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OBSERVING SUBSISTENCE CHANGE IN NATIVE SOUTHERN CALIFORNIA: THE LATE PREHISTORIC KUMEYAAY

John A. Hildebrand and Melissa B. Hagstrum

INTRODUCTION

Among hunters and gatherers, how are subsistence strategies chosen and what factors influence adoption of alternative strategies to provision basic subsistence requirements? Under conditions of subsistence stress, how will traditional hunters and gatherers modify these strategies? We examine these questions to understand mechanisms of subsistence stress adaptation and to account for changes in the late prehistoric and historic archaeological record of interior southern California. Several factors may have contributed to subsistence stress during the late prehistoric and historic periods in this part of California. Lake Cahuilla, occupying the Salton Trough in southeastern California, altered the available subsistence resource base as it filled or emptied, depending on the Colorado River's course. From A.D. 700 to 1640, Lake Cahuilla provided lacustrine subsistence resources which disappeared with the lake's complete desiccation after A.D. 1700. A permanent European presence in southern California, beginning in A.D. 1769, restricted native peoples' access to their customary subsistence resources and displaced coastal native populations to more remote mountain regions. What is not known are the ways in which native peoples adapted their subsistence and social patterns to cope with the multiple stresses wrought by these changes.

Ethnological and archaeological studies (e.g., Minnis 1985, Smith 1988, Arnold 1992) have suggested several adaptive strategies that people use to cope with subsistence stress, including: (1) altering foraging practices, (2) increasing storage, (3) increasing residential mobility, (4) increasing food sharing, (5) exchanging durable goods for food, and (6) warring with competing groups. These strategies will be used in varying combinations and degrees, depending on the severity of subsistence stress. For short-term food shortages, family or household responses will be used before those requiring community or higher levels of organization (Minnis 1985:23). Responses requiring substantially increased social or political integration will be instituted only after less inclusive responses have proven ineffective.

We combine archaeological data recovered from Wikalokal, a site in southeast San Diego County, with Kumeyaay ethnohistoric data to investigate native subsistence stress adaptation. Archaeological data provide evidence for late-prehistoric foraging practice shifts toward greater emphasis on gathering and less emphasis on large-game hunting and an associated increase in storage. Ethnohistoric data suggest extensive residential mobility and kin-based resource sharing over a broad range of ecological zones.

THE ETHNOHISTORIC CONTEXT

The native occupants of contiguous portions of southern California and northern Baja California have been known variously as the Kumeyaay, Tipai, or Southern Diegueno. (For discussions of group name, see Kroeber 1925:723-725, Gifford 1931:1-11, Langdon 1970:2, Hedges 1975:71-83, Luomala 1978:592.) We refer to the group as Kumeyaay, the name used by contemporary descendants. Culturally and linguistically, they were closely related to the Kamia, who lived to the east in the Imperial Valley. It has been argued that the Kumeyaay and Kamia constituted a single ethnic group whose material culture varied with environmental adaptation. Whereas theKumeyaay hunted and gathered in the mountains, the Kamia additionally farmed the river-valley bottomlands, yet both groups claimed to be related, and they traveled back and forth between both areas (Hedges 1975). Together, these groups occupied a range of environmental zones, from the coastal strip, to the interior mountains, to the lowland desert and riverine environment of the Salton Trough.

It is difficult to determine Kumeyaay-Kamia aboriginal population; estimates vary from as low as 3,000 (Kroeber 1925:712, who did not include peoples in Baja California) to as high as 26,000, equivalent to 0.8 persons per square km (Shipek 1993:160). The variability of Kumeyaay terrain - coastal zone, mountain, lowland desert - suggests that population density varied across Kumeyaay territory. For the Luiseno, an adjacent native group to the north occupying the coastal and mountain zones, mission records suggest a population density of 1.0/sq km (White 1963). The technological and geographical similarity between the Kumeyaay and Luiseno suggests that Kumeyaay population, at least in the most productive portions of their territory, may have reached 1.0/sq km, a high population density for a hunting-gathering subsistence economy.

The traditional Kumeyaay subsistence economy may be characterized by flexibility in social relations and in spatial organization (Spier 1923, Luomala 1963). Historically and aboriginally, the Kumeyaay organized themselves in autonomous, seminomadic bands, each associated with specific territories. These territories encompassed a range of elevations, spanning lowland desert to highland mountain regions, allowing access to plants ripening at various seasons and to plants and animals native to several life-zones (Luomala 1978:593-594, 599-601). Cross-cutting these band groupings was a clan system, described as patrilineal and exogamous. There were some 50-75 clans represented in the Kumeyaay bands, and each band would have 5-15 clans represented in its membership (Shipek 1985:297). Clan lineage segments were situated in various ecological zones, and a concept of kin-based sharing within the clan facilitated movement to resource-rich zones during periods of local food shortage (Luomala 1963).

