

MODELING MODES OF HUNTER-GATHERER FOOD STORAGE

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Analyses of the capacity and rates of different acorn storage techniques employed by the Western Mono of California's Sierra Nevada during the very late Holocene indicate hunter-gatherers store food in at least three main modes: central-place storage, dispersed caching, and dispersed bulk caching. The advantage of caching modes over central-place ones is that they entail faster storage rates and thus the chance to maximize storage capacity when seasonality and scheduling conflicts limit storing opportunities. They also result in predictable stores of acorn separate from winter population aggregations but oftentimes near seasonally occupied camps. Central-place storage thus appears most directly related to coping with single-year seasonal variability in environmental productivity and sedentary overwintering strategies; caching, and especially bulk caching, with multi-year environmental unpredictability, overwintering and seasonal residential moves. Storage thus appears to generally develop as a response to seasonality and unpredictable environmental productivity, but its various forms are conditioned mainly by how they articulate with different mobility types. Complex Mono storage behaviors, however, were associated with regionally low population densities and relatively uncomplicated social structures nonetheless characterized by chiefs who maintained their positions by throwing feasts of stored acorn. The connections between storage, population density, and sociocultural complexity thus appear less direct and predicated on specific sociopolitical circumstance. Recognizing different modes of hunter-gatherer storage is consequently critical to assessing the roles ecology, mobility, group size, and social distinctions play in the development of disparate storage behaviors.

Un análisis de la capacidad e índices de las técnicas de amontonar bellotas empleados por el pueblo Mono del oeste de la Sierra Nevada de California durante el bajo Holoceno indica que cazadores-recolectores amontan la comida en por lo menos tres maneras: almacenaje en lugares centrales, la acumulación en lugares dispersados y la acumulación dispersado pero en bulto. La ventaja de estos modos de acumulación sobre el simple almacenaje es que producen índices más rápidos de amontonamiento y por tanto la oportunidad de maximizar la capacidad de almacenar cuando conflictos de variación estacional y conflictos en el horario de actividades limitan las oportunidades de amontonar. Estos modos de acumulación resultan también en provisiones previstas de bellotas que son alejados de las agrupaciones de la población invernal mientras que son muchas veces más cerca a los campamentos ocupados temporalmente por estaciones específicas. El almacenaje en lugares centrales aparece más directamente relacionado a solucionar el problema de la variabilidad estacional de la producción ecológica que ocurre en un solo año tanto como estrategias sedentarias para pasar el invierno mientras el amontonamiento, y especialmente el amontonar en bulto corresponde a unas imprevisibilidades ecológicas multianuales, tanto como el hecho de pasar el invierno y los movimientos residenciales estacionales. Parece que el amontonamiento dentro del pueblo Mono se encuentra generalmente como respuesta a cambios estacionales y a una productividad ecológica imprevista, pero sus varias formas son mayormente condicionadas de acuerdo a su articulación con tipos de movilidad que son diferentes. Su conexión a la densidad poblacional y la complejidad sociocultural, sin embargo, parece desarrollar de manera empírica, predicado de acuerdo a las circunstancias específicas sociopolíticas e históricas en que se encuentre el grupo. Es crítica, por consecuencia, reconocer los modos diferentes de amontonamiento practicados por los cazadores-recolectores para poder evaluar los papeles jugados por la ecología, la movilidad, el tamaño del grupo, y las distinciones sociales en la evolución y el desarrollo histórico de los comportamientos distintos de amontonamiento.

Despite over three decades of modern thinking about the economics of hunter-gatherer food storage, this critical component of many foraging economies and important factor in the evolution of complex social systems remains poorly understood, leading Kuijt

(2009:641) to recently lament that “archaeologists have yet to develop a detailed understanding of the scale of economic contributions of food storage in preagriculturalist communities.” This problem is an important one, arguably beginning alongside Woodburn’s (1980) modeling of de-

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layed-return hunter-gatherer economies and the conceptualization of “complex” hunter-gatherers in the late 1970s and 1980s (Price and Brown 1985). Within this context, some saw environmental characteristics, especially abundance, predictability, and seasonality eliciting the development of “complex” hunter-gatherer storage behaviors (Binford 1980; Colson 1979; Jochim 1979). Others debated the role storage played in the development of sedentism, population aggregations (Keeley 1988; Testart 1982), and the evolution of agriculture and more complex social orders (Bender 1978, 1981). Storage was thus implicated as essential to coping with environmental variability on the one hand and with the development of sedentism, agriculture, and social inequality on the other, although the causal linkages between storage and these fundamental evolutionary shifts resulted in considerable debate (Ingold 1982).

To a large degree, these debates are unresolved. What is overlooked, however, is that there is considerable variability in hunter-gatherer food storage over time, space, and even within the contexts of individual hunter-gatherer societies who store. From this perspective, I might add a caveat to Kuijt’s lament: that archaeologists have only minimally assessed in quantitative ways the causes and effects of food storage variability and how these might play out in evolutionary-ecological context. This situation results in part from the lack of large, contemporaneous samples of hunter-gatherer storage features but also from a focus on polemics and theory (Ingold 1983; Testart 1982), techno-environmental modeling (Binford 1990), and functional analyses (Kent 1999). Combined, these have constrained the types of real-world microeconomic studies that might elucidate meaningful relationships between different hunter-gatherer storage strategies and population size, sociocultural complexity, mobility, and environmental characteristics—the variables guiding the majority of modern thinking about hunter-gatherer storage.

To remedy this situation, this paper presents an analysis of Western Mono storage behaviors in California’s Sierra Nevada. Prehistorically and ethnographically, the Mono were prodigious storers, stockpiling mainly acorn in various facilities throughout their range. Hundreds of these fea-

tures, particularly rock ring cache foundations, are preserved *in situ* and offer the opportunity to estimate storage capacity relative to population size and assess the costs and benefits of using different types of storage techniques. These analyses shed light on how at least one hunter-gatherer group’s storage behaviors related to environmental productivity and variability, population size, different types of mobility, and ultimately, attributes of sociocultural complexity. This research indicates that there are at least two main modes of hunter-gatherer food storage, *caching* and *central-place storage*, the former referring to expedient, dispersed modes, the latter to residential ones. A third mode, *bulk caching*, refers to stockpiling high-volume, yearly or multiyear stores in dispersed locations. Based on how these behaviors articulate with environmental and social characteristics, it appears storage variability is directly associated with variation in environmental productivity and mobility, but less so with population density and attributes of sociocultural complexity. Recognizing this variability, much like the recognition of hunter-gatherer adaptive variability in the early 1980s, provides a way of moving beyond the cycle of polemical arguments on the evolutionary relationship of storage to sedentism, complexity, and the like, ultimately suggesting at least one way of contextualizing both the qualitative and quantitative relationships of storage to larger themes in cultural evolution.

Types of Hunter-Gatherer Food Storage

Hunter-gatherers store food in a many ways. Generalizations vary, but tend to agree that foragers engage in three main types: technological (actually storing food in facilities), biological (storing energy as fat within one’s body), and social (effecting storage either through exchange or redistribution) (Brenton 1988; Ingold 1983; O’Shea 1981). This paper focuses specifically on technological storage and its affiliated behaviors.

Storage technologies and associated behaviors (e.g., drying or smoking) were used mainly to prevent spoilage, reduce vermin infestation, and prevent theft by animals or other people (Dunn 1995). It is clear hunter-gatherers accomplished these tasks in a variety of expedient ways: in cracks or crevices in rock outcrops or rockshelters (Swenson

1984), in the crooks of trees (Bates 1983), and, particularly on the Northwest Coast, in the rafters of houses (Ames and Maschner 1999:141). More labor-intensive techniques (see Brenton 1988; O'Shea 1981; Perlman 1980; and Torrence 2001 for discussions on storage-related labor) involved excavating and filling pits and cysts, oftentimes beneath house floors (Ames et al. 2008), building a variety of granaries (on stilts, in the crooks of trees, on cliff ledges, etc.) (Barlow et al. 2008), assembling cairns and lining basins with slabs (Wilke and McDonald 1989), and using pots, wooden boxes, woven or skin bags or other devices as portable storage facilities (Ames and Maschner 1999:93–94, 252; Eerkens 2003; Fritz 1997).

