A SIGNATURE OF CALAMITY: LATE PREHISTORIC SETTLEMENT PATTERN SHIFTS AROUND CLEAR LAKE, LAKE COUNTY, CALIFORNIA

S. JOE GRIFFIN
DEPARTMENT OF ANTHROPOLOGY
SACRAMENTO STATE UNIVERSITY

This paper develops a hypothesis for the timing of upland resource use around Clear Lake, California, based on Bettinger's (2009) front-loaded/back-loaded model of resource selection. The hypothesis is tentatively tested using obsidian hydration dates from sites on Boggs Mountain and adjacent lowland areas. The obsidian data do not support the predictions developed with the model. A reassessment of the assumptions upon which the model was based indicates that in this case, the model would be more effective using as currency risk rather than net caloric returns.

The introduction of European diseases to North America, starting in the sixteenth century, resulted in the decimation of native population levels. This drastic decrease must have spurred rapid and significant changes as people struggled to recover and survive. Evolutionary ecological models may be used to generate specific predictions about some of the results of this calamity. A handful of sites identified on Boggs Mountain, in the North Coast Range of California, indicate a relatively sedentary late occupation of an upland environment. By modeling a shift from back-loaded to front-loaded resources (Bettinger 2009) and assuming net caloric maximization as the goal, the following hypothesis is generated: increasing population levels in the late prehistoric period caused decreasing returns from acorn production by increasing search time for the nuts. This should have resulted in a segment of the population moving upland to pursue geophyte exploitation. After European diseases drastically reduced population levels in the Clear Lake area, the pressure on acorns should have decreased, and the upland sites would be abandoned.

A test of the hypothesis against available data results in its clear refutation. Restructuring the predictions using risk minimization rather than caloric optimization as the goal results in a better fit between theory and data. This seems to be a more likely explanation for the clear settlement shifts which occurred after European contact.

Boggs Mountain is a small mountain located about 10 km south of Clear Lake, in Lake County, California. Several sites on the mountain have been located during archaeological surveys (Dillon 1995; Gerike and Stewart 1988). The majority of these sites are simple lithic scatters, though three sites have house pit depressions visible on the surface. One of these sites, CA-LAK-1760, contains at least three distinct features, two probable house pit depressions, each about 3 m in diameter, and a smaller feature that appears to be the remains of a pit oven located adjacent to one of the house pits. The pit oven is approximately 1 m in diameter, surrounded by a dense ring of heating cobbles. Such features are closely associated with roasting of geophytes (Thoms 1989; Wandsnider 1997), and the size of it indicates substantial production. The site is located in a mixed coniferous forest with occasional oaks, manzanita, and grasses. A small stream passes by the site, and a broad open meadow is located immediately to the southeast.

In the course of their survey, Gerike and Stewart (1988) collected more than 160 pieces of obsidian from sites on Boggs Mountain and obtained hydration readings from 33 of those. The hydration data indicated late occupation of the mountain. The existence of relatively substantial house pit dwellings and the presence of a pit oven feature suggest fairly established, semisedentary habitation based on intensive geophyte exploitation during the late prehistoric period.

Table 1. Outline of the various chronologies of landscape use.

<table>
<tr><th>Approximate dates (before present)</th><th>White (2002) Berkeley pattern
Lakeside lowland sites</th><th>White (2002) Mendocino pattern
Lakeside lowland sites</th><th>Hildebrandt and Hayes (1993)
Montane upland sites</th><th>Hildebrandt and Swenson (1985)
Upland and lowland sites</th><th>Parker (1993)*
Upland and lowland sites</th></tr>
<tr><td></td><td colspan="2">No substantial settlements</td><td rowspan="2">Only one site, a hunting camp</td><td rowspan="3">Shift towards lowland sites</td><td rowspan="5">Increase in use of upland sites</td></tr>
<tr><td>1000 B.P.</td><td>Radiocarbon gap</td><td rowspan="3">(Radiocarbon gap)</td></tr>
<tr><td></td><td rowspan="4">Substantial lowland lakeside settlements. “Collectors”</td><td rowspan="4">Declining upland use -- only hunting camps</td></tr>
<tr><td>2000 B.P.</td><td rowspan="13">Relatively even mix of upland and lowland site use</td></tr>
<tr><td></td><td rowspan="4">“Forager” camps occasionally near the lake, mostly upland</td></tr>
<tr><td>3000 B.P.</td><td rowspan="7">Use of uplands begins</td></tr>
<tr><td></td><td rowspan="6">(Radiocarbon gap)</td><td rowspan="6">Extensive upland occupation by “Forager” groups</td></tr>
<tr><td>4000 B.P.</td></tr>
<tr><td></td><td rowspan="8">(Radiocarbon gap)</td></tr>
<tr><td>5000 B.P.</td></tr>
<tr><td></td></tr>
<tr><td>6000 B.P.</td></tr>
<tr><td></td><td rowspan="4">Substantial lowland lakeside settlements. “Collectors”</td><td rowspan="11">No data</td><td rowspan="6">More lakeside sites, no upland sites</td></tr>
<tr><td>7000 B.P.</td></tr>
<tr><td></td></tr>
<tr><td>8000 B.P.</td></tr>
<tr><td></td><td colspan="2" rowspan="7">All known sites are around the lake</td><td rowspan="7">Lakeside occupation</td></tr>
<tr><td>9000 B.P.</td></tr>
<tr><td></td><td rowspan="5">Few sites, all by the lake</td></tr>
<tr><td>10,000 B.P.</td></tr>
<tr><td></td></tr>
<tr><td>12,000 B.P.</td></tr>
<tr><td></td></tr>
</table>