Food resources varied seasonally and spatially across Kumeyaay territory (see Table 1). In the western portions of Kumeyaay territory, the coastal foothills and mountains, sage-scrub and oak-chaparral plant zones were found. In these zones, acorns from six species of oak, a predominantly fall crop, provided the dietary staple. Additionally, important foods in the western zones were seeds (chia and grasses), fruit (prickley pear, and islaya), and yucca plants (chaparral yucca, or Yucca Whipplei), available during the spring and summer. In the eastern portions of Kumeyaay territory, the interior uplands and Colorado Desert foothills, a xerophytic plant community was found. In these zones, roasted agave collected in the spring assumed greater importance as a dietary staple. Secondary foraged foods included seeds of datil (Mohave yucca, or Yucca schidigera), cactus fruit, and mesquite beans. Pinyon pine is common at higher elevations (1200-1500m) in Kumeyaay territory (particularly in the Sierra Juarez); the Kumeyaay highly prized pinyon nuts, making regular trips to forage for them or secure them through trade. Kumeyaay fresh foods included greens such as goosefoot, miner's lettuce, and clover, as well as many grasses, stalks and roots; fresh or dried blossoms of clover, rose, cacti; and berries from manzanita, elderberry, and juniper.

During winter, when few foods were available for foraging, the Kumeyaay coalesced into large settlements at low elevations, occupied by several bands. These groups left the lowlands for the interior upland and foothill zones in the springtime as food staples began to ripen. Agave and yucca were the dominant spring food staples. The agave plant consists of a basal head, with a cluster of leaves, and a flower stalk which rises from the head once during the life of the plant; after flowering, the plant dies. Agave heads and flower stalks are edible and are best eaten in the spring, when they are full of sap, sweet and tender (Barrows 1900:58). To prepare agave, the flower stalk was cut off before the head was severed from its root with a chisel-shaped stick of hardwood. Leaves were removed with a stone tool and the head was roasted in a pit, leaving it to cook for several days (Castetter et al. 1938:44-45). The flower stalks could be roasted in the same pit as the heads or cooked in an open fire. The agave propagates itself by sending out shoots from the base of the plant, usually before the plant is mature enough for harvesting. In most cases, a mature plant is surrounded by many younger plants, which may be damaged by harvest of the mature plant. In areas convenient to desirable campsites, such as near springs, agave supply may have been depleted by intensive use, as noted by Aschmann (1959:79-80) for northern Baja California. Agave leaves were also harvested for their fiber, used to make nets and other woven objects. Chaparral yucca (Yucca Whipplei), distributed in the sage-scrub and oakchaparral zones, resembles agave and was prepared for eating in much the same way. A major difference, however, is that chaparral yucca reproduce by seeds rather than shoots and occur as solitary plants. When these yucca are harvested, they do not reproduce and, therefore, may be depleted by intensive use as food.

During summer, the Kumeyaay dispersed into small, mountain campsites, each occupied by a single band (50-100 individuals), where they foraged for seeds (chia, datil, and grass), fruits (prickley pear and islaya) and berries (manzanita, elderberry, and juniper). Their foraging activities intensified in the oak-chaparral zone during the autumn, when they collected several species of acorns. The average productivity of acorns by California oaks is high (Basgall 1987:24), although the production by a particular species of oak tends to vary on a several-year cycle (McCarthy 1993:215), underscoring the motivation for exploiting several species of oak and for storage. The primary problem of storage is to protect acorns from pests and moisture, which the Kumeyaay often accomplished using raised outdoor granaries. As well as being stored whole, acorns were also stored in a processed form, after being pulverized with a stone mortar and pestle, ground into flour with a metate and mano, sealed hermetically in clay jars with pine pitch, and then stashed among rocks or in caves (Spier 1923:334, Rogers 1936:18-19, Bean & Saubel 1972:19-22, Bean 1974:36-38, 53-54). Acorns contain tannic acid, a toxin that must be removed before they are eaten. Ground acorn meal was placed on a small pile of sand, and warm water was poured over it until the tannic acid was leached out. After leaching, the meal was ground again and then cooked with water to make a mush (Spier 1923:335)

Southern California was populated by both large and small game animals, although fewer large game animals were located here than in many other parts of North America. Kumeyaay hunted foods included large game such as deer, sheep, and antelope, as well as small game such as rabbits, rodents, birds, and reptiles (Spier 1923:334-338, Luomala 1978:599-601). Most important were rabbits (jackrabbit and cottontail) and rodents (wood rat and ground squirrel), which were widely available in Kumeyaay territory, including the arid desert and mountain areas. Large animals (mule deer, mountain sheep, and pronghorn antelope) had a more restricted distribution, primarily on the mountain slopes, and were more difficult to kill with native hunting equipment.

A bow and two forms of arrows were used for hunting: a reed arrow shaft with wooden foreshaft was used for hunting small game (quail, rabbits, and squirrels), and a straight stick either with a sharpened end or a stone projectile point attached to a foreshaft was used for big game (deer and sheep) (Spier 1923:351-352). Rabbits were also taken with a rabbit stick, a flat, slightly curved stick which was thrown edgewise, wounding or killing the animal (Spier 1923:337). Rabbits were also captured by groups of hunters. Fire was set to the brush to drive the rabbits out, whereupon arrows and rabbit sticks were used to kill them. When many people participated in rabbit drives, nets were set over runways and the animals were driven into them (Spier 1923:337). Although rabbits were extensively hunted, their high breeding potential makes it unlikely that they were depleted through hunting. The wood rat, another common meat source, builds a conical, above-ground nest of sticks. The Kumeyaay set fire to the nests and then shot the fleeing wood rats with arrows or clubbed them (Spier 1923:336). For large game (deer, sheep, and antelope) the principal problem with hunting involved getting close enough to the animal to kill it with bow and arrow, a range of less than about 50m. Hunters would chase deer to tire them out, at times requiring several days to run down a single animal, or would wait for deer at water holes (Drucker 1937:7, 1941:98). Success in hunting large game was more problematic than for small game, making small game a more reliable meat source.