Most of the literature on food storage, however, does not differentiate between dispersed versus central-place strategies and most theoretical work tends to equate storage with facilities in central-place residences (Gladkih et al. 1984; cf. Binford 1990). There are, of course, several examples of dispersed hunter-gatherer food storage, most conspicuously arctic and subarctic meat caches (Stopp 2002), but also the lava tube meat caches on the Snake River Plain (Henrikson 2003; cf. Plew 2005), dispersed nut caches in Jomon Period Japan (Sakaguchi 2009), isolated seed caches on Australia's north coast (Meehan 1980), and various seed caches in the deserts of California, the Southwest, and Great Basin (Bettinger 1989; Swenson 1984; Wilke et al. 1977). Because of the conflation of residential storage with dispersed caching, however, most researchers do not differentiate between central-place storage and caching, oftentimes using the terms interchangeably (Binford 1990:145; DeBoer 1988; Gerber et al. 2004; Plew 2003).

Further, discovering and accurately identifying storage facilities has proven difficult (Burse 2001; Kent 1999; Plew 2003; cf. DeBoer 1988). Occasionally individual seed caches (Bean and Saubel 1972; Schulz and Johnson 1980), ollas (Swenson 1984), granaries (Barlow et al. 2008), or pits (McNulty 2000; Smith 2003) are found. These sometimes contain stored foods, though archaeologically identified stored foodstuffs are more often associated with early agricultural adaptations (Fritz 1997; Fuller et al. 2009; Gremillion 2004). In any event, the likelihood that stored food items will be found in archaeo-

logical features is low, partly due to taphonomic issues, but mainly because a storer's intent is to re-access and eat stored food (Bettinger 1999a). As DeBoer (1988:4) writes, "an archaeological pit chock-full of nuts or maize is a monument to failed intentions." Because of this, many have tried to distinguish, mainly through quantitative measures or ethnographic analogy, storage features from other archaeological signatures, especially refuse areas or trash pits (Bettinger 1989; Bursey 2001; Eerkens 2003; Kent 1999; Smith and McNees 1999). These efforts have met with variable success.

When storage features are successfully identified, it is rare to see quantitative assessments of their capacity. Plenty of theoretical modeling of delayed-return systems has been undertaken (Bettinger 2009:47–57; Gerber et al. 2004; Tucker 2006; Woodburn 1980). But these are mostly abstract and rarely employ data from actual facilities. In only a few cases have storage capacities been estimated from actual facilities, in the Pacific Northwest (Ames et al. 2008), in Jomon Period Japan (Sakaguchi 2009), and in northeastern North America (MacDonald 1987). These data have been used, in part, to assess contributions of stored food to sustaining hypothetical populations, a tactic likewise employed in this study. In addition to capacity, the current study also assesses the relationship of storage to environmental characteristics, mobility, and ultimately attributes of sociocultural complexity.

The Ecology and Evolution of Food Storage

Food storage is critical to human behavioral evolution. It has variously been seen as a precursor to agriculture (Bender 1978); an indicator of sociocultural complexity (Price and Brown 1985); intrinsically associated with sedentism (Testart 1982); an important step in conceptualizing private property (Bettinger 1999b); a means of social control (Wesson 1999); a form of shared knowledge (Hendon 2000); and as motivation for the development of numerical counting (Divale 1999). More generally, storage is most often seen in three contexts: as a means of coping with environmental variability, as a behavior operating within the context of settlement and subsistence systems, and as a marker of sociocultural complexity.

The relationship between environmental variability and storage has long been noted and hinges on two main ideas, that storage is (1) a delayed-return economic system developed to average seasonal variability in environmental productivity; and (2) an insurance mechanism used to cope with the risks of relying on natural resources when environmental productivity is variable. These ideas are of course not exclusive and there is considerable borrowing between the two.

The former perspective bluntly asserts that seasonality predicates storage. Binford (1990: 140–142) makes this clear when he writes, “I view storage as a response to environmental conditions” and that it is an “overwintering” tactic. From Binford’s (1980, 2001) perspective, foragers with sufficient population density (a function partly of environmental productivity) who live in seasonal, mid-latitude settings take resources in bulk during productive months in the spring, summer, and fall and rely upon these stores during the winter (see also Bailey 1981; Jochim 1981:176; Testart 1982). This is a delayed-return system because the benefit of storage is not garnered until well after labor is invested in obtaining and preparing items for storage and building and filling storage facilities (Woodburn 1980). This thinking has been used to explain the development of storage in Mesolithic Europe (Jochim 1979), the American Southwest (Gilman 1987) and, using Binford’s various iterations of his seasonality argument (1980, 1990, 2001), anywhere hunter-gatherers store in middle latitudes.

A related idea has storage developing not necessarily as a response to seasonality per se, but as a response to variability in environmental productivity more generally. Risk-sensitivity models derived from these ideas see storage decision making taking into account the range of variability about mean expected rewards for different storage decisions (Goland 1991; Winterhalder et al. 1999). Put simply, the greater the variability surrounding average returns, the less chance there is of attaining the mean return for any given resource. This of course can have either negative or positive consequences: coming out ahead of the average could certainly entail greater rewards. In any event, variability in average rewards produces uncertainty for decision makers, particularly when predicated on high spatial or temporal

unevenness in resource productivity or because of missing or incomplete information (Low 1990). This has led many researchers to see storage as a strategy to ensure minimum subsistence targets are met, both as a way of reducing risk and as a way of coping with unpredictability (Binford 1979; Cashdan 1983; Dunn 1995; Forbes and Foxhall 1995; Weissner 1982). Several researchers, however, also note that storage presupposes its own risks due to the problem of future discounting, or the potential for rewards associated with stored foods to have lower-than-expected returns due to rot, spoilage, or altered resource-population dynamics (Brenton 1988; Hawkes 1992; Tucker 2006).

Storage also generates additional risk because it entails an affiliated opportunity cost: it limits mobility, one of the principal means hunter-gatherers employ to cope with scarcity (cf. DeBoer 1988). Due to this, many argue that storage tethers populations to storage locales, keeping them from solving resource acquisition problems via the simplest approach, by mapping on to resources. In this light, storage causes sedentism (Rafferty 1985; Yoder 2005). Testart (1982:524) argues this most directly by stating, “storage brings sedentism and sedentism presupposes storage.” Similarly, Rowley-Conwy and Zvelebil (1989:47) argue that mobility and storage are “to a large extent ... mutually incompatible.” The causal relationship between sedentism and food storage, however, is debated, with some arguing that storage precedes and is a cause of sedentism (Flannery 1972; Pearson 2006) while others (Eerkens 2003; Smith 2001) argue that sedentism arose first, with storage a byproduct of decreased mobility.

Conversely, many have argued against linking sedentism with storage. Ingold (1983:560) was among the first to question Testart, arguing “that storage, even on a substantial scale, is by no means incompatible with nomadic movement” (see also Ingold 1982, 1987). Several lines of research substantiate Ingold’s claim (Chatters 1995; Stopp 2002). For instance, Soffer (1985, 1989) argues that Upper Paleolithic storage capacity on the Central Russian Plain increased twofold over the course of the Last Glacial Maximum while seasonal mobility remained high, concluding that “the connection between storage and sedentism is

neither ethnographically nor historically synonymous" (Soffer 1989:722). Many mobile storers, however, apparently had set seasonal rounds where the likelihood of encountering previously cached items was either high or planned. These behaviors have been interpreted as insurance strategies used to reduce risk associated with seasonal transhumance (Morgan 2008; Smith 2003).

Similar controversies surround debates about the relationship of storage to the emergence of greater population densities and increasingly complex forms of social organization. Despite its problematic linkage with logistical mobility and sedentism, food storage has become defined as either a marker or essential component of more complex societies, hunter-gatherer or otherwise (Arnold 1996; Bettinger 1991; Hayden 1981; Kuijt and Prentiss 2004; Price and Brown 1985). Within this vein, it is thought by many that storage either developed to cope with increasing population densities (Ames and Maschner 1999:127-128, 154; Keeley 1988) or that the transition to surplus-based strategies fostered the growth of storing populations (Croes and Hackenberger 1988; Matson 1992). In any event, food storage appears related in many cases to sustaining the population densities characterizing most complex social orders.

Much thinking about storage and complexity, however, also considers the way storing leads to differential access to surplus and social inequalities (Bender 1978, 1981; Fried 1967; Testart 1988). Holly (1998) argues this occurs by one of two pathways: "Rousseauian," where surplus production is entrusted to leaders for redistribution, and "Marxist," where opportunistic leaders control production and redistribution for their own benefit. Most researchers studying storage and complexity tend toward the latter pathway, for instance among the Chumash of coastal Southern California (Arnold 1992), in the American Southeast (Wesson 1999), along the coast of Peru (Pozorski and Pozorski 1991), to some degree along the Northwest Coast (Ames 1981; Ames and Maschner 1999:175), and in pre-agricultural (Natufian) societies in the Near East (Hayden 2009). Confounding such interpretations is evidence pointing to temporal discontinuities between the inception of food storage and socio-cultural complexity, for example along the

Northwest Coast (Cannon and Yang 2006) and in the ancient Near East, where storage facilities in pre-agricultural societies are rare (Bar-Yosef 1998; Kuijt 2008).