* Time periods based on the Borax Lake hydration curve developed in White (2002).

Ethnographically documented, named Pomo village sites were located in lowland areas along the shores of Clear Lake, on islands in the lake, and along streams or springs in the surrounding valleys. People were largely sedentary and tended to reside in the main villages for most of the year, except during fishing trips in late spring and during the fall acorn harvest when many people moved to seasonal collecting camps (Kniffen 1939). Though the Clear Lake area was the focus of a number of ethnographic studies (e.g., Barrett 1916, 1952; Kniffen 1939), there is no ethnographically documented occupation of Boggs Mountain (Dillon 1995).

Archaeological models of prehistoric landscape use in the area may be built on data from several survey-level reports developed in the late 1980s and early 1990s (Table 1). The first of these, by Hildebrandt and Swenson (1985), was built on an analysis of all the previous site records from a tract of land comprising most of Lake County and parts of Mendocino, Trinity, Tehama, Glenn, and Colusa counties. This work examined the frequencies of different artifact types relative to one another and to the surrounding vegetation, topography, and the presence or absence of a midden. Salient conclusions they generated included an observation that early points were more commonly found at higher elevation than late prehistoric points (i.e., Rattlesnake and Gunther types); that late points, along with mortars and pestles, tend to be located in lowland valleys and along streams; whereas manos and metates were more likely to be encountered in upland conifer zones (Hildebrandt and Swenson 1985). Though none of these correlations were particularly strong, these data may indicate a general shift toward lowland site exploitation after around 1500-900 B.P.

The Pilot Ridge project (Hildebrandt and Hayes 1993) took place farther north in the Coast Range, in an environment broadly analogous to the upland areas around Clear Lake. Shallow test excavations were done on a number of sites to a depth of 10 cm, in small units aligned along transects, with the intention of separating contexts horizontally. The majority of components encountered were Borax Lake or mixed Mendocino/Borax Lake (6000-3000/1500 B.P.). The earliest sites (Borax Lake) appeared to have been base camps for foraging groups, with a possible structure on one site and a broad variety of materials, including milling equipment. The later mixed Borax Lake/Mendocino components were marked by a high occurrence of flake tools, hammer stones, and bifaces. The authors attribute this to the sites' use as hunting camps. The only late site was also a hunting camp. Though this work was done a considerable distance from that of Hildebrandt and Swenson, both projects seem to illustrate a similar trend: an early broad-based subsistence strategy exploiting upland and lowland environments evenly, developing into a more sedentary pattern with people maintaining longer-term camps in lowland areas and making limited logistical forays into upland environments to hunt.

Around this same time, Parker (1993) mapped all the known sites in the Clear Lake area and worked out perceived patterns of land-use change. He observed that over time people began to settle in the surrounding hills and mountains, increasingly distant from Clear Lake. Parker's chronology is based on obsidian hydration measurements of Borax Lake glass. For the purposes of comparison, I have converted those readings into dates, using the rate established by White (2002). The trends Parker observed seem to reflect a general trend towards increasing use of upland environments, with a constant and continued use of lakeside contexts.