The contribution of ocean fish, freshwater fish, and shellfish to the Kumeyaay diet may have varied greatly with geographic location. For campsites along the Pacific coast, there is little doubt that fish and shellfish were obtained from the sea. Early Spanish reports stated that fish and shellfish comprised the bulk of the diet for the many natives they saw near the shore, especially at San Diego Bay (e.g., Costanso\(aa 1934:39-40). Fishing was sometimes done from small canoes composed of reed bundles; not suited to the open sea, they were primarily used in sheltered bays and estuaries (Heizer & Massey 1953). Although fish and shellfish formed an important portion of the diet while the Kumeyaay were camped on or near the shore, these resources do not appear to have been carried inland in large quantities. Along these lines, Christenson (1992) has suggested that the Kumeyaay subsistence diet had minimal dependence on marine resources, despite abundant ethnohistoric documentation of coastal villages. Kumeyaay territory was not well-endowed with freshwater fish, except along the Colorado River valley and during periods when Lake Cahuilla was present in the Salton Trough, as will be discussed below.

It has been suggested that native Californians actively manipulated their environment as a component of their subsistence practices, especially by planned burning to enhance plant and animal resources (Lewis 1973, Bean & Lawton 1973, Timbrook et al. 1982). Fire can modify plant communities to provide improved forage for game animals, to increase the availability of plants with energy-rich reproductive parts directly consumed by humans, and to remove pests that would otherwise damage resource-rich trees, such as oak and palm. Ample ethnohistoric evidence supports Kumeyaay use of fire for these purposes before European intervention (Bean & Lawton 1973:37-42, Shipek 1993).

THE PREHISTORIC CONTEXT

Late Prehistoric Cultural Sequence (A.D. 600-1769)

The late milling, or late prehistoric, occupants of southern California and western Arizona have been designated Yuman (Gladwin & Gladwin 1930, Rogers 1945), Patayan (Colton 1945), and Hakataya (Schroeder 1957, 1979). Recognizing objections to the terms Yuman and Hakataya (Colton 1945, Harner 1958), we will use the designation Patayan, following Waters (1982). Broadly, the Patayan occupied the Colorado River margins and adjacent areas. Ceramic evidence for their occupation consists of paddle-and-anvil constructed, predominantly undecorated wares. The Patayan occupants of the Colorado River and adjacent Salton Trough, who produced Lower Colorado Buffware ceramics, are called Lowland Patayan; the Patayan occupants of the Peninsular Ranges of southern California and Baja California, the manufacturers of Tizon Brownware, are called Upland Patayan (Harner 1958).

The Patayan cultural sequence is divided into three phases based on changes in material culture and settlement pattern (Rogers 1945, Waters 1982:281). Patayan I (A.D. 600-1000) is characterized by the beginning of ceramic production near the Colorado River, the use of small projectile points, cremation of the dead, and presumably the beginning of maize agriculture. The principal area of Patayan I settlement was within the lower Colorado and Gila River valleys. Additional settlement was within the eastern portion of the Salton Trough. During this period a large freshwater lake, known as Lake Cahuilla, was present (or filling) within the Salton Trough (Waters 1983).

During Patayan II times (A.D. 1000-1500), use of ceramics spread to the Peninsular Ranges of southern California and new ceramic forms were developed within the Colorado and Gila River valleys and within the Salton Trough, possibly reflecting changes in diet and cooking practices related to expansion of maize agriculture in the Colorado River Valley. The water level of Lake Cahuilla was at its maximum height during most of this time, and settlement data show occupation of the lakeshore was intensified (Rogers 1945, Wilke 1978).

During Patayan III times (A.D. 1500-1769), Lake Cahuilla was largely dessicated, and only a few sites are found associated with its shoreline. Ceramics from this period are recovered along the Colorado River, in the Peninsular Ranges, and within the Salton Trough (Waters 1982:292). Agricultural practices appear to have been adopted by the inhabitants of the New River and Alamo River in the Salton Trough, as well as the inhabitants of the Peninsular Ranges (Treganza 1947, Wilke & Lawton 1975). The Patayan III period ended with the arrival of Europeans, whose increasing numbers eventually disrupted aboriginal subsistence and settlement patterns. Documentary evidence for cultural identity between the Patayan III and the historic Yumans (Quechan, Kamia, and Kumeyaay) is related by Spanish chroniclers and missionaries (Forbes 1965:96).

Geographic Setting

Depending on its wet or dry state, Lake Cahuilla's presence or absence impacted the resource base available to prehistoric inhabitants of southeastern California. The lake was created when the Colorado River shifted its course and flowed into the Salton Trough. Much of the Salton Trough is below sea level, and the basin fills to approximately 12 m elevation when the Colorado River is directed into it, requiring about 20 years to completely fill (Figure 1). When the river reverts to its original course, the lake evaporates in about 60 years (Wilke 1978).

