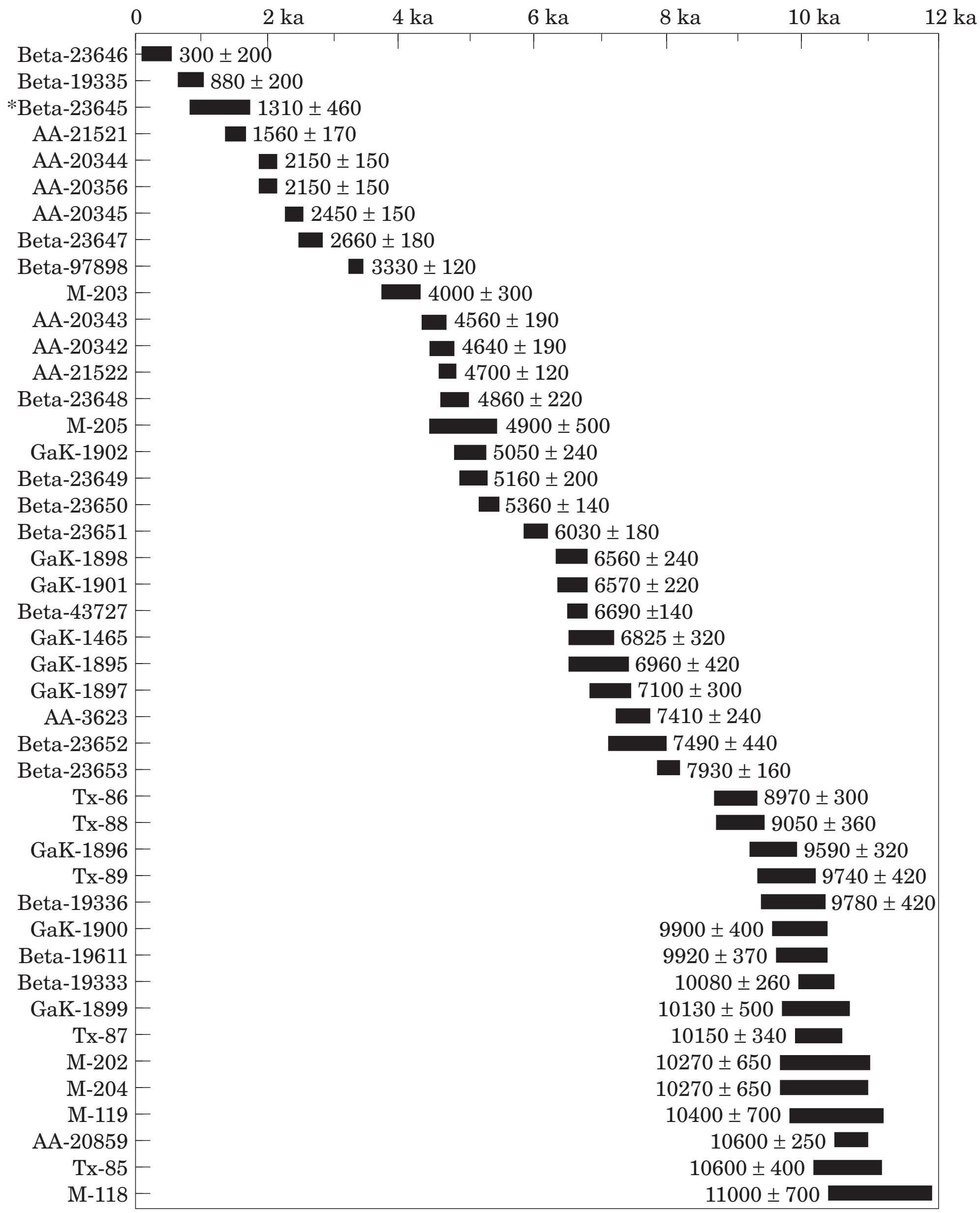
plant macrofossils in the Danger Cave archaeological record. We also assess the potential role of owls and other taphonomic agents of pine nut deposition in Danger Cave and other archaeological and palaeoenvironmental deposits. Finally, the history of pine nut use by Early Holocene foragers is considered in light of plant migrations that occurred during the Early to Middle Holocene in the eastern Great Basin.

Danger Cave

Danger Cave is a large wave-cut limestone cavern on the western margin of the Bonneville Basin in western North America (Figure 1). At an elevation of 1314 m, the base of the cave lies ~20 m above the modern playa and ~15 m above the Gilbert level of Lake Bonneville. The cave was exposed during the regressive phase of the lake sometime after 13,000 BP (Oviatt, Currey & Sack, 1992; Rhode & Madsen, 1995; Light, 1996), and has remained open since that time. These deposits contain one of the longest stratigraphic archaeological records in North America, with well-preserved and finely stratified deposits spanning at least the last 10,000 years, including an array of perishable materials laid down primarily by human occupants, but also by woodrats, coyotes, owls, and other depositional vectors.

Danger Cave has been investigated a number of times over the course of the last 60 years. Initial work was conducted by Elmer Smith in the 1930s (Smith, 1942), but by far the most extensive research was carried out by Jesse Jennings in the late 1940s and early 1950s (Jennings, 1957). These excavations were oriented towards the definition of a cultural historical framework for the region, and produced a dated artefact sequence that remains in use at present. The Jennings project was one of the first to extensively use radiocarbon dating and was important in demonstrating human antiquity in the New World. Subsequent work at the cave by Gary Fry in 1968 (Fry, 1976, 1978), and ourselves in 1986, involved limited excavation directed at specific goals. In both cases, attempts were made to correlate recovered materials with the stratigraphic framework defined by Jennings.

Stratigraphy in the cave, like many other dry caves in the Bonneville Basin, is a product of an array of depositional events ranging in duration and extent from a basket load of pickleweed chaff dumped from a winnowing tray in a matter of seconds, to layers of rock spall deposited throughout the cave over hundreds if not thousands of years during periods of abandonment. Stratigraphic relationships are complicated by earth moving events resulting from the construction of storage pits and attempts to create a level occupation surface by the cave's human occupants, as well as from fires which reduced the dry deposits to ash throughout large areas. As a result, it is often impossible to correlate depositional events across the entire cave floor (Figure 2), and strata must be grouped into major depositional units with traceable surfaces. In Danger Cave, this problem led Jennings to define five major depositional units he called DI–DV. The lowest of these, DI, is composed of isolated, scattered hearths in otherwise culturally sterile beach sands derived from reworked sediments of Lake Bonneville. Units DII–DV, the main occupation layers, consist of large quantities of dessicated vegetal material, rock fall, dust, and artefacts. Aikens (1970) has since postulated the presence of a sixth such major unit, DVI, located primarily at the cave mouth.



*This date is derived from a hearth in the bog below the mouth of the cave rather than in the cave itself. Solid carbon dates are not included.Two additional dates, a date of 13,250 ± 160 on tufa from the cave wall and a bomb contaminated date on a twine seed beater from the surface deposits, are not included here.