These data do not necessarily contradict the findings of other studies. The common thread between the work of Hildebrandt and Hayes (1993) and Hildebrandt and Swenson (1985) is the observation of upland hunting associated with high residential mobility during the earlier periods and a later shift towards less mobile lowland sedentism. If upland areas begin to be exploited for resources other than meat, different activities could potentially produce sites on which projectile points are comparatively rare. Such a site encountered on a pedestrian survey might well remain undated. Parker's use of obsidian hydration rather than projectile point frequencies for temporal control may explain this apparent discrepancy.

In a synthesis built for the Anderson Flat Project using only securely dated, excavated lowland components, White (2002) notes a radiocarbon gap between 1900 and 650 B.P. The terminal prehistoric Augustine pattern appeared after 650 B.P. but is poorly represented around the lake, despite the fact that the type site for that period's diagnostic projectile points, the Rattlesnake series, is located on an island toward the southeast end of the lake (White 2002).

Informed by evolutionary ecological theory, I developed a model to explain the apparent late prehistoric upland sedentism observed on Boggs Mountain. This model was based on a number of assumptions. First was that human decisions are phenotypic, having evolved and continuing to be subject to selective pressures. Second, that these evolved behaviors were oriented towards maximizing reproductive potential and survival. Third, because subsistence is the baseline of survival and reproduction, it should have been accomplished as economically and sustainably as possible. This means that people should have pursued a suite of resources that maximized their caloric intake, with as low energy expenditure as possible. Thus the model was constructed assuming a goal of maximizing net caloric yields from subsistence activities.

Different suites of resources were available in different areas, so we may assume that subsistence strategies were a factor in choosing the locations of habitation sites. People probably attained a broad diet breadth and began intensifying certain resources well before the occupation of Boggs Mountain (White 2002), so the choice considered in the model was between the intensified use of acorns and the intensified use of geophytes.

Oak is widespread throughout the Clear Lake area, but is especially common at lower and middle elevations. Eating acorns requires leaching toxic tannins from the nuts, so people whose subsistence was based on this resource should have preferentially located themselves in close proximity to a steady and plentiful water source. This would favor lowland occupation, near either the lake or a stream.

At higher elevation, oaks are still represented, but in much lower numbers. Various kinds of pine dominate a varied biological zone. Occasional wet meadows may support quantities of edible geophytes. Barrett (1952) observed that the local Pomo occasionally roasted and consumed camas, though not intensively. Upland areas are favored for camas growth because the seeds require 42-100 days of cold (below 4˚C) for full germination (Stevens and Darris n.d.). Therefore intensive geophyte exploitation would have favored upland site locations.

Besides their geographic distribution, acorns and geophytes differ in the methods used to process them prior to storage and prior to consumption. For the sake of the model, acorns and geophytes were both considered in the context of intensive exploitation in which a surplus is collected and stored for use later in the year. Relative to one another, I consider acorns back-loaded resources and geophytes front-loaded resources. Storing acorns involves no processing; they may be stored effectively in the shell and need only be processed prior to consumption. Geophytes are best stored in processed form, either dried or made into cakes (Thoms 1989), and then require little further processing to eat. Bettinger (2009) refers to the time cost of collecting a resource, preparing it for storage, and storing it as *storage cost*, and the time it takes to prepare a cached resource for consumption *culinary cost*. The storage cost plus the culinary cost of however much of a cache is ultimately consumed equals the total cost of those resources.

The decision to focus on one or the other of these resources may depend on the likelihood that a cache will be used. Back-loaded resources are cheap to cache, and so there is little at risk if the cache isn't used. In fact, unless the total cost of a back-loaded resource (that is to say, the cost of storing it plus the cost of processing it after the cache is used) is higher than the total cost of the front-loaded resource (the cost of processing it to prepare it for storage plus the eventual cost of preparing it to eat after the cache is used), then the front-loaded resource will not even be considered.

In order to predict a shift in emphasis from one resource to another, one or more of the above costs or yields must change. Barring a categorical shift in processing methods, we can hold constant the cost of a resource after a cache is used. Assuming that the caching is undertaken to feed at least seasonally sedentary people who are very likely to use their cache, the probability of a cache being used is dependent on other factors such as spoilage, bug infestations of the cache, and so on. We can hold these environmental factors generally constant. This leaves as the variable factor the cost of storing the resource. Again, assuming that pre-storage processing isn't different, this boils down to the time it takes to find a sufficient quantity of a resource.