Geomorphological evidence, historical observations, and radiocarbon dating suggest that there were at least six fillings of the Salton Trough in the last 2,000 years, with five intervening periods of at least partial desiccation (Figure 2). Waters' (1983) lake chronology is based primarily on stratigraphic observations and radiocarbon dates; the chronological precision of these lake stands is no better than the best radiocarbon dating uncertainty of ± 50 years. Waters (1983:382) dates the initial (less than 2,000 B.P.) high-water stand of Lake Cahuilla to around A.D. 700-890, followed by a period of recession but perhaps not complete desiccation. A second full lake stand dates to between A.D. 970-1150, suggested by high-water lacustrine sediments. Another recession or complete desiccation of the lake occurred in the early 13th century, followed promptly by the third full lake stand, A.D. 1230-1300. At approximately A.D. 1300, one or more partial lake recessions occurred, returning to another full stand during A.D. 1350-1400. Another partial recession, based on fluvial sediments, is proposed for the early 15th century, returning to a full stand during A.D. 1450-1500. The first Spanish accounts of this region, dating to A.D. 1539-1540, present clear evidence that the Colorado River was draining directly into the Gulf of California, rather than filling Lake Cahuilla at this time. Likewise, the Colorado River natives made no mention of a large, nearby freshwater lake, suggesting that the lake was absent during this period. A brief historic period full lake stand, A.D. 1625-1640, has been documented by excavations at the Elmore Site within the basin (Laylander et al. 1994). After this time, there is ample historic documentation that the basin was completely desiccated. Despite the fluctuations of Lake Cahuilla described above, during the period A.D. 700-1500 the lake was primarily filled to its highest water level; periods of recession during this time are not documented to have resulted in complete dessication, and modeling suggests that prohibitive levels of salinity would not have been reached during recession until the lake had fallen to an extremely low level (Laylander et al., 1994:91).

During the high stands of Lake Cahuilla it would have provided a lacustrine environment appropriate for diverse and productive food resources including waterfowl, freshwater fish and shellfish, and a variety of plants. Habitation sites were first located along the lake shore during Patayan I times and were increased in numbers during Patayan II times, especially at the high water shoreline, before substantial abandonment of the lake area during Patayan III times.

Two models have been presented for assessing the effect of Lake Cahuilla on native populations. Wilke (1978) suggests that, when Lake Cahuilla remained at its maximum level for several generations, native population increased. Population growth was permitted, in part, by the reliable lacustrine resource base. A permanent occupation of lakeshore sites is suggested by the varying seasons of resource use and by the large number of Patayan II settlements along the shoreline. As Lake Cahuilla dried up, the Patayan III period records large-scale population movements out of the Salton Trough into the Colorado River Valley and into the Peninsular Ranges of southern California (Rogers 1945, O'Connell 1971). The spread of agriculture is thought to have been a way to restore a population/resource balance during this period (Wilke & Lawton 1975).

Weide's (1976) model, alternately, suggests that, since the lake remained full only for short periods (at most 200 years), its fluctuations were severe enough to discourage substantial reliance on its resources. Native peoples, therefore, would have maintained flexible subsistence and settlement patterns, and only slight population increases would have occurred during the Patayan II period. The lake's desiccation during the Patayan III period would have encouraged greater reliance on a broad range of subsistence strategies, including agriculture, but would have produced only minor population displacements (Weide 1976:91). A partial resolution of the differences between these two alternate models may be that the intensity of lakeshore occupation varied at different locations. The northern lakeshore, the site of Wilke's (1978) study, may have harbored a more sedentary and enlarged population than the southern lakeshore, perhaps owing to accessibility of non-lacustrine resources. Although testing the regional applicability of these two models would require additional study of both Lake Cahuilla's history and native subsistence-settlement practices, it is clear at this juncture that the lacustrine history of Lake Cahuilla is key to understanding the region's prehistory.

THE HISTORIC CONTEXT

Europeans first arrived in southern California in the mid-16th century, and extensive colonization of the area began in the late 18th century. At this time, missions were established in Kumeyaay territory on the Pacific coast, and a trail for Spanish settlers was opened across the interior desert. The late 18th and the 19th centuries marked a period of mounting stress for the Kumeyaay, beginning in the Spanish period

(A.D. 1769-1821) and continuing in the Mexican period (A.D. 1821-1848) into the U. S. period (from A.D. 1848). The presence of missionaries, entrepreneurs, settlers, and military personnel permanently altered Kumeyaay existence. The foreign presence impacted Kumeyaay territorial organization, particularly in the coastal margin, forcing indigenous inhabitants to move eastward and southward with the intent of joining kinsmen or establishing new sociopolitical groups (Phillips 1975:40, Shipek 1970:26); foreign presence impacted the Kumeyaay population by introducing new labor systems (Castillo 1978:99) and by disease and epidemics which reduced the Kumeyaay to some 20-30 percent of their original numbers (Kroeber 1925:883); foreign presence impacted the Kumeyaay food supply by introducing a new element of competition in addition to new concepts of property rights and new technology, plants, and animals. "Extensive [European] agriculture prevented communal hunts for rabbit and deer. The Whites' fences prevented women from gaining access to oak groves for acorn gathering" (Castillo 1978:108). "Domestic animals changed the plant ecology as the original seed-food grass disappeared and was replaced by European grasses and weeds. Overgrazing brought a period of accelerated erosion and lessened surface water availability. Antelope and bear disappeared; mountain sheep and mountain lion became almost extinct; deer were reduced in range and numbers. Access to coastal food was reduced" (Shipek 1978:610).