An explanation for these disjunctions is that storage may entail fundamental alterations, not only of technology and ecological relationships, but also of social constraints. Among many hunter-gatherer ethnographic populations, sharing or "tolerated theft" (Blurton Jones 1987) is the norm (Hawkes 1992; Hegmon 1991). Storage would thus arguably require developing the idea of food as private property, which allows storers to benefit from "selfish" behavior (Bettinger 2006; cf. Ingold 1983:562). Though contentious, this argument is supported by evidence from several sources, in particular the shift of food preparation and storage indoors among Central African ethnographic populations (Colson 1979) and among archaeological ones along the Northwest Coast (Ames et al. 2008). Similar patterns are arguably seen in the Puebloan Southwest (Gilman 1987), among the seasonally mobile hunter-gatherers of mid-Holocene Wyoming (Smith 2003), and with the prehistoric agriculturalists of eastern North America (DeBoer 1988, although DeBoer argues these facilities were made to protect against theft). The underlying constraint on the development of storage is thus argued to be neither technological nor environmental but instead social, with changes required of behavioral norms to elicit what is in most cases a rather intuitive technology (Brenton 1988; Testart 1982, 1988).

In summary, food storage most likely developed to cope with variability in environmental productivity, seasonal or otherwise, but may or may not be linked to increased sedentism, larger populations, and the evolution of complex social orders. As demonstrated in the rest of this paper, the role storage played in the evolution of these phenomena is explained more precisely by recognizing and quantifying variability in different hunter-gatherer food storage behaviors.

Ethnographic, Environmental and Archaeological Context of Mono Storage

Storage variability is clearly expressed in the ethnography and archaeology of the Mono, a hunter-gatherer group from the western slopes of

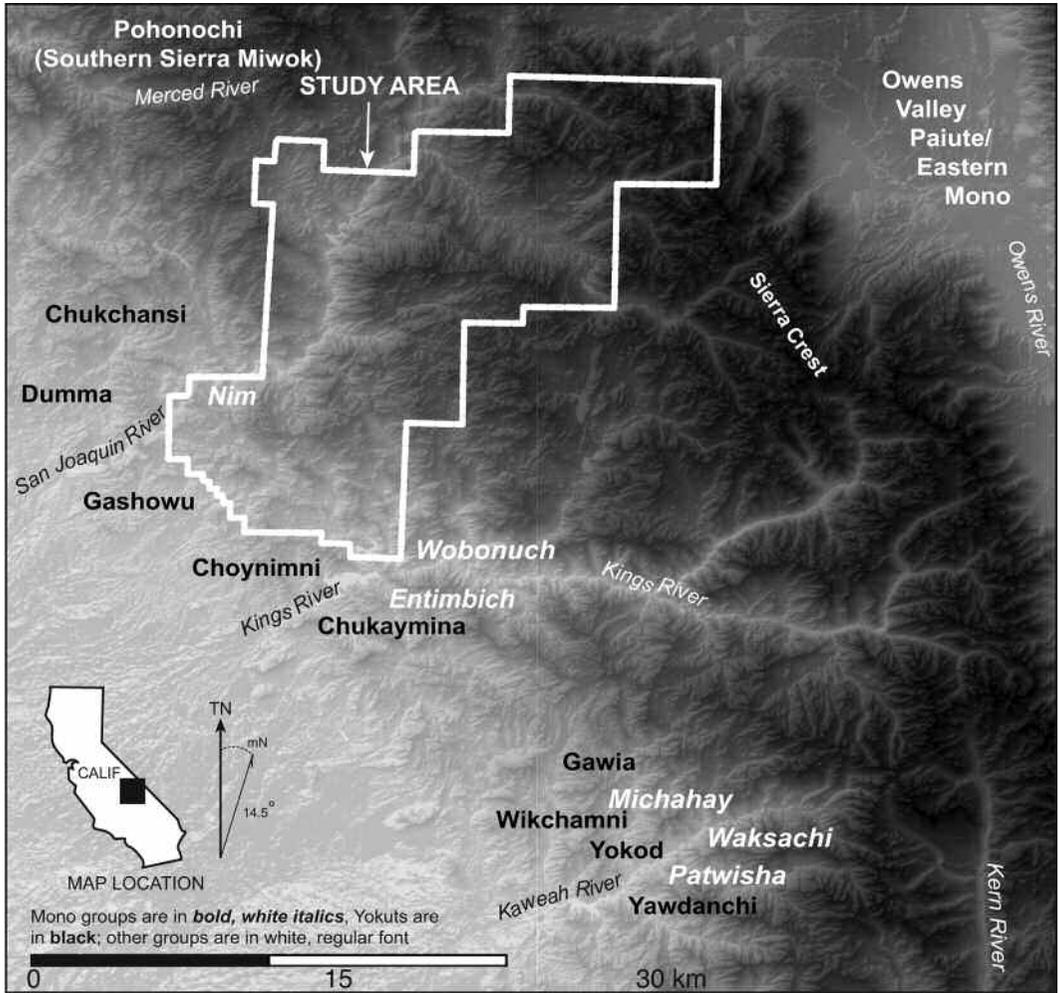


Figure 1. Map showing study area and distribution of ethnographic groups.

California's Sierra Nevada. The Mono, many of whom still live in the area, historically occupied a territory extending from the San Joaquin River watershed in the north to the Kaweah River in the south, and from the foothills (elevation ~500 m) overlooking California's Central Valley to the higher passes of the Sierra Nevada (elevation ~3300 m) (Spier 1978) (Figure 1). Like that of most indigenous central California groups, Mono diet was diverse, but based mainly on the California triumvirate (Baumhoff 1963): acorn, deer, and salmon, with women gathering, processing, and storing especially black oak (*Quercus kelloggii*) acorn in the fall (Jackson 1991; Merriam 1955). Although from California, the Mono connection to Great Basin groups was and remains

strong, speaking as they do a variant of the Numic languages of Owens Valley to the east and throughout the Great Basin more generally (Lamb 1958; Miller 1986). Several lines of evidence (especially linguistic ones) point to their recent (i.e., in the last 500 years or so) migration west into California (Kroeber 1959; Lamb 1958; Morgan 2010; cf. Jackson 1989), including their seasonal transhumance pattern, which resembled the fission/fusion pattern Steward (1938) described for western Great Basin Shoshone and Paiute groups (Morgan 2009a).

Mono groups aggregated in politically autonomous hamlets, sometimes referred to as *home places* or *settlement areas* (Lee 1998; Morgan 2006), in winter and dispersed to exploit eleva-

tionally distinct Sierran resources in spring, summer, and fall (Gifford 1932:17; Hindes 1959, 1962). Winter hamlets, on terraces on or near major river courses just below winter snowline, were by no means large: populations varied from 1 to 39 people, with a mean of about 13 per hamlet (Gayton 1948). Like Owens Valley groups, Mono social structure and economic decision making was mainly household based. These were typically comprised of a married couple, their children, and a few extended family members, particularly consanguines of the woman's family (Gifford 1932). Beyond the household, lineages and in some cases moieties structured Mono society (Kroeber 1925). Patrilineally inherited totems and offices, including chief and messenger, completed the supra-familial social organization of some Mono groups. Importantly, McCarthy (1993) convincingly argues chiefs gained and maintained power by throwing feasts based on the appropriation of the considerable amount of women's labor associated with producing acorn meal.

The environment the Mono occupied was ripe for the development of storage, characterized by pronounced variability in resource productivity on both spatial and temporal scales (its effective temperature [ET] of 14.59 falls just below Binford's general storage threshold of 15.25 [Binford 2001:63, 260]). Spatially, the resources the Mono exploited were distributed in three main biotic zones, with fish, grass seeds, deer (*Odocoileus hemionus*), pine nuts (*Pinus sabiniana*) and acorn in the *foothills* below 900 m and resources like deer, black oak acorn and sugar pine (*Pinus lambertiana*) nut in the *montane forest* between 900 and 2,700 m. *Subalpine* and *alpine* areas above 2,700 m were resource-poor, although they provided some items like mountain sheep (*Ovis canadensis*).

Temporally, resource productivity varied mainly by season, with acorn masting in the fall, anadromous fish running the larger rivers in the spring and fall, and high-elevation resources like mountain sheep accessible mainly in the summer. Resource productivity was also notably affected by the paleoclimatic variability of the last 650 years or so, the period of time when the Mono most likely came to occupy the region. Generally cooler and wetter Little Ice Age conditions interspersed by a series of intensive, long-term

droughts likely resulted in more pronounced variability of resource productivity, both in frequency and amplitude, for key nut-bearing trees like black oak (Graumlich 1993; Koenig and Knops 2005; McKone et al. 1998; Morgan 2009a).