Given easy availability of acorns, people should always choose them over geophytes. As populations grow, however, it will become increasingly costly to collect a sufficient supply of the nuts, as more people depend on the same amount of acorns. The costs of the resource that is not being intensively exploited however, is not changing. At some point, the storage cost of acorns will rise to the point where, for some of the population, switching to the front-loaded resource makes economic sense. Some people are likely to continue with acorns as a staple, but others will begin to intensify geophyte exploitation as well, potentially relying on them to the exclusion of acorns. Conversely, a sharp decrease in population levels would reduce the ratio of people to acorns, and intensively exploiting geophytes would no longer be economically validated (Figure 1).

The hypothesis is as follows: increasing population levels in the late prehistoric period caused decreasing returns on acorn production by increasing search time for the nuts. This resulted in a segment of the population moving upland to pursue geophyte exploitation. After European diseases drastically reduced population levels in the Clear Lake area, the pressure on acorns was decreased and the upland sites were abandoned. Therefore, during periods of high population levels, there should have been people settled in lowland areas in close proximity to acorns and the means to leach them, while other people

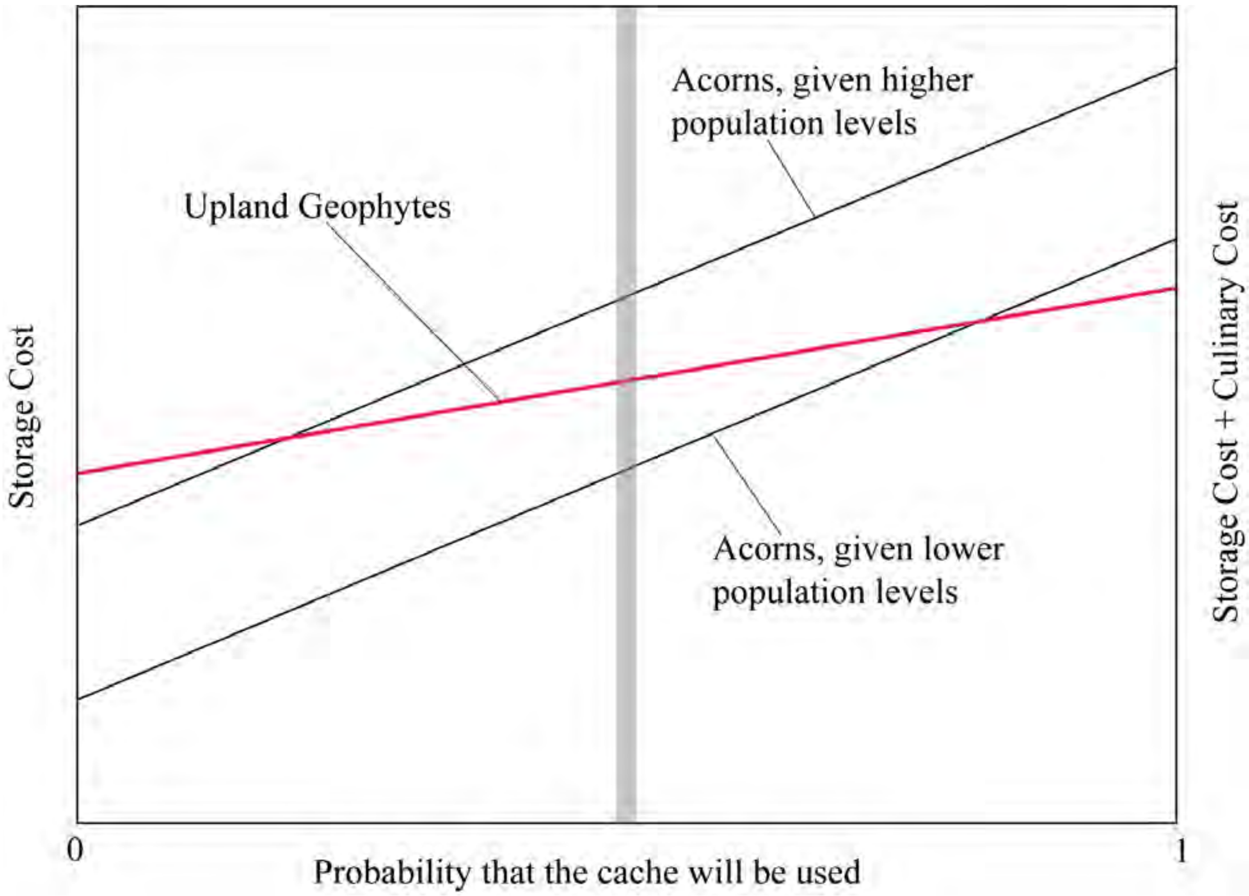

Figure 1. Graph indicating hypothetical costs of acorns and geophytes, demonstrating the potential for one resource to become more economical than another. The gray line indicates a constant value representing the probability that cached resources will be used. Note that at lower population levels, acorns cost less, while at higher population levels they are more expensive than geophytes.

were settled in upland areas closer to the supply of geophytes. Given somewhat lower population levels, groups should be based only in the lowland areas. Because this hypothesis assumed that population pressure was the determining factor in settlement location, a severe population reduction should result in the abandonment of upland areas and intensive geophyte consumption.