In short, the European, Mexican, and U. S. presence destroyed traditional Kumeyaay subsistence patterns, albeit with varying rates and amounts of change. Variation depended on relative isolation from the newcomers. The more rugged mountain and desert reaches of Kumeyaay territories remained relatively independent until 1850, some until 1910 (Shipek 1978:610; cf. Bean 1974:17-18, Phillips 1975:41, Luomala 1963, 1978:592). Between 1850 and 1910, U. S. settlers took the best lands and forced the Kumeyaay bands onto reservations under bureaucratic controls (Shipek 1987).

THE ARCHAEOLOGICAL CONTEXT

The archaeological data for our study come from the site of Wikalokal (SDI-4787), located in the Peninsular Range of southeastern San Diego County (see Figure 1). In Kumeyaay, Wikalokal means "singing rocks" (M. Langdon, pers. comm.) or "rocks near the cottonwoods" (M. Rogers, San Diego Museum of Man, File W-205), indicating key features of this site reported to have been important aboriginally--outcropping rocks and trees. It is located near the boundary between oak groves in the Cottonwood Valley and chaparral on the surrounding hillsides. The acorn, dietary staple of the Kumeyaay, is easily accessible, outcropping bedrocks provide attractive milling features, and a nearby permanent spring and intermittent stream provide water. Situated at an elevation of 975m, Wikalokal is within 10 km of the 1800m summit of Laguna Mountain and within 16 km of the pinyon pine forests of the Sierra Juarez Mountains, providing a broad range of vegetation zones and food resources.

Wikalokal may have been seasonally inhabited beginning in the spring and intensifying during the summer and autumn months, when a series of seeds and nuts became available. In the spring, yucca would be available nearby, although more abundant areas of agave would be found in the interior uplands and desert foothills to the east. In summer, grass and chia seeds would be available, both requiring milling. The greatest use of Wikalokal was probably during the fall; it is specifically mentioned as a fall gathering area for four different Kumeyaay bands (Cline 1984:25). In October and November the acorn was harvested and milled, and acorn-foraging game, abundant at this time, was hunted.

The occupation of Wikalokal spans preceramic to historic time periods, from about 400 B.C. to A.D. 1890 based on radiocarbon samples excavated from the site and on typological changes in lithic tool types (Rogers 1966). Two components of occupation are represented at Wikalokal: a preceramic early milling horizon related to the La Jollan (Warren 1968) or Amargosan Complex (Rogers 1939, Wallace 1962), and a late prehistoric/historic horizon representing the Patayan/Kumeyaay. For reasons we assume that the site was abandoned by A.D. 1890: (1) Kumeyaay reservations were established nearby at Campo and at La Posta in 1893 (Shipek 1978:612), and (2) few non-indigenous artifacts were recovered at the site--a porcelain projectile point and crockery fragments. Even accounting for curation of metals, porcelains, or other European artifacts, it is remarkable that the middens did not yield more evidence of interaction between the Kumeyaay and European groups.

MODELING SUBSISTENCE CHANGE

Models of hunter-gatherer subsistence activities have been patterned after ecological studies viewing subsistence variations as adaptations to varied environments. Optimal foraging models address questions of hunter-gatherer diet choice--which foods are selected from the variety of foods available (see Winterhalder 1981; Smith 1983). Optimal foraging studies assess the strategies that foragers follow in diet selection. Strategies that have been suggested are maximization of energy and/or nutrient acquisition, minimization of time spent foraging, or minimization of famine risk. The idea that foragers choose optimal solutions has been criticized (Jochim 1983) but this approach does provide a quantitative test of diet selection models. It is not yet clear under what conditions these (or other) strategies were used by hunters-gatherers or how environmental stress would modify foraging strategy selection.

We represent foraging by two behavioral categories: hunting and gathering. This is done for simplicity and because hunting and gathering may have toolkits that are recognizable in the archaeological record. We assume that subsistence strategies are chosen based on their costs and benefits. Subsistence costs are the time and energy expended and include search costs (expended in locating the subsistence items) and handling costs (expended in capturing, preparing, and consuming the subsistence items) (Hawkes & O'Connell 1992). The sum of search and handling costs is called the cropping rate; quantitatively, this is the time required per kilogram of acquired resource. Table 2 gives search and handling cost estimates for several hunted and gathered foods obtained from experimental (Simms 1987) and ethnographic (Lee 1968) studies.

Since hunting and gathering provide restricted yields, their costs increase as the levels of resource exploitation and depletion increase. For hunters and gatherers, increased subsistence costs reflect the need to travel further from a base camp to find resources, the need to search longer for resources, and the need to procure products of smaller size and lower quality (Lee 1969). For deer hunting, search costs are highly dependent upon deer population density; fewer deer are seen at lower population density, requiring greater search time to encounter them (Van Etten et al. 1965:67, Holsworth 1973:338). If search time is the primary cost for resource procurement, as it is for hunting large game, the abundance and density of the resource becomes the critical factor in the cost for procurement.