The Mono coped with this variability via a combination of mobility and food storage. These behaviors were reconstructed in an archaeological study of a roughly 30-x-30-km area in the San Joaquin River watershed (Figure 1). This study resulted in a 30 percent sample of the surface archaeology of the area, equally distributed within each of its three main biotic zones (Morgan 2006). The sample encompassed a cross-section of the entire range exploited by the N^{im}, the northernmost Mono group, and was developed to reconstruct the entirety of the N^{im} settlement pattern, with temporal and cultural affiliation controlled by radiocarbon assay, obsidian hydration, projectile point typologies, and more distinctive markers of Mono ethnicity like brownware pottery. This resulted in a sample of 419 sites representing principal and subsidiary residential areas, temporary camps and retooling stations, and processing stations. Importantly, seasonal population fission and fusion is indicated by a dispersal of late prehistoric, Mono residential sites above the winter snowline and a clustering of large processing and residential sites into 11 main winter settlement areas corresponding to principal ethnographic hamlet locations below the snowline (Morgan 2009a) (Figure 2).

Mono storage is recorded by ethnographies as occurring both within and outside hamlets, and by a sample of 340 dispersed rock ring acorn cache foundations. Ethnographies indicate the Mono stored acorn in camps and hamlets within roofed or thatched granaries built on platforms, in the crooks of trees, set on posts, on bare ground, or on bedrock outcrop (Aginsky 1943; Driver 1937; Gayton 1948; Gifford 1932) (Figure 3). Dispersed rock rings typically measure between one and two meters in external diameter and are made of stacked, local rock, usually granite cobbles and small boulders. They are found almost exclusively on large granite outcrops with southern exposures conducive to drying acorn prior to storage (Morgan 2009b) (Figure 4).

No identified rock rings retained positively identified prehistoric acorn (when acorn was pre-

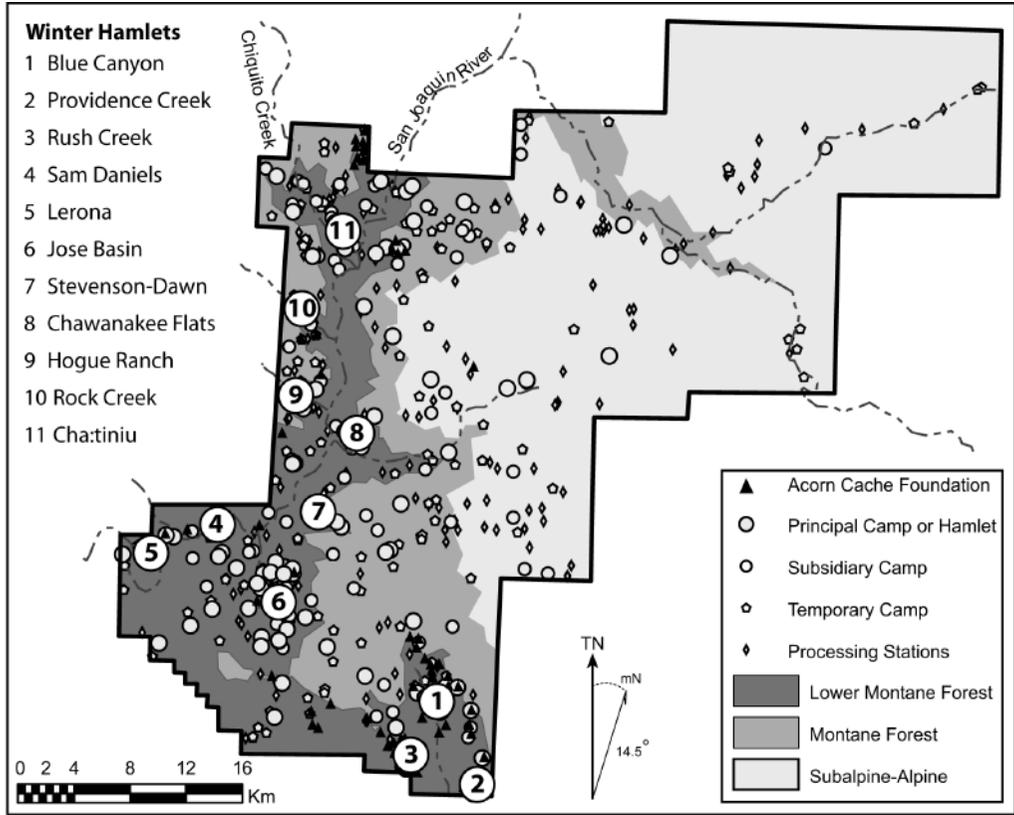


Figure 2. Map showing the distribution of Mono sites, winter settlements and acorn cache foundations.

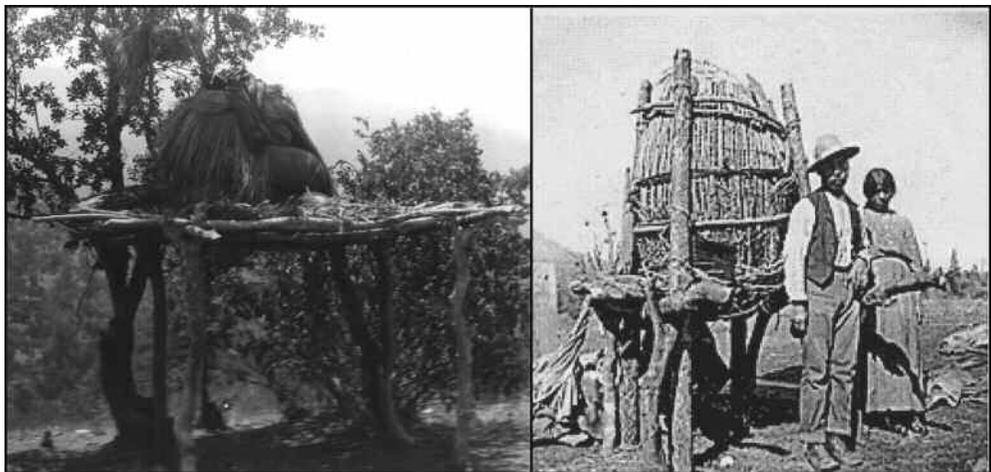


Figure 3. Historical photographs of different types of Mono acorn storage facilities. Left: a platform granary in the Nim village of Peakiyutie. Right: a pan-Sierran style acorn granary (all photos courtesy Sierra National Forest archives).

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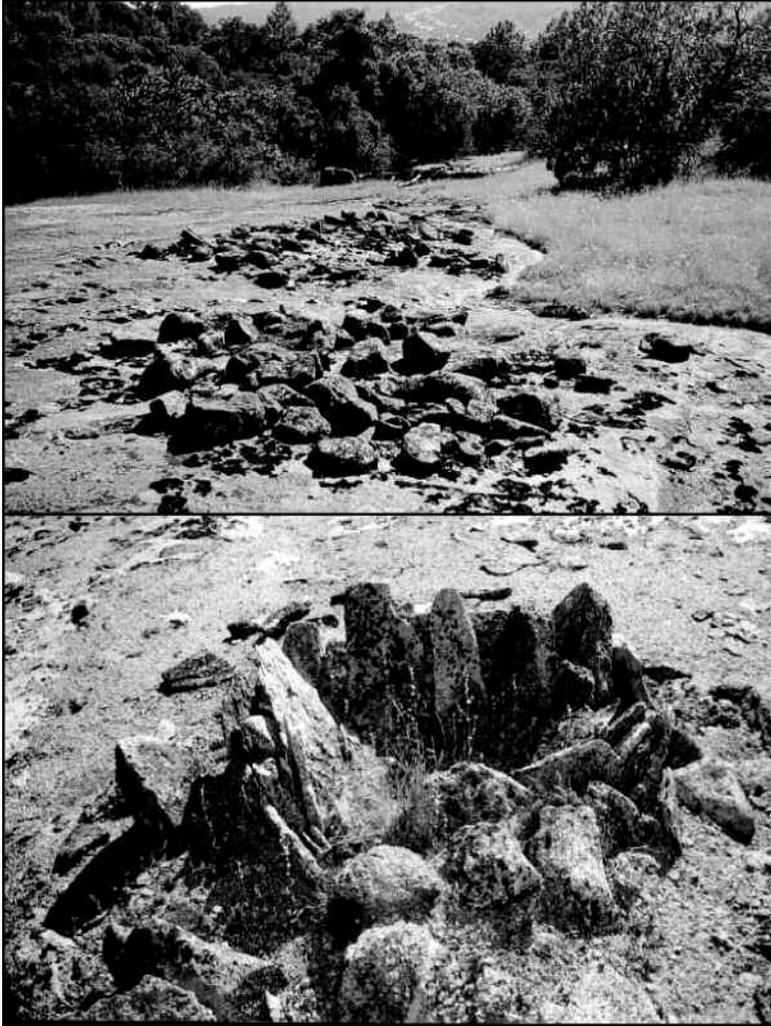