Figure 3. Graphic display of 44 radiocarbon dates from Danger Cave. All dates are displayed with two standard deviations, and are not ^{13}C corrected, for purposes of consistency.

The presence of dry deposits in the cave, together with stratified evidence for some of the earliest human occupation in North America, has led to the accumulation of a large series of radiocarbon dates. Currently, 44 gas dates are available from the cave sequence (we have excluded the early solid carbon dates obtained in the early 1950s), with most of these derived from the earliest occupations (Figure 3). Together, the dates from DI and the lowest part of DII average ~10,100 BP, suggesting the initial occupation of the cave was associated with the regression of Lake Bonneville from the Gilbert level ~10,300 BP (Currey, 1990), the subsequent exposure of a nearby spring and creation of a large marsh system near the cave.

Fifteen of these dates are derived from a 1·5 m^2 column we collected from the cave in 1986 to examine the changing use of vegetation in the longest human occupation record in the Bonneville Basin. Since our

Table 1. Identification of pine nut remains from Danger Cave based on surface features

Stratum	Total number and weight of pine seed fragments		Specimens identified by surface characteristics		Number of burned seed fragments	Number of *P. monophylla* cone fragments	Date (BP, uncorrected)
			P. monophylla	*P. flexilis*			
37	(no bulk sample)						330 ± 100 (Beta-23646)
35/36	12	0·1459 g	5				880 ± 100 (Beta-19335)
34	77	0·4262 g	8		6		
33		—					
32		—					
31	26	0·1036 g	2		1		2660 ± 90 (Beta-23647)
30	15	0·1305 g	5				4860 ± 110 (Beta-23648)
29	22	0·2442 g	4				
28	4	0·0254 g			3		
27	9	0·0578 g			1		
26	48	0·5768 g	2				
25	15	0·0855 g	1				5160 ± 100 (Beta-23649)
24	95	0·8237 g	3				5360 ± 70 (Beta-23650)
23	9	0·0453 g					
22	4	0·0217 g					
21	6	0·0267 g					
20	3	0·0072 g					
19	12	0·0575 g					
18	18	0·1089 g					6030 ± 90 (Beta-23651)
17	93	0·7047 g	7			1	
16	48	0·3557 g					
15	38	0·3247 g	1		2	4	
14	24	0·1730 g			2	6	6710 ± 70 (Beta-43727)
13		—					
12	4	0·0144 g	1				
11		—					7490 ± 120 (Beta-23652)
10	125	0·4179 g		11			7410 ± 120 (AA-3623)
9	3	0·0220 g					7920 ± 80 (Beta-23653)
8	(moist, poorly preserved)						
7	(moist, poorly preserved)						
6	(moist, poorly preserved)						
5	(moist, poorly preserved)						10,080 ± 130 (Beta-19333)
4	(moist, poorly preserved)						
3	(moist, poorly preserved)						9780 ± 210 (Beta-19336)
							9920 ± 185 (Beta-19611)
2	(non-cultural)						
1	(non-cultural)						

horizontal exposure was limited, in contrast to the extensive excavations of Jennings and his colleagues, we were able to define 106 "mappable" depositional layers within the column. These were combined into 37 "excavatable" units to ensure the chronological integrity of materials within each layer (Madsen & Rhode, 1990). In dry Bonneville Basin caves, fine-grained material, such as pickleweed chaff, is often deposited over course-grained layers of spall and/or brush, making it impossible to confidently separate depositional events. In removing the column deposits, we concentrated only on those surfaces that could be readily and confidently traced across the column. In total, the fill from 36 of the 37 layers was removed, placed in large plastic bags and taken to the laboratory where they were hand-sorted, identified and tabulated. (The uppermost stratum, Stratum 37, consisted of an assortment of surface artefacts, and consequently a separate bulk sample was not gathered; this stratum is not considered further here.) Vegetal materials were present in the upper 29 excavation units but, unfortunately, moisture in the lower eight units significantly diminished the preservation of perishable materials from the earliest deposits. Pine macrofossils, including both limber pine and pinyon pine, were present in nearly all units that contained significant amounts of perishable materials (Table 1). These macrofossils include numerous fragments of seed coats, identified as pinyon pine and limber pine, one nearly complete pinyon pine seed, and a few pinyon pine cone (strobilus) fragments as well.

Distinguishing Limber Pine from Pinyon Pine Nuts

When whole and fresh, single-needled pinyon pine nuts are readily distinguished from limber pine nuts (Figure 4). Pinyon pine nuts are significantly larger and usually have a more rounded outline than the somewhat angular limber pine nuts. The angular appearance of limber pine nuts is enhanced by the existence of a detachable ring of tissue around the perimeter of the nut, tissue that is the vestigial remnant of a seed wing (or "alae"). Seed wings are commonly found in pine species with smaller seeds, where they aid in dispersal

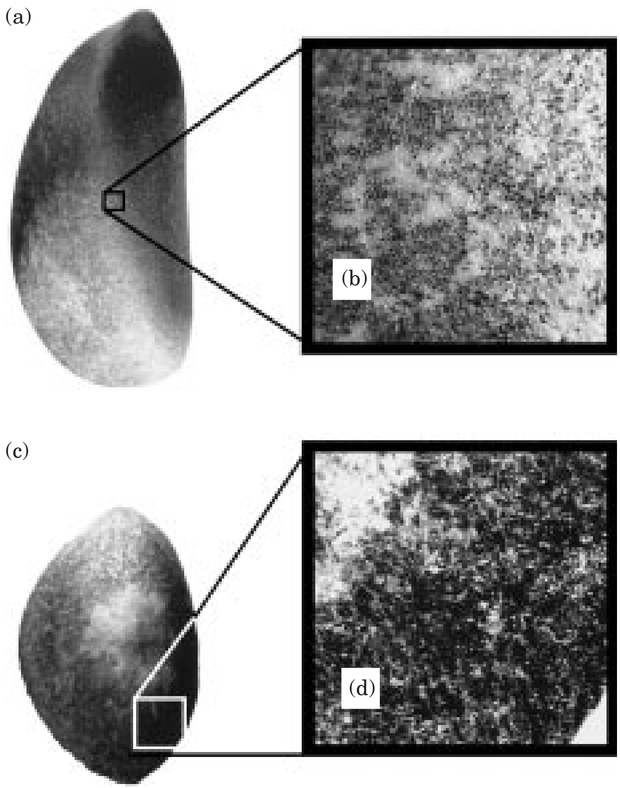


Figure 4. Modern pine nut morphology and surface characteristics. (a) Single-needled pinyon (*Pinus monophylla*), seed is 15·7 mm long. (b) Surface of pinyon seed hull; note punctate pigmentation. (c) limber pine (*Pinus flexilis*), seed is 11·1 mm long, including vestigial seed wing at base of seed. (d) Surface of limber pine seed, showing rugulose tissue of seed wing.

from the parent tree. In larger-seeded pines such a limber and pinyon, a seed wing would be nearly useless, and dispersal is typically facilitated by corvid birds (Vander Wall & Balda, 1977; Lanner & Vander Wall, 1980; Lanner, 1981; Tomback, 1983; McCaughey, Schmidt & Shearer, 1985). The larger pinyon pine nuts lack even a vestigial seed wing. Pinyon pine nuts also tend to have thinner hulls than do limber pine nuts, but hull thickness varies significantly within a single hull and probably between pine populations, and the two taxa overlap in hull thickness measurements (Table 2).