We propose that search costs, and therefore cropping rates, increase exponentially with increased resource utilization. This suggestion is based on the idea that resource utilization above a certain level (λ) will result in depletion. A quantitative expression of this relation for hunting is,

$$K_h \equiv B_h \exp(H / \lambda_h) \tag{1}$$

and for gathering,

$$K_g \equiv B_g \exp(G / \lambda_g) \tag{2}$$

where K is the cropping rate, B is the baseline rate, λ is the utilization level for depletion, and H or G are the actual utilization of hunted or gathered resources, respectively. By resource depletion we mean that the resource is instantaneously more difficult to procure, for example, greater search costs are required to find acorns after the most easily accessible nuts have been procured. At high exploitation levels, those approaching λ, the cropping rate, K, increases significantly. Since it is generally true that animal biomass is far more limited than plant biomass, hunted resources are generally more restricted and are depleted more rapidly than are gathered resources. The utilization level for animal depletion by hunting, λ_h , is far lower than for plant depletion by gathering, λg . High exploitation of a resource may also result in long-term depletion (lowering λ) and may not be sustainable (see Winterhalder & Goland 1993). Depending on the animal or plant species, the potential for long-term depletion varies greatly; for example, large game animals (e.g., deer, mountain sheep) with long gestation periods and small numbers of offspring are much more easily depleted than small game species (e.g., rabbits and rodents) with short gestation and large numbers of offspring. Likewise, utilization of nuts, seeds and fruits, without destroying the parent plant (e.g., acorns, prickley pears) is less likely to lead to long-term depletion than when the parent plant itself is collected (e.g., yucca and agave).

The baseline rate, B, is the marginal cost of resource utilization when the exploitation level is low, for example, when no significant resource depletion has occurred. This is the time and energy expended on tool manufacture and other preparations for a given subsistence activity; for example, production of bows and arrows for hunting, or carrying nets and baskets for gathering. As high resource utilization levels are attained, the cropping rates of horticulture may be as low as those of hunting and gathering, but, the baseline costs, B, of horticulture are higher than hunting or gathering due to the need for field preparation and tending (Earle 1980:20).

Quantitative cropping rate estimates for the Kumeyaay are lacking. These data were not collected by ethnographic research before Kumeyaay subsistence practices were significantly altered by European contact. However, qualitative descriptions of aboriginal Kumeyaay subsistence practices are available (Spier 1923, Hicks 1963, Shipek 1989) and can guide selection of analogous cropping rate estimates from modern studies. We use hunter-gatherer cropping rate estimates from the experimental studies by Simms (1987) for the Great Basin and from the ethnographic studies by Lee (1968, 1979) for the !Kung San. Lee observed that hunting meat required 3.3 hr/kg, butchering and cooking meat required 0.8 hr/kg, and maintaining hunting tools required 1.3 hr/kg. These estimates give a total cropping rate of 5.4 hr/kg for !Kung San hunting.

We recognize that there may be significant differences between !Kung San and Kumeyaay hunting practices. In particular, the Kumeyaay region was not as heavily populated with large game animals as the !Kung San region, making small game such as rabbits and rodents the more important hunted foods for the Kumeyaay. The search cost for small animals may be less than those of large game animals (Table 2). Improved comparability with Kumeyaay hunting may be obtained by using data from modern Great Basin hunters pursuing deer, jackrabbit, cottontail rabbit, and squirrel (Simms 1987). These data suggest an average hunting search time of 2.8 hr/kg and butchering time of 0.1 hr/kg. To these values we add !Kung San ethnographic data on cooking costs (0.7 hr/kg) and tool maintenance (1.3 hr/kg)--costs not included in Simms' (1987) handling time estimates. These experimental Great Basin data then yield an estimated cropping rate of 4.9 hr/kg, slightly less than but comparable to the !Kung San cropping rate for hunting.

For !Kung San gathering, mongongo nuts comprise 40-50 percent of the total gathered vegetable foods by weight (despite periodic failure of the mongongo nut crop). Combining mongongo and other vegetable foods, a seasonally averaged search rate for !Kung San gathered foods is 1.3 hr/kg (Belovsky 1987). Adding a food preparation rate of 5.3 hr/kg and a tool repair requirement of 0.4 hr/kg yields a total cropping rate of 7.0 hr/kg for !Kung San gathered foods.

Acorns provided a vegetable staple for the Kumeyaay, analogous to mongongo nuts for the !Kung San. The high energy return for acorns (980 kcal/hr) contributes to their desirability, although this return is not substantially greater than for some other gathered foods; based on Simms' (1987) experimental studies for Great Basin foodstuffs, Table 2 presents the cropping rates for acorns, pinyon nuts, and representative seeds. The energy return rate for some seeds can be quite low (e.g., Saltgrass = 100 kcal/hr); a net energy loss can result from their collection, suggesting that the importance of these seeds may be as stored foodstuffs to be eaten during the more barren wintertime. If we assume Kumeyaay gathered foods to be dominated by acorns (50 percent), and if we exclude the most energy expensive seeds, we estimate an average cropping rate of 6.5 hr/kg for the gathered foods in Table 2, slightly less than for the !Kung San.