From this hypothesis the following simple prediction was derived and tested: hydration dates from Boggs Mountain should be late, but should drop off significantly after 400 to 500 B.P., around the time of European contact and the onset of disease. Dates from lowland sites should reflect little change through this time period.

Testing this hypothesis involved compiling the obsidian hydration values from Boggs Mountain and two lowland areas, Cache Creek and Anderson Flat, and converting them into dates. This was done using the most recent hydration rate for Borax Lake obsidian, derived from 18 obsidian hydration/radiocarbon pairs (White 2002). The Anderson Flat project yielded more than 1,200 usable hydration readings from five sites, Boggs Mountain yielded 17, and Cache Creek yielded 25 readings. In light of these smaller sample sizes, the Cache Creek data and the Boggs Mountain data were treated as aggregates; no attempt was made to separate the chronology of different sites in those areas. The

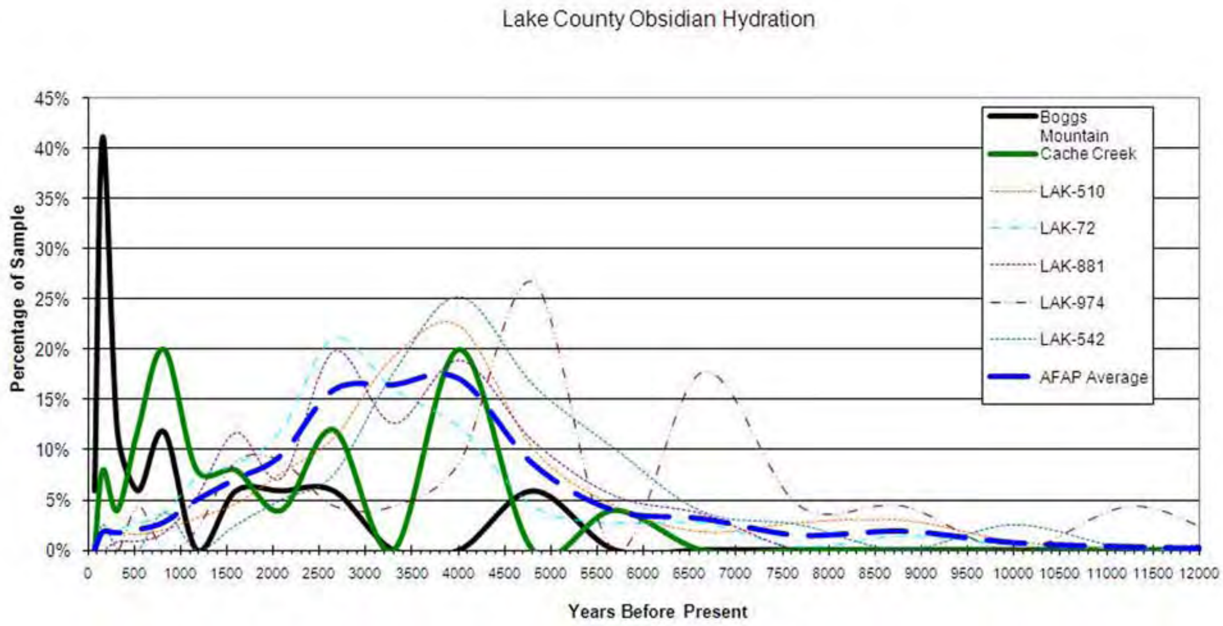

Figure 2. Relative frequencies of obsidian hydration dates from several Clear Lake area sites.

percentage of hydration values through time was then graphed (Figure 2), and the patterns were examined.

As the graph indicates, the expected pattern was not manifested; in fact, quite the opposite occurred. A strong plurality of hydration readings from Boggs Mountain postdate the arrival of European disease. Boggs Mountain was occupied most intensively after a decrease in population levels. This means that the assumptions built into the model must be reevaluated.