In contrast to fresh whole seeds, pine seed coats found in archaeological contexts are often fragmentary and may have degraded surfaces, which can prevent identification of the species involved. The size and degree of rounding of the whole shell is not usually evident in smaller fragments, and the keeled appearance of limber pine nuts can disappear since the vestigial wing tissue is easily removed. Because of the overlap of hull thickness measurements between the two taxa and the variation of thickness within a single hull, thickness measurements of small fragments are not very useful except for extreme cases. Hence,

Table 2. Pine nut size and hull thickness for samples from two pinyon populations and one limber pine population in the Great Basin

	Length of seed (mm)	Hull thickness (mm)		
		tip	midsection	base
Pinus monophylla Silver Island Range, UT (*N*=9)				
Range	12·7–16·1	0·27–0·46	0·14–0·31	0·23–0·39
Mean	14·5	0·37	0·24	0·32
Standard Dev	1·4	0·05	0·05	0·05
Pinus monophylla Virginia Range, NV (*N*=10)				
Range	14·3–17·7	0·27–0·37	0·17–0·33	0·20–0·34
Mean	16·1	0·31	0·25	0·32
Standard Dev	1·3	0·03	0·05	0·05
Pinus flexilis East Humboldt Range, NV (*N*=10)				
Range	10·1=11·3	0·37–0·45	0·24–0·36	0·35–0·41
Mean	10·8	0·43	0·30	0·38
Standard Dev	0·3	0·02	0·04	0·02

identification of archaeological specimens of limber and pinyon pine nuts may be problematic.

One potentially diagnostic feature for some archaeological specimens is the surface sculpturing of the seed coat and adhering tissue (Figure 4). The limber pine seed coat often retains patches of the vestigial wing tissue, even when most of the wing is removed. The surface sculpturing of the remnant vestigial wing tissue is rugulose, appearing as elongated corrugations under magnification. In contrast, the pinyon pine lacks the vestigial wing tissue and therefore has no such rugulose surface sculpturing: its surface is mostly smooth and bald, though it often shows a distinctive punctate pigmentation in places.

We have used the morphological evidence of surface sculpturing to identify pine nut remains from Danger Cave. Our initial interpretation of these pine remains was that they were all pinyon (Madsen & Rhode, 1990). Pine nut hulls found in Stratum 12 and above, that can be identified using the surface sculpturing criteria outlined above, do indeed appear to be pinyon pine (Table 1). However, rugulose surface tissue on hull fragments from Stratum 10 indicates that these Early Holocene pine nut remains are limber pine, not pinyon. Pine nut remains that we previously reported as dating to 7410 BP using the AMS radiocarbon method are also limber pine, according to these surface characteristics. Pinyon pine may be represented by some of the remains found in these older strata, but they are not conclusively identified to either species because they lack the requisite surface characteristics. The distribution of limber pine nut fragments in early levels, followed immediately by pinyon pine nuts, has several implications for both the biogeography of pinyon expansion and advent of pine nut procurement by human foragers in the Great Basin (see below).

Owls and Pine Nut Deposition

Although the vast bulk of the plant remains found in Danger Cave were undoubtedly brought in by humans, other taphonomic agents were also clearly responsible for plant deposition within the cave environment as well. Many small twigs bear recognizable marks of rodent chewing, and woodrat nests are found along the cave walls. Some vegetal debris incorporated in these nests probably gathered from the archaeological midden deposits, but there is little doubt that woodrats also brought in fresh plant material from outside the cave for construction and food. Coyotes, too, may have deposited plant remains in their faeces on the occasions they used the cave for shelter. Consequently, the archaeobotanical record of Danger Cave is not exclusively a record of human plant use.

One taphonomic factor that needs to be more fully recognized is the potential for raptors, particularly owls, to deposit plant remains in archaeological deposits. Owls are often an important taphonomic agent affecting the composition of faunal remains in archaeological deposits (Andrews, 1990), but the role of owls in leaving plant remains in those same deposits has been neglected. This neglect is no doubt the result of the fact that owls are typically considered obligate carnivores, and plant remains are usually not reported as constituents in owl pellets (e.g., Ross, 1969; Marti, 1974; Gleason & Craig, 1979; but see also Brown *et al.*, 1986; Plumpton & Lutz, 1993). Yet we have found modern owl pellets, in numerous caves and shelters around Danger Cave and throughout the eastern Great Basin where owls have roosted, that contain abundant plant remains, including pinyon pine nut hulls. We have not directly observed the species of owl(s) involved, but pellet morphology and food contents implicates a small owl such as the western screech owl (*Otus kennicottii*) as a strong candidate in this region. We have noted other plant materials (notably grass seeds) in barn owl (*Tyto alba*) pellets in the same region.

Some pellets consist, nearly entirely, of pinyon pine nut hulls, even in roosting sites located several km away from the nearest modern pinyon woodlands. The hulls may have been ingested incidentally as the owls foraged for small mammals that had pine nuts stored in their food pouches or stomachs, presumably from pinyon groves located within the owls' foraging radius of the roosting site. The pine nut hulls and other plant materials are expelled, along with undigestible bones, feathers, fur, and insect parts, as pellets. Pellets that contain a high concentration of hull fragments are not typically associated with large concentrations of skeletal elements or fur normally found in owl pellets, however. This may suggest that owls forage for the pine nuts directly, but to our knowledge owls have neither been observed foraging for nor eating pine nuts. However the pine nuts may have got into the owl, what matters here is that owls can and do expel pellets containing pine nut hulls into cave sites at distances of up to 3–5 km away from any pinyon groves (Schmitt, in prep.), and these pellets can contribute to the contents of packrat midden deposits (a phenomenon we have observed) and presumably also to the contents of (mostly) human-created archaeological midden deposits.

Fortunately, the pine nut remains found in owl pellets may have certain distinguishing characteristics that allow separation from pine nut remains brought in by humans. The owl pellets we have observed include hulls only, not other parts of the pine such as needles or cone fragments. The pine nut hulls in the pellets are relatively small, flat, and somewhat rounded on the edges, the product of being partially processed in the digestive tracts of an animal or two. They often have adhering particles of animal parts such as hair or feathers, especially on internal curves of the nut shell, part of the original meal coughed up in the pellet.