Quantitative foraging models apply constraints to the potential range of hunting and gathering behaviors (Belovsky 1987). In one approach, called linear programming, constrains are written as a linear combination of the foraging behaviors. Taking the food acquired by hunting and gathering to be H and G, respectively, a behavioral constraint is written:

$$C \geq K_h \; H + K_g \; G \;, \tag{3}$$

where C is the limitation or constraint. Based on physiological considerations, Belovsky (1987) suggests a time constraint of approximately 7 hr/day devoted to foraging. Using the !Kung San cropping rates for hunting ($K_h = 5.4$ hr/kg) and gathering ($K_g = 7.0$ hr/kg) the linear model suggests that in a subsistence economy based entirely on hunting, one adult forager would yield 1.3 kg/day of meat. Likewise, in an economy based entirely on gathering, the yield would be 1.0 kg/day. These estimates do not consider the consequences of resource depletion (both short-term and long-term) that accompany intensive utilization of a foraging resource. In particular, a foraging strategy based entirely on hunting large game could deplete the animal resource base and consequently increase the cropping rate for hunted foodstuffs. To account for this, we earlier defined (Equation 1) a cropping rate that is dependent on the level of resource usage. For initial estimates of the baseline cropping rate B and usage level for depletion λ, we double the !Kung San hunting output (λ_h = 0.70 kg/day, B_h = 3.3 hr/kg) and quadruple their gathering output (λ_g = 3.12 kg/day, B_g = 5.1 hr/kg). Combining the time constraint with the above gives:

$$C \text{ hr/day} \geq 3.3 \text{ hr/kg} \; \exp(0.70 \text{ kg/day } H)\, H \; + \; 5.1 \text{ hr/kg} \exp(3.12 \text{ kg/day } G)\, G \qquad (4)$$

This is a nonlinear equation requiring numerical methods (e.g., Newton-Raphson method in Press et al. 1986:254) to find solutions for H and G, given a time constraint C.

Total caloric food intake is another constraint that can be placed on Kumeyaay foraging. Following Bently (1985), hunter-gatherer minimum energy requirements are approximately 2,000 kcal/day. Assuming that there are dependent children and elders, support is needed for one-half of a non-foraging individual, making the adult Kumeyaay foraging output at least 3,000 kcal/day.

Estimates of the energy content of hunted meat range from 1,000 to 4,000 kcal/kg (Lee 1979, Dwyer 1983, Hill et al. 1984, Simms 1987). Variable meat fat content determines its overall energy yield, since fat content may vary by species and by season (Speth & Spielmann 1983). We use 2,500 kcal/kg as an estimate for the average energy content of Kumeyaay hunted foods, higher than expected for small game but lower than expected for large game with significant fat content.

The energetic values of Kumeyaay gathered foods (Table 3) are: acorns and pinyon nuts, approximately 5,000 kcal/kg; fruits, berries, and seeds, approximately 3,000 kcal/g. Assuming gathered foodstuffs are divided equally between these two categories, the average value is approximately 4,000 kcal/kg. With these estimates, the energy constraint on Kumeyaay foraging is:

$$3{,}000 \text{ kcal/day} \quad \geq \quad 2{,}500 \text{ kcal/kg } H \; + \; 4{,}000 \text{ kcal/kg } G \; . \tag{5}$$

This is a linear relation between the acquired energy (kcal/day) and the output level of hunting or gathering (kg/day).

The protein provided by Kumeyaay foraging places an additional constraint on the relative contribution of hunted and gathered foods. The recommended daily allowance (RDA) for protein is 60 g/day. Allowing for the support of non-foraging individuals, the foraging requirement per adult is 90 g/day of protein. The protein content derived from !Kung San hunting is estimated to be 15 percent by weight for cooked meat (Lee 1979). The protein derived from Kumeyaay gathering (Table 3) is taken to be an average of acorn protein content (5 percent) and the protein content of other representative gathered foods (9 percent). An aggregate percentage protein for gathered foods is 7 percent, resulting in the following protein constraint:

$$0.09 \text{ kg/day} \quad \geq \quad 0.15\, H \; + \; 0.07\, G \; . \tag{6}$$

This is a linear relation between the acquired protein (kg/day) and the output level of hunting or gathering.

The time, energy, and protein relations (Equations 4, 5, and 6) are shown in Figure 3 for three different levels of resource utilization and/or depletion ((a) low resource exploitation $\lambda_h = 1.05$ kg, $\lambda_g = 3.5$kg, (b) medium resource exploitation $\lambda_h = 0.7$ kg, $\lambda_g = 3.12$kg, and (c) high resource exploitation $\lambda_h = 0.35$ kg, $\lambda_g = 2.5$kg.) In each plot, the time equation is shown for three constraint values (5, 6, or 7 hr/day foraging), displayed as three dashed lines. As discussed above, hunters and gatherers devote no more than approximately 7 hr/day to foraging; the possible levels for hunted and gathered foods will lie to the left of the 7 hr/day curve in Figure 3.

The energy and protein equations, displayed as solid lines in Figure 3, represent minima. The possible levels for hunted and gathered foods will lie to the right of both solid lines in Figure 3. The allowed region, that which satisfies all three constraints, is shaded in Figure 3. At low levels of resource depletion, for example, in an area with low population and a large resource base, a broad range of strategies will satisfy the time, energy, and protein constraints (Figure 3a). The time minimizing solution, found at the lower left vertex of the roughly triangular allowed region, requires less than 5 hr/day of foraging for the low resource depletion model (Figure 3a), whereas the energy maximizing (upper left vertex) and the protein maximizing (lower right vertex) solutions utilize the limit of 7 hr/day of foraging. The center of mass for the region satisfying all three constraints is a median foraging solution (open dot in Figure 3). In Figure 3a the median solution is 460g (44 %) hunted and 580g (56 %) gathered foodstuffs, expending 6 hr/day in foraging. In Figure 3b, the level of resource depletion is moderate, the average values given for Kumeyaay foraging above. In this case the median foraging solution is 390g (39 %) hunted and 620g (61 %) gathered foods, and the time expended is 6.2 hr/day. For heavy resource depletion, Figure 3c, there are a narrow range of viable foraging solutions. In this case, the median foraging solution is 320g (33 %) hunted and 640g (67 %) gathered food, and the time expended is 6.8 hr/day. Since the depletion of hunted resources is more rapid than the depletion of gathered resources, the models predict a shift toward greater reliance on gathered foods when the level of resource utilization is increased.