Figure 4. Photographs of rock ring acorn cache foundations on granite bedrock outcrops. **Top:** three rock rings between hamlets in Jose Basin and Stevenson-Dawn. **Bottom:** well-preserved foundation showing upright slab near the hamlet of Stevenson-Dawn (photos by C. Morgan).

sent in rings, it could easily have come from nearby trees). Their function as acorn caches, however, is supported by historical and ethnographic descriptions of rock rings on granite outcrops (referred to as “storage bins” or more typically, “granaries on bedrock or stone foundation”) that served as foundations for cylindrical twined mat superstructures filled with acorn (Aginsky 1943:402; Driver 1937:65; Fresno Bee 1936; Gayton 1948:146; Gifford 1932:20–21) (Figure 5). Further, they resemble caches used by related Great Basin groups for piñon (*Pinus monophylla*) nut (Bettinger 1989) and even more critically, are distributed only within the territory Kroeber

(1925) and others associate with the Mono. They are consequently perhaps the clearest marker of Mono ethnicity.

The distribution of rings is particularly interesting when looked at relative to winter hamlets, camps above average winter snowline, and other large Mono campsites. Roughly two-thirds of these features are distributed in five-km catchments around, but almost never within winter hamlets, a distribution found to optimize foraging time when working from winter hamlets. The remaining third of the rings are above average winter snowline, more than five km from winter settlements, but almost always less than two km



Figure 5. Historical photograph of Mono acorn caches dated December 1, 1936. Note rock ring foundations and ellipsoidal cone shape of cache superstructures (photo courtesy Fresno County Public Library).

from large Mono residential campsites used after winter snows retreated. These data have been interpreted as facilitating early spring mobility by reducing risks associated with early spring moves into the high country (Morgan 2008, 2009b). Mono caching was thus critical for not only sustaining relatively sedentary winter populations, but also for insuring the success of Mono seasonal residential moves (Figure 6).

Quantitative Analyses

The following analyses seek to understand related questions about Mono storage behaviors, particularly how they worked relative to hamlet population densities and why Mono groups might choose a more mobile strategy, caching, over an ostensibly more sedentary one, central-place storage.

Storage Capacity and Population. This analysis measures caching capacity relative to estimated late prehistoric/ethnographic populations. It is predicated on the bias that understanding how hunter-gatherers meet subsistence goals in variable environmental conditions is informed by taking into account risk and uncertainty. A basic assumption here is that humans have a minimum daily nutritional requirement to subsist and reproduce (Winterhalder et al. 1999). If this minimum is not met, they face starvation or failure to reproduce, with associated evolutionary conse-

quences obviously quite dire. As described previously, Little Ice Age climatic conditions resulted in a particularly variable and uncertain resource base for Mono decision makers at the time they came to occupy the Sierra Nevada. If the Mono behaved in a risky manner, they would store only enough acorn to sustain themselves through a typical winter (i.e., about four months) and neglect to plan for longer periods of resource depression. Doing so, they opt not to invest the extra time and labor required to increase storage capacity, betting instead that future productivity will meet or even exceed demand. This bet obviates the costs of building and filling more caches, a strategy that conceivably increases returns on other pursuits like hunting. Conversely, if the Mono were risk averse, they would store more acorn than needed to make it through a typical winter. Here, they opt to spend the extra time to construct and fill enough caches to exceed the yearly storage capacity requirement of their hamlet. Because acorn masting tends to result in two or three lean years following bumper yields, additional storage capacity should arguably be somewhere near two to three times this capacity (Gardner 1997). Determining whether Mono behaviors were risk seeking or risk averse thus requires a reasonable estimate of the amount of stored food required by a typical hamlet and

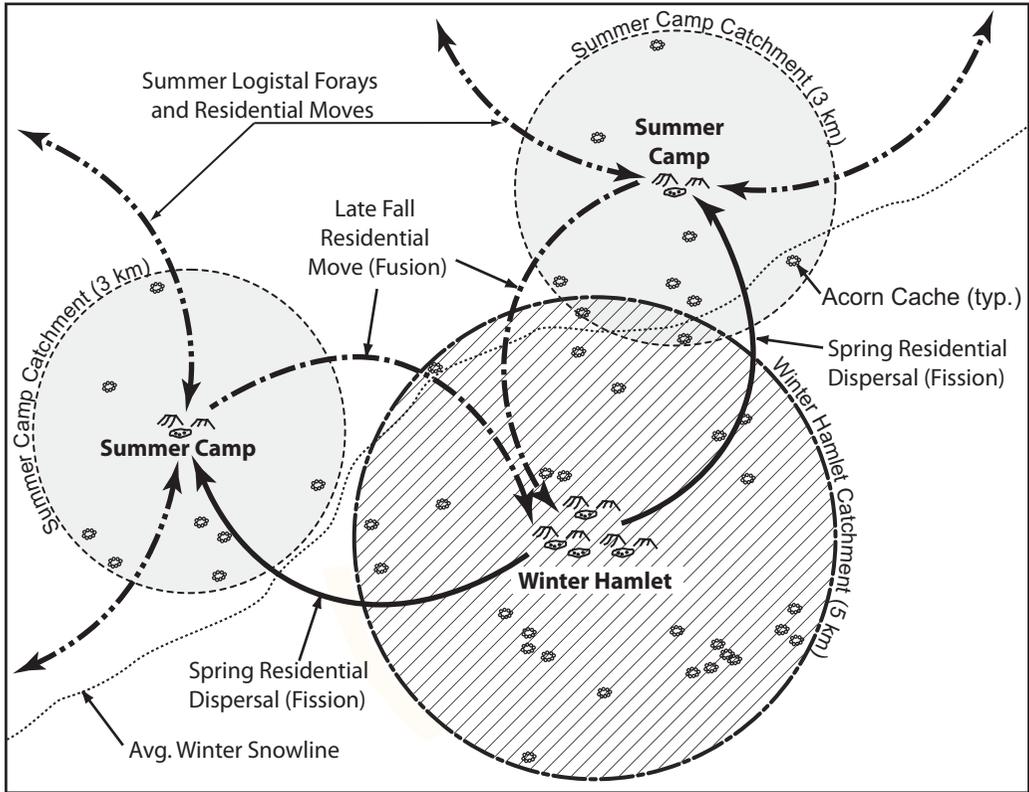


Figure 6. Idealized depiction of Nim settlement and mobility strategies by season.

comparison of these data to an estimate of the actual storage capacity of caches associated with hamlets.

Hunter-gatherer caloric requirements vary by age, sex, health, and other factors and consequently are difficult to quantify. For hunter-gatherers, Speth and Spielmann (1983) argue that caloric requirements range from 1,606 calories per day (cal/day) for women to 1,920 cal/day for men, averaging about 1,763 cal/day. Data on actual hunter-gatherer caloric consumption, however, range from 1,800–3,827 cal/day, with a mean of 2,440 cal/day (Kelly 1995:102). At 2,440 cal/day, 13 people in a Mono hamlet subsisting on nothing but stored acorn¹ for four months would require 3,806,400 cal to make it through the winter, assuming all inhabitants were adults. Unhulled acorn (the way acorns were typically stored) contains 3,270 cal/kg (McCarthy 1993:324) but processed and cooked acorn contains only 793.4 cal/kg (Bettinger et al. 1997:894). Dividing this latter number into seasonal hamlet caloric requirements results

in approximately 4,798 kg unhulled and unprocessed acorn required to sustain a 13-person hamlet subsisting solely on stored acorn for four months (at 369 kg/person).

Cache capacity is determined by volume. Mono caches resembled elliptical cones, whose volume is determined by the formula

$$\frac{\pi(\text{diameter})^2 \times \text{height}}{6}$$

(Benson 2010). Internal rock ring diameters average 1.21 m. Judging from historical photographs of caches (Figure 5), mean cache height was approximately 1.4 m. This means the empty volume of a typical cache was approximately 1.07 m³, or simply 1 m³ (1,000 l). Conservatively estimating one-half of each cache was filled with pine needles to keep acorns dry and reduce pest infestation, as was the case for larger granaries (Bates 1983), leaves 500 l storage space per cache. The amount of unhulled acorn storable per liter is 1.45 kg (Bettinger et al. 1997:894),

Table 1. Estimated Storage Capacity of Winter Settlement Catchments.