Most of the Danger Cave pine nut materials do not match these criteria, and available evidence strongly indicates that humans were the primary agent of deposition of pine nut remains in the cave. Many pine nut hull fragments in Danger Cave are larger, more curved and often more complete than any found in owl pellets; one pine nut still contains the seed itself. Human-derived coprolites from Danger Cave contain pine nut fragments (Fry, 1978), and numerous pine nut fragments found in Danger Cave have adhering vegetal matter (not animal matter as seen in owl pellets), suggesting that they were also once part of human coprolites. Numerous hull fragments also show evidence of light burning, probably as part of processing for consumption (Steward, 1941: 279–280; Stewart, 1941: 374; Madsen, 1986). The Danger Cave strata also contain pine cone scales, which are not found in owl pellets. Lastly, the distance between Danger Cave and the nearest limber and pinyon pine lies well beyond the foraging radius of owls, but well within the foraging radius of prehistoric humans. Taken together, this evidence makes a strong case that people were the most likely agent of deposition of virtually all pine nut remains in Danger Cave.

Use of Pine Nuts at Danger Cave

Pine nut remains are found in small but rather consistent quantities throughout the Danger Cave strata spanning the last 7500 years. Pinyon pine does not grow in the vicinity of the cave today, and probably never did (see below), so people travelling to Danger Cave must have brought pine nuts with them from some distance away. Many pine nut fragments are small and have weathered surfaces, and numerous fragments bear attached vegetal materials indicating they were once incorporated in coprolities, so some of the pine nut hulls were probably brought by people to Danger Cave internally, as part of a meal previously eaten elsewhere. At least some pine nuts were brought to Danger Cave to be processed and eaten while at the cave, however. One complete pine nut (hull and enclosed seed) was found, and numerous pine nut hulls are too large and pristine to have been digested and subsequently deposited in coprolites. As noted in Table 1, fragments of single-needled pinyon pine cones (including the central spine of one strobilus and several cone scales) were also recovered in Strata 14–17, fragments that were probably accidentally carried into the site along with unhulled pine nuts. The evidence clearly suggests that human inhabitants of Danger Cave used pine nuts for food for at least the last 7500 years, but there is no evidence that they ever brought large quantities into the cave for further processing or consumption.

Recently, a number of investigators (Jones & Madsen, 1989; Kelly, 1990, 1995; Metcalfe & Barlow, 1992; Barlow & Metcalfe, 1996; Bettinger, Malhi & McCarthy, 1997; Bird & Bleige Bird, 1997) have developed economic models (drawn largely from central place-foraging theory; cf. Orians & Pearson, 1979) that examine trade-offs between the caloric content of food resources and the caloric costs to process and transport those resources, to assess what kinds of residues may be expected in different settlements within a foraging system. One of these models, that of Barlow & Metcalfe (1996), is especially germane to the Danger Cave situation. This model considers how field processing of plant foods may affect transport costs and in turn the profitability of those resources, expressed in caloric return rates. The model assumes that foragers depart from a base camp to forage in distant field camps, process the collected plants to increase the proportion of edible product, and then transport the processed foods back to the base camp. More processing in the field results in a transported load with a higher proportion of edible material, but at a cost in labour and collecting opportunity. In general, Barlow & Metcalfe (1996) find that as the distance between base camp and field camp increases, in-field processing costs should increase because those costs will be offset by savings in transporting more edible plant food and less inedible waste. When the distance between base camp and field camp is short, transport costs are relatively small, and there is little to be gained by processing in the field rather than at home in the base camp. When the distance between base camp and field camp is far, transport costs can be large and each load's value should be maximized, so in-field processing to maximize the load's value is worthwhile.

In their model, Barlow & Metcalfe specifically measured how field processing affected the caloric profitability of single-needled pinyon pine nuts in relation to transport costs and then considered some of the archaeological implications. They concluded that transporting pinyon pine nuts in the cone is quite costly and is to be expected only immediately around the base camp. Pine nuts removed from the cones can be transported profitably for much longer distances, so transport of unhulled pine nuts should be expected when the base camp is more than a few hundred metres away from the field camp. Removal of the hull requires considerable extra processing time and provides little gain in transportability, and Barlow & Metcalfe's model suggests that pinyon nuts would not be hulled in the field unless they were to be carried for very long distances (Barlow & Metcalfe, 1996: 359).

Barlow & Metcalfe used the Danger Cave pine nut record (Madsen & Rhode, 1990) as a partial test of their model. They found that:

> "the remains from several levels are not inconsistent with our expectations about waste components returned to base camps . . . five of nine cultural levels dating from approximately 7400 to 6000 years BP yielded relatively large numbers of hull fragments, and three of these also contained a few cone fragments. Higher in the stratigraphic profile, two levels dating to approximately 5300 and 5000 years BP, and one level dating before 880 years BP, yielded similar assemblages of pinyon remains. Conversely, our predictions about the deposition of large quantities of pinyon hulls appear to be falsified for at least half of the occupational units if foragers were staging collection trips to pinyon groves during these times."

Clearly, foragers occupying Danger Cave brought pine nuts in the hull, consistent with Barlow & Metcalfe's model (no hulled nutmeats were found in our sample, though if large quantities of pine nuts were brought to Danger Cave as previously hulled nutmeats, there would be very little evidence of that activity). However, the Danger Cave macrofossil suggests to us that large quantities of pine nuts were never transported to Danger Cave from distant field camps. The quantity of nut hulls recovered from each stratum is very small, representing, at the most, a half dozen nuts and usually far less, and these small amounts do not add up to strong evidence that pine nuts were a substantial food resource at Danger Cave. We are mindful that our sample is restricted to a small part of the Danger Cave deposits and that significant quantities of pine nut hulls could have been scattered through the rest of the cave's deposits. However, both Jennings (1957) and Harper & Alder (1972) reported finding very few pine nut hulls in these deposits.

It is more likely, in our view, that people who travelled to Danger Cave, to make use of the shelter and nearby resources it provided, routinely carried quantities of pine nuts with them as part of provisions for travelling and initial occupation of the site. Economic transport models (e.g., Jones & Madsen, 1989; Rhode, 1990; Barlow & Metcalfe, 1996) suggest that prehistoric foragers travelling from a distant pinyon collection area to Danger Cave should have maximized the amount of food (such as pine nuts) they could carry. However, these same models suggest that once the foragers were at the cave, logistical foraging for pine nuts was probably not as cost-efficient as foraging for plant resources locally. As a result, it was probably not economically viable for Danger Cave residents to mount logistical pinyon gathering expeditions to distant hinterlands and return with large quantities of pine nuts.

One way to examine whether pine nuts were brought to Danger Cave as initial provisions while travelling to the site, versus large-scale logistical field processing and transport from satellite camps, is to assess the abundance of pine nut remains in relation to other food resources. If large quantities of pine nuts were logistically collected and transported in bulk to Danger Cave, this would imply that local resources around Danger Cave were calorically much less economical to procure than pine nuts. If so, one should expect pine nuts to occur most commonly in the Danger Cave strata that lacked other significant resources, and would not be found in strata where other resources were abundant. On the other hand, if the pine nuts were brought in during initial occupation of the site, the abundance of pine nuts is more a function of frequency of visitation than of the economic superiority of distant pine nuts versus local resources: one might expect more abundant pine nuts when Danger Cave was visited more frequently (i.e., when resources at Danger Cave were abundant), and fewer pine nuts when Danger Cave was not frequently visited (presumably when Danger Cave was not a pleasant or profitable place to live).