As described earlier, the model was designed using net caloric yield as the adaptive goal, and population pressure was assumed to be the most important factor in determining which strategy would maximize yield. Other potential factors might be environmental conditions or technological innovation.

Environmental changes in the Clear Lake area have been examined in two ways: through temperature fluctuations as reflected in the growth patterns of fish scales (Casteel and Beaver 1978), and through pollen counts in soil cores from Clear Lake itself (Adam 1988; West 2002). The fish scale data indicate increasing temperatures between about 12,000 and 8000 B.P., then a cooling trend until about 5000 B.P., followed by a maximum temperature reached between about 5000 and 3000 B.P. (Casteel and Beaver 1978). The old-carbon effect in Clear Lake, along with rough estimates of sedimentation rates, makes dating the changes manifested in the pollen samples difficult. Despite this, West (2002) attempted to look at the late Pleistocene and Holocene in finer detail than an earlier analysis of the same cores (Adam 1988) that concerned a much broader sweep of time. This work indicated a general warming trend through the Holocene after a brief regression early on, probably during the Younger Dryas, followed by a slight decline in temperatures after the middle Holocene.

The warm middle Holocene may correspond with the apparent peak in obsidian hydration dates from the Anderson Flat area, illustrated in Figure 2. However, if this was followed by a general and gradual cooling trend, there would be no clear mechanism for the significant settlement shifts which appear to have occurred after A.D. 600. Neither the fish scale nor the palynological studies detected a warm period between 1150 and 650 B.P. (known commonly as the Medieval Climactic Anomaly). If such a warm period were hypothesized, and environmental factors were assumed to have been the key cause of settlement and subsistence shifts, then one would expect that period to have produced obsidian hydration frequencies similar to those noted from the longer middle Holocene warm period. In fact, whereas the Anderson Flat sites appear to have reached their maximum intensity of occupation during the middle Holocene, they yielded very little obsidian dating from this hypothetical warm period. Additionally, White (2002) noted a distinct gap in radiocarbon dates between 1200 and 650 B.P. In this case, environmental or climatic changes seem to be poor predictors of subsistence and settlement change.

The caloric and nutritional value of many geophytes has been shown to increase dramatically after roasting, which breaks down almost indigestible fructans into easily digestible fructose (Wandsnider 1997). Pit-roasting technology significantly increases the value of geophyte resources, and the development of this technology could have opened upland areas to exploitation by significantly increasing the caloric yield of many geophytes. However, the ethnographically documented Pomo consumed camas and were aware of this technology but did not make intensive use of geophytes as staple resources.

None of these factors seems able to account well for the patterning evident in Figure 2. The problem may lie, then, with my selection of maximization of net caloric yield as the adaptive goal. While this may yield adequate predictions in many cases, it is important to consider what may have become the most significant selective pressure after the arrival of European diseases: the risk of an early death.

If the adaptive goal is changed from maximizing net caloric yield to minimization of risk, the model may more closely reflect reality. Instead of holding risk constant, if the maximization of net caloric yield is held constant, then risk management may be isolated as a decision-making factor.

Lowering risk is most commonly associated with reducing variability in the access to key resources through the course of a year or from year to year. In other words, minimizing risk is equivalent to minimizing the variable availability of important resources over time (Wiessner 1982). Wiessner (1982) identifies several ways foragers may reduce risk, including management of predictability, charity or theft, resource storage, or pooling risk among a group of people. By not directly considering these means of risk mitigation, the original model did not deny that they took place; rather, it assumed that they would be applied as necessary but could be held constant.

In the extraordinary circumstance of a calamitous epidemic, however, some of these risk mitigation techniques could potentially increase risk rather than mitigating it. Both the methods of pooling risk among a group of people and of charity or theft demand close social ties and, potentially, social aggregation. As highly contagious diseases spread, large groups could quickly fall victim *en masse*. Smaller, more isolated groups may have been able to reduce their contact with others sufficiently to increase their odds of survival. Thus the increased cost of geophyte intensification may have been offset by the reduced risk of disease brought about by a more dispersed population.

Foraging models often employ net caloric yield as the currency in decision-making models. This exercise has illustrated a situation in which risk may be a more useful currency for model development (see also Torrence 2001). When people choose, they take into account far more factors that archaeologists could ever hope to model. But as goals, currencies, and contexts change, so do the patterns of decision making. Through the deductive process of archaeological reasoning, it becomes possible to approach the ultimate factors driving decisions made hundreds or thousands of years ago.

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