Settlement Area	Caches in Catchment	Capacity ^a (kg)	Factor Capacity Exceeds Target ^b	Notes
Blue Canyon	14	10,150	2.12	Survey coverage poor to east and south; no. of caches in allotment likely underestimated
Providence Creek	69	50,025	10.43	
Rush Creek	45	32,625	6.80	
Sam Daniels	2	1,450	0.30	Survey coverage to north, west and south incomplete: number of caches in allotment likely underestimated
Lerona	9	6,525	1.36	Survey coverage to west and south incomplete: number of caches in allotment likely underestimated
Jose Basin	23	16,675	3.48	
Stevenson-Dawn	10	7,250	1.51	
Chawanakee Flats	0	0	nd	The dearth of caches in Chawanakee Flats is an interesting anomaly: one ethnographic source (Gaylen Lee, personal communication 2003) says it was not occupied by the Mono.
Hogue Ranch	29	21,025	4.38	
Rock Creek	21	15,225	3.17	
Cha:tiniu	70	50,750	10.58	
Mean	26.5	19,213	4.41	

^aCapacity determined by multiplying the number of caches in each catchment by mean cache capacity (725 kg).

^bTarget is 4798 kg, enough acorn to sustain a population of 13 individuals for four months.

meaning 725 kg acorn was storable per cache. Given this, it would take 6.6 caches to feed a group of 13 people for four months (i.e., winter requirement [4,798 kg]/cache capacity [725 kg]).

There are 70 caches recorded in the *Cha:tiniu* winter hamlet catchment (Morgan 2008). The capacity of these caches is 50,750 kg (70 x 725 kg), over ten times the amount of acorn required to sustain a population of 13 for four months.² If all these caches were filled, their capacity could sustain a population of 137 people for roughly the same amount of time, meaning that even if the population of *Cha:tiniu* was near a maximum population of 39 (Gifford 1932), capacity was still 3.5 times the yearly storage requirement. The point here is not so much the exact percentage by which capacity exceeded hamlet requirements (it is very likely not all caches were used in any given year and that hamlet population size varied considerably from year to year), but that the capacity of dispersed caches exceeded each hamlet's yearly requirement, on average by about four times, a phenomenon evident in the caching capacity of other hamlet catchments as well (Table 1).

The fact that catchment caching capacities exceeded single-year hamlet requirements is particularly intriguing when viewed in the light of pronounced, masting-related, multiyear variability in acorn abundance. Pronounced masting all

but guarantees poor acorn harvests the year following a productive one, with no guarantee of successful harvests in succeeding years. Acorn, however, is eminently storable, with properly dried and stored acorn lasting up to three years (Bates 1983; McCarthy 1993). Some cached acorn would undoubtedly be lost from year to year; it is likely bears and other animals would raid unprotected caches and fungus and rot would render some nuts inedible (Dunn 1995; McDonald 1969). But at a conservative estimate that caches exceeded hamlet subsistence requirements by a factor of four means that even with a 33-percent loss of acorn each year to animals and rot, there would be enough acorn cached after a bumper year to support a hamlet for another four-month winter, with a small amount left over for a third year (Table 2). These calculations indicate that even with conservative estimates of cache capacity relative to population, capacity was well in excess of the minimum requirements for populations living in winter hamlets, a conclusion supporting assertions that Mono storage was used to offset multiyear variability in the acorn harvest (McCarthy 1993:272).

Storage Rate Comparison. The dichotomy in Mono storage behaviors engenders the question of whether there is a benefit to the uniquely Mono caching strategy over the centralized strategy

Table 2. Cache Capacity over Projected Two-Year Period.

Storage Capacity (4X yearly target)	19,192 kg
Year 1 Loss (33%)	6333 kg
Accessed Food (= yearly target)	4798 kg
Remainder:	8061 kg
Year 2 Loss (33%)	2660 kg
Accessed Food (= yearly target)	4798 kg
Remainder:	603 kg

used by both the Mono and many other California groups. In other words, what was the benefit of dispersed caching when it involved additional travel costs to return and exploit stored foodstuffs? This analysis looks at the costs and benefits of doing both by employing methods derived from central-place foraging theory (Orians and Pearson 1979), an approach taking into account travel costs when operating from a central place, as well as perhaps more familiar costs like handling time (MacArthur and Pianka 1966).

There are three costs associated with acorn storing: post-encounter handling time, building and filling the storage facility, and travel time. Search time is not included because of the way Mono embedded monitoring and then targeting productive resource patches with other activities prior to moving to groves to harvest acorn. Post-encounter handling time consisted of the time it took to harvest and dry acorn. McCarthy (1993:263) estimates it took Mono women 3.4 hours to gather 36 kg acorn, enough to fill a typical burden basket. Drying, consisting of simply spreading collected acorn on bare rock and periodically turning the harvest, took almost no effort and was typically embedded with other activities. McCarthy (1993:271) argues it took 16 minutes per 36 kg load to dry acorn. Combined, handling costs for a 36 kg load of black oak acorn were 3.6 hours (10 kg/hr) regardless of storage strategy used.

There is little information on the time it took to build granaries and caches. Cache construction was likely less costly than building granaries as caching employed a smaller, more expedient technology and could be embedded with other activities like drying. For ease of analysis, however, they will be considered equivalent. To reiterate, caches hold approximately 725 kg, or about twenty 36 kg loads of acorn. Even if caches took

a particularly long time to build, perhaps on the order of four hours, the per-load cost of cache construction was only about 12 minutes (at four hours [240 minutes] divided by 20 loads), or roughly .2 hour. Combined with 3.6 hours handling time, the total time to cache 36 kg acorn is thus 3.8, or roughly four hours. Acorn storage rates are consequently 9 kg/hr. The final cost is travel. This is simply the time it takes to walk to and from a grove as a function of distance. The fundamental difference in costs between the two strategies is thus travel time, which directly affects the rate at which acorn is stored.

Travel costs directly affect the rate at which acorn can be stored in the fall. With a storage target of 4,798 kg and a burden basket capacity of 36 kg (Bettinger et al. 1997), approximately 133 round trips were necessary to meet this target. With gathering, handling, and storage costs set at 4.0 hrs/36 kg, this leaves four hours traveling time per day, more than enough time to move one load of acorn five km (the average radius of a typical hamlet catchment) to a central place each day (i.e., 10 km roundtrip at an optimal [Bastien et al. 2005] 4.7 km/hr = 2.1 hrs), but not enough time to return to a grove, gather and handle acorn and return back to camp with a second load (i.e., 20 km travel costing 4.2 hours). The rate of storage here is thus 36 kg/person/day, with each storer working approximately 6.1 hours to accomplish this task (4.0 hrs gathering, handling and storing + 2.1 hours transport). At this rate, a group of six women (half a hamlet's population) setting out each morning to harvest, dry, and transport 4,798 kg of acorn back to a central place would take about 22 days (812 hours) (Figure 7).

Dispersed caching travel costs consist of only the time it took to travel to groves from hamlets because caches are in oak groves, meaning transport costs to storage locations were zero. Further, foraging groups often camped in producing groves while harvesting (McCarthy 1993:256), meaning there were no additional costs associated with traveling back to hamlets. A total of eight hours were thus available to harvest, dry, and cache acorn each day. If acorns can be cached at a rate of 9.0 kg/hr, each cacher can store 72 kg acorn per day. At this rate, six cachers working together could store 4,798 kg acorn in about 11 days, twice the rate of central-place storer.

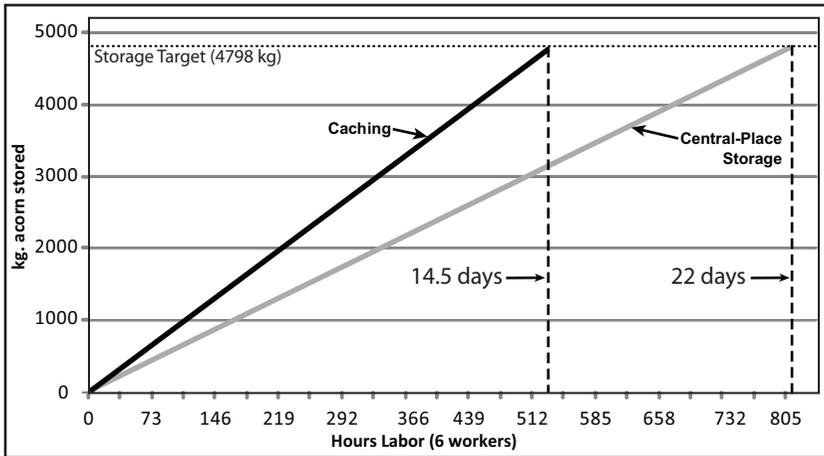


Figure 7. Storage rate comparison: central-place storage vs. dispersed bulk caching.