These contrasting expectations can be tested by examining the abundance of pine nuts relative to two other economic plant taxa common in the Danger Cave strata: marsh plants (especially *Scirpus*), and pickleweed (*Allenrolfea occidentalis*). A small spring located on the playa margin immediately below Danger Cave periodically provided an oasis of relatively abundant wetland resources in an otherwise rather barren desert. From the standpoint of caloric return rates, the food resources in this small wetland would have ranked among the highest for long distances around Danger Cave, making the site a magnet for settlement during those times the wetland existed. Abundant rhizome and stem tissue of bulrush (*Scirpus sp.*) are found in Danger Cave, often in the form of chewed quids. These plant remains are found primarily in three separate intervals in the Danger Cave strata (Table 3): Strata 17–21 (~6000 BP), 26–30 (~5000–4800 BP) and 34–36 (~800 BP). The abundance of marsh plants in the Danger Cave strata is a good indicator of the quality and abundance of food resources in the immediate vicinity of Danger Cave. On the other end of the caloric spectrum is pickleweed. Remains of pickleweed are also common throughout the Danger Cave strata, derived from the margin of the playa below the cave. Pickleweed seeds were used as food, as the evidence from Danger Cave coprolites attests (Fry, 1978), but experimental caloric return rates for the seeds are low (Simms, 1987), lower than marsh plant resources and much lower than pine nuts.

If pine nuts were collected and transported in large quantities to Danger Cave, it would be expected that this activity would occur when pine nuts were economically profitable relative to the local resources. Hence, pine nuts should not have been collected and transported when marsh resources were available, and we should expect a strong inverse correlation between the abundance of marsh resource remains and the abundance of pine nut remains in Danger Cave strata. It is expected that pine nuts would be logistically transported in bulk to Danger Cave more often when only low-ranked resources such as pickleweed were available, and so we might expect a more positive relationship between pine nuts and pickleweed than between pine nuts and marsh plants.

If, on the other hand, pine nuts were brought in as part of provisions for travelling to and initially occupying the cave, we might expect a positive correlation between strata containing abundant marsh resources and those containing pine nuts, since the abundance of pine nuts would be related to the frequency of visitation and the relative value of Danger Cave as a habitation site. That correlation may be rather weak, however, as it depends on the quantity of pine nuts initially carried to the site (which may in turn be a function of other variables such as the anticipated potential for collecting food resources on the trip to Danger Cave, anticipated risks of delays and the expected availability of resources at Danger Cave) and the subsequent length of stay at Danger Cave. Since Danger Cave apparently served as a long term over-wintering base camp throughout most of its history (Madsen, in prep.), the relative proportion of pine nut hulls compared to other vegetation in our sample column would usually be small, unless a significant amount of logistical collection and transport occurred.

Table 3. Relative abundance of pine, bulrush, and pickleweed (expressed as grams/kg of the >$\frac{1}{4}''$ vegetation fraction)

Stratum	Pine	Bulrush	Pickleweed
35/36	0·035	63·323	3·466
34	1·029	14·662	3·913
33*	0	0	0
32*	0	0	0
31	0·925	7·768	2·054
30	0·372	37·778	4·644
29	0·300	296·916	10·369
28	0·285	220·787	0·449
27	0·121	479·036	3·124
26	0·279	59·036	3·939
25	0·037	1·880	4·058
24	2·496	3·424	2·061
23	0·199	3·553	8·070
22	0·040	7·712	0
21	0·045	32·529	5·863
20	0·011	18·170	5·300
19	0·148	12·397	9·665
18	0·219	22·052	3·964
17	0·303	18·259	5·834
16	0·288	4·162	5·514
15	0·135	0·622	2·086
14	0·207	0·168	9·592
13	0	0·490	4·510
12	0·026	0	3·766
11	0	0·253	6·371
10	4·542	0	34·565
9	0·026	0·334	4·708

*Not used in analysis.

The amount of pine nuts brought to Danger Cave would be expected to decrease when only low-ranked resources such as pickleweed were locally available, since the frequency of occupation would also decrease, so we might expect to find fewer pine nuts in strata dominated by pickleweed. However, people who travelled to Danger Cave, knowing that only low-ranked resources such as pickleweed were available there, might well be expected to bring some provisions such as pine nuts with them, without making multiple logistical trips to do so. Under these circumstances, the relationship between pickleweed and pine nut abundance is not strong or clear-cut.

To test these expectations against the Danger Cave archaeobotanical record, the abundance of pine remains is correlated with the abundance of bulrush remains (representing marsh vegetation and a relatively high-ranked local resource base) and with pickleweed remains (indicating a relatively low-ranked resource base). To compensate for different sample sizes of the strata (which might force a spurious correlation), all measures are standardized by expressing their abundance as grams per kilogram of all vegetation caught by $\frac{1}{4}''$ mesh in the lab (Table 3). It is assumed for this analysis that the $\frac{1}{4}''$ fraction adequately represents overall abundance of bulrush and pickleweed in each stratum. (This assumption is likely true for bulrush remains, which tend not to pass through $\frac{1}{4}''$ mesh, but most pickleweed remains are smaller than the $\frac{1}{4}''$ mesh fraction, and whether this fraction adequately represents actual pickleweed abundance is not yet certain; detailed quantitative analysis of the smaller size fractions remains to be completed.)

Rank-order correlation of the abundance of pine nuts and bulrush (Table 3) for Strata 9–36 (excluding Strata 32 and 33, where no vegetation is found) yields a value of $R_s=0{\cdot}220$. This is a slightly positive but not significant correlation ($P>0{\cdot}20$). Rank-order correlation between pine nut and pickleweed abundance for the same strata (Table 3) yields an even lower value of $R_s=0{\cdot}020$; effectively no relationship at all. Analysis of cases indicates that Stratum 10 is anomalous among all strata in the quantity of pine nut remains relative to both bulrush and pickleweed abundance, and it has a large impact on the statistical outcome. Stratum 10 contains a relatively large number of limber pine (not pinyon) remains. If Stratum 10 is removed from the analysis, then the rank-order correlation between pine nuts and bulrush rises to $R_s=0{\cdot}371$, and the correlation between pine nuts and pickleweed drops to $R_s=-0{\cdot}108$. Again, neither of these values is statistically compelling (at $P>0{\cdot}05$). The anomaly with Stratum 10 may arise because limber pine nut fragments weigh more than pinyon pine nut fragments; alternatively, this stratum could be an example of stocking up with provisions for a trip to a site known for its low-ranked local resource base. In general, however, a weak but positive relationship is indicated between pine nut and bulrush (=high-ranked marsh) resources, while there is little or no relationship between pine nut abundance and low-ranked pickleweed.

These results tend to run counter to the expected relationships if pine nuts were collected and transported logistically from distant hinterlands to a Danger Cave base camp. Pine nut remains do not appreciably increase in abundance when Danger Cave had a low-ranked local resource base, nor do they decline in the record when the local resource was more plentiful. The results fit quite well with expectations if pine nuts were part of provisions brought to the site by groups planning to over-winter at Danger Cave and exploit the local resource base. It is likely that the cost of transporting large quantities of pine nuts from distant pine groves was too great, or it may also be that Danger Cave was not frequently used as a major base camp during those times when the local resource base was low-ranked. In either case, the small quantity of pine nut remains found in the cave, together with the distribution of those remains in relation to other economic plant indicators, both point to the same conclusion: the inhabitants of Danger Cave used pine nuts for food for at least the last 7500 years, but the costs of procuring and transporting large quantities of pine nuts from distant hinterlands back to Danger Cave was not a viable alternative to collecting resources available closer to the cave, even if those resources were as low-ranked as pickleweed.

Transition from Use of Limber Pine Nuts to Pinyon Pine Nuts

Limber pine woodlands and forests occupied much of the mountains and foothills of the western Bonneville Basin between ~13,000–11,000 radiocarbon years ago, extending down to the margin of the shallow lake which filled the basin at that time (Rhode & Madsen, 1995). Limber pine occupied the slopes immediately around Danger Cave until at least 10,800 BP, when it was replaced with a scrubland of sagebrush, shadscale and common desert associates. On larger mountains, such as the Cherry Creek Range and the Snake Range west and south of Danger Cave, midden data suggest limber pine persisted at relatively low elevations until the Mid-Holocene (Wells, 1983; Thompson, 1990; Rhode, n.d.). Thereafter, it retreated up-slope to sub-alpine elevations. Given this palaeoenvironmental evidence of delayed up-slope migration of limber pine and the absence of competing stands of pinyon pine, together with the modern presence of limber pine in cold air drainages of the nearby Deep Creek Mountains at elevations less than 1800 m asl, limber pine probably persisted locally in protected canyons and on the higher peaks of the Silver Island Range until well into the Holocene. While our midden data and the Danger Cave archaeobotanical record both suggest limber pine was not found in the immediate vicinity of Danger Cave during the Early Holocene, it was certainly available to the early inhabitants of the site well within an economically viable foraging radius in the Pilot Range ~35 km to the north and the Toano Range ~25 km to the west (Jones & Madsen, 1989; Rhode, 1990; Barlow & Metcalfe, 1996).

Pinyon pine was not found at the latitude of Danger Cave until well into the Holocene. At the end of the Pleistocene, single-needled pinyon was restricted to the southern margin of the Great Basin. After ~12,000–13,000 BP it began to migrate northward, reaching the Schell Creek Range, 150 km south of Danger Cave, by 6500 BP (Thompson, 1990). It had migrated to areas within range of human foragers at Danger Cave by at least 7000 BP. A date of 5960 ± 90 (Beta-73389) on single-needled pinyon pine in a packrat midden we collected from the Marble Head Mine locality in the Toana Range (Rhode & Madsen, 1995) indicates pinyon had replaced limber pine in lower elevations there by at least 6000 BP. As noted above, securely identified pinyon pine was found in Danger Cave in Stratum 14, dated to 6700 BP, but first appears in Stratum 12, which is undated but was deposited sometime between 6700 and 7400 years ago. The pine nut specimen previously reported as dating to 7410 BP (Madsen & Rhode, 1990) is now identified as limber pine, not pinyon. Pinyon may not have occurred quite as early in the Danger Cave region as we first speculated (Madsen & Rhode, 1990), but it did reach the site earlier than previously expected (Lanner, 1983; Wells, 1983; Madsen, 1986; Thompson, 1990; Grayson, 1993).

The close chronological spacing for the initial appearance of pinyon throughout the central and northeastern Great Basin strengthens the possibility that humans may have played a role in its dispersion as suggested by Mehringer (1986). Lanner (1983) has, alternatively, suggested the principal vector for pinyon migration was probably dispersal by Clark's Nutcracker and other corvid birds, and he has calculated maximum and minimum dispersal rates of 0·13–0·24 km per year based on the maturation rate of trees and the length of dispersal flights of these birds. However, pinyon now appears to have migrated rapidly through much of the eastern Great Basin in a matter of a few hundred years or less, a rate which greatly exceeds even the maximum rate suggested for avian dispersion. Given that the known historic range of human pine nut transport is much larger than that of corvid birds (e.g. Rhode, 1990), it is increasingly likely that people may at least be partially responsible for the rapid spread of pinyon.

Pinyon does not now, and probably never did, grow in the immediate vicinity of Danger Cave. A small population lives on the most protected north-facing slope on the highest peak on the far distant end of the Silver Island Range, 28 km northeast of Danger Cave, but the nearest substantial groves are some 25 km to the west, on the Toano/Goshute Range and to the north on the Pilot Range. This is virtually the same distribution pattern as that of Late Pleistocene-Early Holocene limber pine, and pinyon seems to have replaced/displaced limber pine as the principal pine in lower elevation forests of the Bonneville Basin in a rather seamless fashion during the first several millennia of the Holocene. The use of pinyon and limber pine nuts by human foragers seems to track this change in the same continuous way. Although the archaeobotanical record from Danger Cave only begins ~8000 BP, a number of factors suggest this is probably due to a lack of preservation in the earliest deposits and that hunter-gatherers were quite likely using pine nuts from the beginning of the archaeological record at Danger Cave. Primary among these is evidence that early foragers were following a mixed hunting and gathering subsistence strategy, including a focus on the collection and processing of a variety of seed resources such as saltbush (*Atriplex canescens*) and pickleweed seeds (Jennings, 1957; Harper & Alder, 1972; Fry, 1978). As noted above, experiments with the collection and processing of these seeds suggest they have some of the lowest caloric return rates of any tested resource used by prehistoric peoples in the Bonneville Basin, much lower than those associated with pine nut use (Simms, 1987; Barlow & Metcalfe, 1996). Foraging models (e.g., Winterhalder & Smith, 1981; Stephens & Krebs, 1986; Simms, 1987) suggest that if people occupying the region around Danger Cave sometimes ate pickleweed, then they should also have included pine nuts in their diet.

Two dates of 9900 ± 200 (Gak-1900) and 9590 ± 160 (Gak-1896) directly on pickleweed chaff confirm the use of pickleweed by Danger Cave foragers during the earliest period of occupation (Harper & Alder, 1972). To test the assumption that pine nuts would also have been used, we dated dried faecal material containing nut hull fragments reportedly collected from DI, the lowest and earliest of the depositional units excavated in the early 1950s (Jennings, 1957; Fry, 1976, 1978). Unfortunately, the date of 3310 ± 60 (Beta-97899) suggests the faecal material may have come from mixed deposits and is not useful in addressing the question.