Cachers working 6.1-hour days instead of eight (to equate with central-place storing labor) increases the time it takes to meet the target to 14.5 days (533 hours), still 34 percent faster than central-place storing (Figure 7).

There are three benefits to reduced storage rates. First, the reduced storage rates more effectively cope with the time constraints of the acorn harvest. Black oak acorn ripen and begin falling in late September, continuing to do so through October. First snowfall is usually in late October, but severe storms and snow accumulation typically do not occur until around mid-to-late November. This leaves a roughly one month period (October) in which to store enough acorn to see a hamlet through a winter, a situation clearly ameliorated by caching rates 34–50 percent less than central-place storage rates. Second, quickly storing acorn leaves time for other activities, particularly important in the fall when grass seeds ripen and are harvested, winter villages are reoccupied, and feasts are planned and undertaken. Third, caching generates more stored acorn in the same amount of time. For example, if all of October was spent doing nothing but gathering, drying, and caching acorn, six cachers could store nearly three times the amount of acorn needed for a hamlet to make it through the winter. Combined, caching's greater storage efficiency, paid for by significantly reduced travel costs, offsets the limits time places on acorn harvest and storage.

Front-Versus Incremental Back Loading. The last benefit of caching is its lower transport costs

when considered over the period of time when cached acorn is accessed, processed, and eaten. Central-place storage is a completely front-loaded strategy: it pays harvest, drying, storing, and transport costs together. When foodstuffs are exploited, however, there are no additional costs associated with gaining access to the resource: it is in camp and ready to be processed and cooked, where the costs are the same for both cachers and central-place storers. Using data from the preceding section (storage costs [6.1 hrs] x 133.2 loads), yearly hamlet handling, storage, and transport costs are fixed at approximately 812 hours for a single central-place storer working 6.1 hours per day (Figure 8). Because this strategy is front loaded, its transport costs are temporally static relative to when the benefit of stored acorn is accessed. In this scenario, every time a hamlet exploits a day's worth of acorn during the winter, it has already paid all the year's storage costs up front.

The opposite obtains for cachers, who employ an incremental back-loaded strategy. Cachers pay additional roundtrip travel costs to return to caches and carry loads of acorn back to their hamlet, paying incrementally for the greater storage rates they enjoyed in the fall.³ But they also exploit the fact that caching transport costs increase only per load of acorn transported back to a hamlet, rather than upfront. A simple way to compare caching's incremental costs with the static costs of central-place storage is with the formula for a linear equation: $y = mx + b$. Here y is the cost, measured in hours labor, x is benefit,

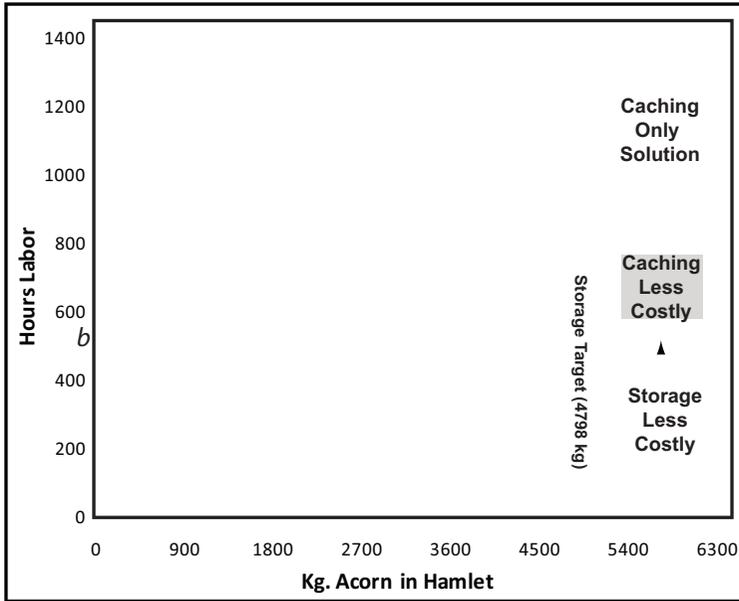


Figure 8. Cost-benefit comparison: central-place storage vs. dispersed bulk caching. Top line (in gray) shows rate for caching 2x yearly target, an amount of acorn that can be cached in the same amount time it takes for central-place storers to meet their yearly target (at 45-50% faster storage rates for caching).

measured in kg of acorn in camp, m is the slope of the line and b its y-intercept. As with central-place storage, the cost of caching (y) is time, with 36 kg of acorn transported per 2.1 hour average roundtrip, making the slope of the line (m) .0583. Initial caching costs (b) are 533 hours (storage target [4798 kg]/ [9.0 kg/hr]) paid to cache 4798 kg acorn. Solving for the benefit, x , the amount of acorn in camp, inverts the linear equation to:

$$x = \frac{y - b}{m};$$

for Mono cachers:

$$x = \frac{y - 533}{0.0583} \text{ (Figure 8).}$$

At zero trips to access caches ($y = 533$), there is no acorn in hamlets, so the return (x) is zero. Once cached acorn is accessed, however, the benefit of dispersed caching is clear: costs increase incrementally with each trip of four hours, with a corresponding benefit (x) of 36 kg acorn moved back to hamlet. For instance, at 10 roundtrips the amount (x) of acorn brought to camp is 360 kg. But the cumulative cost of caching and transporting such is 554 hours, 258 hours less than the static costs (812 hrs) of central-place storage.

Caching costs, at least until equivalent amounts of cached acorn are brought back to camp, are thus always less than the 812 hours required to store acorn in a central place (Figure 8).

Four main points are evident in this analysis. First, there is no benefit to dispersed caching prior to making additional trips to exploit the food they contain. This implies that if reliance on stored food is relatively low, then it is more cost effective to pay the up-front costs of centralized storage. Second, caching is less costly roughly 45 percent of the time, when larger amounts of acorn are required, because costs associated with extracting the benefit contained in acorn are incremental, rather than frontloaded. Third, it is no surprise the Mono used a mixed strategy: there are benefits to doing both. When small quantities of acorn are required, central-place storage is less costly; when larger quantities are required and the length of time groups might expect to subsist on stored foods is uncertain, caching is more effective. And fourth, if more than the 4,798 kg necessary to sustain a population through the winter is required, either because of a long winter or because of masting-related failures of acorn production, the economics of caching versus central-place storage are obviated: only cachers might

have a supply of acorn to rely upon; central-place storers do not, given the seasonal time constraints on this strategy. Caching thus provides multiple benefits to its practitioners: it serves as insurance when environmental productivity is uncertain, it entails rapid storage rates, and it is ultimately less costly when large quantities of surplus are either required or desired.⁴

Discussion

Ethnographic information, archaeological signatures, and environmental and paleoclimatic data indicate that Mono food storage was predicated mainly on coping with variability in environmental productivity. On the surface, this coping strategy appears geared toward laying in sufficient stores to rely upon in winter, superficially supporting Binford's (1980) main argument that collector-type strategies develop in seasonal, middle latitudes. But this study also shows that the Mono stored copious amounts of acorn, in volumes great enough to offset multiyear rather than seasonal variation in acorn productivity. This is most parsimoniously explained as having developed as a response to variability in the fall acorn mast causing considerable uncertainty regarding the productivity of acorn from year to year. This portion of the Mono storage equation indicates they were risk averse and perfectly willing to sacrifice additional labor and opportunity costs to ensure subsistence from one year to the next. Put more simply, the Mono economy sacrificed potentially higher returns on labor to pay for insurance covering the possibility of future starvation.

Rather than entailing only tethering and sedentism, Mono storage behaviors also facilitated residential mobility. This is not entirely unexpected because plenty of seasonally mobile hunter gatherers cached. The argument could end there, with central-place storage tethering hunter-gatherers to seasonally occupied winter camps and dispersed caching reducing the risk of moving residential bases in spring, summer and fall. But what is especially intriguing in the Mono case is the *scale* of their dispersed caching: they stored as much, if not more, food *out* of camp as *within*. This presents a third alternative to the caching:central-place storage dichotomy running through this paper, as it entails the same kind of

bulk acquisition and large-scale delayed-return tactics Binford (1980), Testart (1982), and many others ascribe to tethered, more sedentary populations. The fact that this type of what might be called *bulk caching* developed in at least one instance suggests similar strategies may have developed in other contexts where pronounced climatic/ environmental variability was faced by populations with established seasonal transhumance patterns. Similar conditions, for example, may have pertained during the Last Glacial Maximum in the Ukraine, when environmental productivity was particularly unstable and seasonally mobile hunter-gatherers increased their reliance on stored food (Soffer 1985, 1989). Likewise, acorn-reliant economies in terminal Pleistocene Korea and Japan may have faced circumstances markedly similar to those of the Mono: pronounced climatic variability, masting variability from year to year, and economies increasingly reliant on caching (Habu 2004). Given these cases and high degrees of climatic-environmental variability during the Pleistocene, and perhaps during neoglacials in the Holocene, we might expect to see analogous adaptations in other regions and temporal spans, particularly among nut-reliant groups and populations experimenting with storage and its various permutations.