Although we remain convinced pine nuts were part of the subsistence base by 10,000 BP direct evidence is not yet in hand (Madsen, 1986). Regardless of how early the use of pine nut began, people living in the Danger Cave region certainly used pine nuts by at least 7500 years ago, as early as our archaeobotanical record allows. They first used limber pine, prior to pinyon becoming locally available. These limber pine nuts were probably not available in the immediate vicinity of Danger Cave, but they may have been available within a few km of the cave in the Silver Island Range, and were certainly available on nearby ranges. When pinyon pine migrated into the region, at the cusp of the Early-to-Middle Holocene transition, people immediately switched to this new crop. Once pinyon pine appears in the Danger Cave record, limber pine nuts drop out completely. We can speculate as to why this should have happened. Firstly, the return rate for pinyon is likely higher than that for limber pine. Although the return rate for the latter has not yet been measured experimentally, the fewer number of nuts per cone, increased hull thickness and smaller nut meat size makes it likely that the return rate for limber pine is lower than that for pinyon (Simms, 1987). In addition, limber pine nuts are more difficult to collect in mass than pinyon: the cones often grow higher in the much taller limber pine trees, the cones tend to persist on these high branches until they open and widely scatter their seeds, and limber pine trees are often themselves scattered thinly on the landscape, rather than as dense forests. By contrast, pinyon cones can be readily knocked off the tree with a long stick, the nut-bearing cones are often more profligate on the tree, and dense stands of the trees are often found in the pygmy woodlands, yielding many more collectable nuts per unit area than the limber pine. Other things being equal, prehistoric hunter-gatherers were more likely to collect and process pinyon nuts when the choice was presented to them. Secondly, other things were not equal because pinyon quickly became more widely distributed than limber pine at lower elevations and was thus available at shorter transport distances. To get to limber pine trees in subalpine areas, the occupants of Danger Cave would have had to travel through the closer pinyon groves.

Summary

(1) The available Danger Cave record strongly suggests that pine nuts have been a foodstuff for a very long time in western North America. Both pine nuts and small seeds such as pickleweed were probably in the diet of Great Basin foragers for at least the last 10,000 years, and certainly for the last 7500 years.

(2) A seamless transition exists from use of limber pine to use of pinyon pine nuts in the eastern Great Basin during the Early-to-Middle Holocene, as pinyon pine migrated into middle elevation mountain settings and limber pine moved up slope to the subalpine zone.

(3) Pine nut fragments in a site do not always imply pine nut use by people. Pine nuts were also eaten by other animals, and may have been brought into the site by non-human foragers. Even owls, who are obligate carnivorous birds, may introduce pine nut hulls or other plant materials into cave deposits. Some morphological criteria exist that can help tease apart the taphonomic vectors involved.

(4) At Danger Cave, situated at least 25 km from the nearest pinyon groves, pine nuts were probably a minor dietary element, as part of provisions brought to the site. Evidence for the logistical transport of large quantities of pine nuts to a Danger Cave base camp from distant groves, of the kind described by Barlow & Metcalfe's plant utility index model, is lacking.

(5) We have not discussed the intensification of pine nut use into an economic staple in some regions. This is a matter of local ecological processes and the options available to the resident societies. Our Danger Cave evidence suggests that pine nuts, be they limber or pinyon, were valued as food throughout the time represented by the available archaeobotanical record. How that value fluctuated through time in the region around Danger Cave is a question yet to be answered.

Acknowledgements

Our thanks to K. R. Barlow, D. K. Grayson, R. Lanner and R. S. Thompson, who have influenced our thinking on these issues over the years and helped provide identifications of specimens. Several of the radiocarbon dates listed in Figure 3 were made available through the kind permission of Chris Mullin. We are also grateful for the constructive comments made by two anonymous reviewers.

References

Aikens, C. M. (1970). Hogup Cave. *University of Utah Anthropological Papers* **93**.

Andrews, P. (1990). *Owls, Caves, and Fossils*. Chicago, IL: University of Chicago Press.

Aschmann, H. H. (1959). The central desert of Baja California: demography and ecology. *Ibero-Americana* **42** Berkeley, CA: University of California Press.

Barlow, K. R. & Metcalfe, D. (1996). Plant utility indices: two Great Basin examples. *Journal of Archaeological Science* **23,** 351–371.

Bettinger, R. L., Malhi, R. & McCarthy, H. (1997). Central place models of acorn and mussel processing. *Journal of Archaeological Science* **24,** 887–900.

Bird, D. W. & Bleige Bird, R. L. (1997). Contemporary shellfish gathering strategies among the Meriam of the Torres Straits Islands, Australia: testing predictions of a central place foraging model. *Journal of Archaeological Science* **24,** 39–63.

Brown, B. A., Whitaker, J. O., French, T. W. & Maser, C. (1986). Notes on food habits of the screech owl and the burrowing owl of southeastern Oregon. *Great Basin Naturalist* **46,** 421–426.

Currey, D. R. (1990). Quaternary paleolakes in the evolution of semidesert basins, with special emphasis on Lake Bonneville and the Great Basin. *Palaeogeography, Palaeoclimatology, Palaeoecology* **76,** 189–214.

Farris, G. (1982). Pine nuts as an aboriginal food source in California and Nevada: some contrasts. *Journal of Ethnobiology* **2,** 114–122.

Fowler, C. S. (1986). Subsistence. In (W. L. d'Azevedo, Ed.) "Great Basin". *Handbook of North American Indians* **11,** 64–97. Washington, DC: Smithsonian Institution Press.

Frison, G. C. (1992). The foothills-mountains and the open plains: the dichotomy in paleoindian subsistence strategies between two ecosystems. In (D. G. Stanford & J. S. Day, Eds) *Ice Age Hunters of the Rockies*. Niwot, CO: Denver Museum of Natural History and University Press of Colorado.

Fry, G. F. (1976). Analysis of prehistoric coprolites from Utah. *University of Utah Anthropological Papers* **97**.

Fry, G. F. (1978). Prehistoric diet at Danger Cave, Utah as determined by the analysis of coprolites. *Miscellaneous Paper 23, University of Utah Anthropological Papers* **99**.

Gleason, R. L. & Craig, T. H. (1979). Food habits of burrowing owls in southeastern Idaho. *Great Basin Naturalist* **39,** 274–276.

Grayson, D. K. (1993). *The Desert's Past: A natural Prehistory of the Great Basin*. Washington, DC: Smithsonian Institution Press.

Harper, K. T. & Alder, G. M. (1972). Paleoclimatic inferences concerning the last 10,000 years from a resampling of Danger Cave, Utah. In (D. D. Fowler, Ed.) "Great Basin Cultural Ecology: A Symposium." *Desert Research Institute Publications in the Social Sciences* **8,** 13–23.

Jennings, J. D. (1957). Danger Cave. *University of Utah Anthropological Papers* **27**.

Jones, K. T. & Madsen, D. B. (1989). Calculating the cost of resource transportation: a Great Basin example. *Current Anthropology* **30,** 529–534.