The question of population density and Mono storage is more problematic, due in part to the difficulty of estimating the former. The largest recorded Mono village contained 75 people, resulting in a population density of 96.17 persons/100 km² in the 11 winter hamlets in the 30 km by 30 km study area. But this was likely the result of an anomalous historical amalgamation of Mono and Yokuts groups pushed together by Euroamerican incursions (Gayton 1948:270). With an average hamlet size of 13 individuals, however, N_m population density was 16.67 persons/100 km². This is substantially less than the 28.7, 40.9 and 66.7 persons/100 km² recorded by of Binford (2001:122), Kelly (1995:223) and Baumhoff (1963:231), respectively for the Mono as a whole. The lowest figure (16.67/km²) puts them in the 60th percentile for hunter-gatherer population density worldwide (Binford 2001:118–129), which ranges from as little as .3 in arctic Canada to an anomalously high 633 persons/100 km² on the northern California coast

(Kelly 1995:222–226). Alternatively, Baumhoff's higher figure, which is debatable (it is based on environmental productivity rather than archaeological or ethnographic data) puts them in Binford's (2001) 90th percentile for hunter-gatherer population densities. Combined, these data indicate Nîm population density was by no means anomalous and was even high by global hunter-gatherer standards (although these are based in large part on ethnographic populations in very high or low latitudes). But these densities, whichever estimate is used, are low for ethnohistoric California. Even if Baumhoff is correct and population density was 66.7 persons/km², Mono population density was still over five times lower than those he identified for Foothill Yokuts groups living on the western edge of Mono territory, and among the lowest densities recorded for any California group, which according to Kelly (1995:223–224) ranged from 25 to the aforementioned 633 persons/km². Mono population densities were thus about average or even relatively high compared to most other hunter-gatherers, but markedly low compared to other California groups, even those in adjoining territories. But they exhibited arguably the most complex food storage behaviors recorded in precontact California, a region renowned for its large, socioculturally complex hunter-gather populations.

As might be expected with regionally low population densities, Mono social organization was not particularly complex, at least by coastal and central valley California standards, focused as it was on household economies and decision making. As mentioned previously, however, lineages and sometimes moieties (these are both recorded for the Nîm) structured Mono society outside the household and patrilineally inherited titles, most notably those of chief and messenger, are recorded for some Mono groups. Chiefs maintained prestige via a form of, if not competitive feasting, at least lavish resource redistribution based in large part on acorn meal that was produced by a great deal of women's labor. This means that the accumulation, control, and redistribution of surplus were indeed important players in the maintenance, and perhaps the development of this ascribed role. In any event, we are left with another interesting conundrum: regionally low population densities but also the occasional

prestige position based in part on the control of stored surplus. Such a situation might be expected, given that hunter-gatherer wealth-based status distinctions can develop in populations from as little as .03 to as many as 300 persons/km² and that the Mono economy was a terrestrial system of the type rarely associated with the levels of complexity found in more aquatic-based systems, like those on the California coast (Binford 2001). But what is fascinating about the Mono case is that its markedly complex storage system was associated with more-or-less expected (in terms of environment) population densities and degrees of sociocultural complexity. The connection between population density and social complexity on the one hand and Mono storage behaviors on the other thus appears tenuous and suggests, in a larger sense, that neither is necessarily connected with storage per se, except in instances where it can be empirically demonstrated.

Conclusion

This study indicates there is substantial variability in the way hunter-gatherers store food. Because different storage strategies are affiliated mainly with variability in environment and mobility, it is useful to model these strategies as representing two, and arguably three basic forms: *central-place storage*, dispersed *caching*, and dispersed *bulk caching*. In the first instance, it is evident that central-place storage equates with what Testart (1982) had in mind when he argued that storage, predicated on coping with seasonality, tethers populations to particular locales. If the Mono example is in any way typical, Testart's argument at first appears more-or-less intact. Caching, on the other hand, can facilitate residential mobility when done either in isolation or in bulk. It can also maximize the amount of food stored around a central place, a critical factor when gathering is time-compressed or when very large stores of food are required or desired. This insures at least some labor invested in storage will result in adequate future returns and population maintenance from season to season and year to year. Such insurance-oriented strategies might be favored by risk-averse groups when there is great variability about expected mean reward: for instance, during periods of pronounced climatic, social, or political instability

(cf. Winterhalder et al. 1999). Climate often takes the lead in these types of explanations, but evidence of caching to escape raids by outsiders, for example, is documented for Utah's Fremont (Barlow et al. 2008) and in the Eastern Woodlands (DeBoer 1988). An alternative explanation has bulk caching developing along with prestige systems to provide the resources required of big men and chiefs to throw the feasts where they gained their status (Hayden 2009). Teasing apart the relative import of each of these to the evolution of different storage behaviors may rest largely on empirical evidence, as storage has appeared to develop in response to a wide range of demographic and social variables.

Finally, if the Mono case is to be taken as a model, five generalizations can be made about hunter-gatherer food storage. First and foremost, there is variability in storage behaviors. Food storage should thus not be conceived of as a single strategy, but rather as a series of related but ultimately separate behaviors predicated on how they articulate with environment and different forms of mobility. Second, sedentism does not require central-place storage (bulk caching could do the trick) but central-place storage entails some degree of sedentism, seasonal or otherwise. Third, environmental uncertainty can lead to risk-averse behaviors like the multiple forms of bulk storage the Mono used as insurance against potential lulls in environmental productivity. Fourth, caching is often associated with residential mobility but can also be, depending on degrees of uncertainty and storage targets, a faster and more efficient way to sustain sedentary residential populations. And lastly, storage, population density, and sociocultural complexity strongly correlate in just about every situation where complex social orders have developed, but the presence of the former does not necessarily require the development of the latter. In any case, it seems entirely possible that bulk caching strategies similar to those used by the Mono may have been employed when people faced particularly variable environmental or social conditions and perhaps also when competitive feasting played a role in the development of social inequalities. The diversity of hunter-gatherer storage behaviors, however, especially during critical periods of cultural evolution during the late Pleistocene and early Holocene, remains to be seen.

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Notes

1. Such a scenario is of course highly unlikely, especially given the markedly low protein content of Black Oak acorn (McCarthy 1993), but the analyses in this paper are consistent with models like diet breadth (MacArthur and Pianka 1966) that focus solely on caloric content.

2. Though taphonomic problems could affect estimates of cumulative storage capacity, it is clear from geomorphological evidence that most recorded caches are fairly recent because they are found in very active geomorphic environments, on exposed and sloping granitic outcrops.

3. It might be argued that caching's transport costs would be lower due to the embedded nature of Mono (and many other hunter-gatherer's) procurement strategies. This depends, however, on how embedded labor costs are divided among different tasks. The model here presents a simple and more generally applicable roundtrip model for three reasons: (1) retrieval costs absolutely have to be paid (otherwise there is no acorn in camp), meaning these costs are directly associated with caching; (2) embeddedness would result in a less-conservative estimate of caching's costs relative to central-place storage; and (3) central-place storage was also associated with other tasks, meaning travel should be modeled consistently between the two strategies.

4. Another possible benefit of dispersed caching may have been low-cost defense: dispersed caching would have hidden food stores from people outside of the caching group and thus be a low-cost way of defending acorn stores. If early historical accounts of hostility between Yokuts and Mono groups are true (see Morgan 2010), dispersed caches might have been used to protect acorn stores from theft or raiding. It is also possible, as some Mono people have suggested, that caches were a way of storing food away from camps so that when Euroamericans

came and raided camps, there were sufficient stores of food outside of camps. Although this might have pertained in the late 1800s and early 1900s, it does not fully explain the economic benefits or the historical roots of the behavior. This is due to three factors: (1) there are very few ethnohistorical accounts of Euroamericans entering camps in the study area, (2) winter hamlets and caches are mostly in remote areas that were rarely accessed by whites until the early 1900s, and (3) the strong his-

torical and morphological connection of Mono acorn caches to Paiute piñon caches in the Great Basin, the use of which date to at least 1000 B.P. (and probably earlier), suggests the behavior came west with the Mono prior to the 1800s.

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