Kelly, R. L. (1990). Marshes and mobility in the western Great Basin. In (J. C. Janetsky & D. B. Madsen, Eds) "Wetland Adaptations in the Great Basin". *Brigham Young University Museum of Peoples and Cultures Occasional Paper* **1,** 259–276.

Kelly, R. L. (1995). Hunter-gatherer lifeways in the Carson Desert: a context for bioarchaeology. In (C. S. Larsen & R. L. Kelly, Eds) "Bioarchaeology of the Stillwater Marsh: Prehistoric Human Adaptation in the Western Great Basin." *American Museum of Natural History Anthropological Papers*, **77**.

Lanner, R. M. (1981). *The Piñon Pine—A Natural and Cultural History*. Reno, NV: University of Nevada Press.

Lanner, R. M. (1983). The expansion of singleleaf pinyon in the Great Basin. In (D. H. Thomas, Ed.) "The Archaeology of Monitor Valley 2: Gatecliff Shelter." *Anthropological Papers of the American Museum of Natural History* **59,** 169–171.

Lanner, R. M. & Vander Wall, S. B. (1980). Dispersal of limber pine by Clark's Nutcracker. *Journal of Forestry* **78,** 637–639.

Light, A. (1996). Amino acid paleotemperature reconstruction and radiocarbon shoreline chronology of the Lake Bonneville Basin, U.S.A. MA Thesis, Department of Geography, University of Colorado, Boulder.

Madsen, D. B. (1986). Great Basin nuts: a short treatise on the distribution, productivity, and use of pinyon. In (C. Condie & D. D. Fowler, Eds) "Anthropology of the Desert West". *University of Utah Anthropological Papers* **110,** 21–41.

Madsen, D. B. (in prep.). The Silver Island Expedition. University of Utah Anthropological Papers.

Madsen, D. B. & Rhode, D. (1990). Early Holocene pinyon (*Pinus monophylla*) in the northeastern Great Basin. *Quaternary Research* **33,** 94–101.

Marti, C. D. (1974). Feeding ecology of four sympatric owls. *Condor* **76,** 45–61.

McCaughey, W. W., Schmidt, W. C. & Shearer, R. C. (1985). Seed-dispersal characteristics of conifers in the inland mountain west. In (R. C. Shearer, Ed.) Proceedings—Conifer Tree Seed in the Inland Mountain West Symposium. *USDA Forest Service Intermountain Research Station General Technical Report* **INT-203,** 50–62.

Mehringer, P. J., Jr. (1986). Prehistoric environments. In (W. L. d'Azevedo, Ed.) "Great Basin" *Handbook of North American Indians* **11,** 31–50. Washington, DC: Smithsonian Institution Press.

Metcalfe, D. & Barlow, K. R. (1992). A model for exploring the optimal tradeoff between field processing and transport. *American Anthropologist* **94,** 340–356.

Muir, J. (1917). *The Mountains of California*. New York: The Century Company.

Munger, B. (1997). Comparison of the archaeology in three mountain areas of western Montana. Paper delivered at the 3rd Rocky Mountain Anthropology Conference, Bozeman, Montana.

Orians, G. H. & Pearson, N. E. (1979). On the theory of central place foraging. In (D. J. Horn, G. R. Stairs & R. D. Mitchel, Eds) *Analysis of Ecological Systems*. Columbus: Ohio State University, pp. 155–177

Oviatt, C. G., Currey, D. R. & Sack, D. (1992). Radiocarbon chronology of Lake Bonneville, eastern Great Basin. *Palaeogeography, Palaeoclimatology, Palaeoecology* **99,** 225–244.

Pennington, C. W. (1969). *The Tepehuan of Chihuahua: Their Material Culture*. Salt Lake City: University of Utah Press.

Plumpton, D. L. & Lutz, R. S. (1993). Prey selection and food habits of burrowing owls in Colorado. *Great Basin Naturalist* **53,** 299–304.

Rhode, D. (n.d.). Paleoecological investigations in the Cherry Creek Range, Nevada: progress report on woodrat middens from Cottonwood Canyon. Report prepared for Bureau of Land Management, Elko District, Nevada.

Rhode, D. (1990). On transportation costs of Great Basin resources: an assessment of the Jones-Madsen Model. *Current Anthropology* **31,** 413–419.

Rhode, D. & Madsen, D. B. (1995). Late Wisconsin/Early Holocene vegetation in the Bonneville Basin. *Quaternary Research* **44,** 246–260.

Ross, A. (1969). Ecological aspects of the food habits of insectivorous screech-owls. *Proceedings of the Western Foundation of Vertebrate Zoology* **1,** 301–344.

Schmitt, D. N. (in prep.). Faunal accumulations and animal foraging behavior in the Lakeside Mountains. In (D. B. Madsen, D. K. Grayson & D. Rhode, Eds) *Late Quaternary Paleoecology in the Bonneville Basin*. Utah Geological Survey Bulletin.

Simms, S. R. (1987). *Behavioral Ecology and Hunter-Gatherer Foraging: An Example from the Great Basin*. Oxford: BAR International Series **381**.

Smith, E. R. (1942). Early Man in the Great Salt Lake Area. *Mineralogical Society of Utah* **3,** 27–32.

Stephens, D. W. & Krebs, J. R. (1986). *Foraging Theory*. Princeton, NJ: Princeton University Press.

Steward, J. H. (1938). Basin-Plateau Aboriginal sociopolitical groups. *Bureau of American Ethnology Bulletin* Washington, DC **120**.

Steward, J. H. (1941). Cultural element distributions, XIII: Nevada Shoshoni. *University of California Anthropological Records* **4,** 209–259.

Stewart, O. C. (1941). Cultural element distributions, XIV: Northern Paiute. *University of California Anthropological Records* **4,** 361–446.

Thomas, D. H. (1973). An empirical test for Steward's Model of Great Basin settlement patterns. *American Antiquity* **38,** 155–176.

Thomas, D. H. (1983). The Archaeology of Monitor Valley, 1: Epistemology. *American Museum of Natural History Anthropological Papers* New York **58**.

Tomback, D. F. (1983). Nutcrackers and pines: the coevolution of coadaptation. In (M. Nitecki, Ed.) *Coevolution*. Chicago, IL: University of Chicago Press.

Thompson, R. S. (1990). Late Quaternary vegetation and climate in the Great Basin. In (J. L. Betancourt, T. R. Van Devender & P. S. Martin, Eds) *Packrat Middens: The Last 40,000 Years of Biotic Change* Tucson, AZ: University of Arizona Press, pp. 200–239.

Vander Wall, S. B. & Balda, R. P. (1977). Coadaptations of the Clark's nutcracker and the piñon pine for efficient seed harvest and dispersal. *Ecological Monographs* **47,** 89–111.

Wells, P. V. (1983). Paleogeography of montane islands in the Great Basin since the last glaciopluvial. *Ecological Monographs* **53,** 341–382.

Winterhalder, B. & Smith, E. A. (1981). *Hunter-Gatherer Foraging Strategies: Ethnographic and Archaeological Analyses*. Chicago, IL: University of Chicago Press.