KUMEYAAY SUBSISTENCE STRATEGIES

Kumeyaay ethnohistoric data suggest that animal foods provided a much smaller portion of their diet than plant foods, despite a substantial dedication of men's time to hunting (Hicks 1963). Subsistence energy return data, presented in Table 2, confirm that gathered staples (acorns and pinyon nuts, and presumably also agave/yucca, although quantitative data are not available) provide a far higher energy yield than any form of hunting available to the Kumeyaay. Likewise, hunting of small game (rabbits and squirrels) provides a greater energy yield than large game (deer), primarily because of increased search costs. When protein considerations are included, the potential contribution from hunting becomes more attractive; for example, in the median foraging model with moderate resource depletion (Figure 3b), hunting contributes 39 percent by weight, a proportion that may be higher than actual Kumeyaay subsistence practice. One explanation may be that an abundance of high energy return plant resources, particularly acorns, supported a high population density to the extent that there were too few game resources proportionally to make a large contribution to the total diet. On the basis of high oak productivity levels, Baumhoff (1981:81) previously noted for the southern North Coast Ranges of California that acorns alone could have supported a much higher population density than that observed at the time of European contact.

Subsistence stress is another factor to consider relative to the above foraging model, as well as to previous ethnohistoric and archaeological research. The model predicts that, for subsistence stress leading to resource depletion, subsistence practices shift toward greater reliance on gathered foodstuffs and toward less reliance on hunted foodstuffs, to the extent that hunted resource are depleted before gathered resources. Along these lines, depletion of large game is more likely than small game, because of relatively lower fertility rates. Expansion of food storage is another possibility; greater reliance on gathering may require greater storage to buffer for periods of insufficient plant food availability. Given a 2-3 year cyclic productivity for most oak varieties (Basgall 1987:24), storage of at least a one-year supply of acorns would appear to be a beneficial strategy. A set of social responses also may have been implemented; the scope of intra-band economic and social integration may have increased, to foster greater coordination for efficient food procurement or to incorporate clan members seeking refuge from European-occupied zones. Depending on the nature and duration of the subsistence stress, other options that may have come into play include exchange of durable goods for subsistence resources, changes in residence or mobility, or changes in subsistence processing techniques.

Casual horticulture is a strategy that may be initiated when the costs for gathering become high. Bean and Lawton (1973), following the suggestion of Lewis (1973), detailed how burning may have been a form of proto-agriculture in pre-European southern California. Timbrook et al. (1982) have presented ample evidence for this practice among the Chumash. Shipek (1993) has suggested that the Kumeyaay invested substantial effort in field preparation by burning and drainage control to provide an environment for propagation of beneficial plants, particularly native grasses. Restrictions by European settlers made these practices disappear, with subsequent loss of subsistence resources.

Stressors on Kumeyaay subsistence, resulting in resource depletion, may relate to environmental fluctuations, to population increases, and to the invading European population. It has been previously suggested that Lake Cahuilla provided a lacustrine resource base, albeit with lake-level fluctuations, during the period A.D. 700-1640 but was absent after A.D. 1700. Following the desiccation of Lake Cahuilla, populations dependent on its resources may have made greater demands on the subsistence resources of surrounding areas, such as the Peninsular Range of southern California (Rogers 1945, O'Connell 1971), creating a period of regional subsistence stress. The desiccation of Lake Cahuilla may be coincident with the apparent population increase that occurred in the Peninsular Range between the early milling horizon and late prehistoric horizon, suggested by the increased numbers and densities of sites (see Wilke 1971, Cook & Fulmer 1981). Finally, a multitude of environmental changes were produced by European arrival beginning in the 18th century and intensifying in the 20th, some of which significantly impacted the Kumeyaay subsistence resource base.

EXCAVATIONS AT WIKALOKAL

Excavations at Wikalokal (Figure 4) yielded information pertaining to prehistoric subsistence strategies. Impacted by an interstate freeway, Wikalokal was excavated by San Diego State University under the auspices of the California Department of Transportation in 1971. The excavation proceeded by 2m x 2m units (keyed north-south and east-west from site datum) and by arbitrary 10 cm levels. The excavated volume of 138.4 m^3 yielded 85,841 ceramic sherds, 6,143 lithic flakes, 118 lithic tools, 74 projectile points, 159 ground stones, 3,327 bone fragments, and 90 mollusk shells.

The site of Wikalokal is situated at the edge of the Cottonwood Valley in a depositional setting of primarily sandy alluvial sediments (Figure 4). Metamorphic bedrock outcrops occur as two knolls within the site area, an attractive feature for native site inhabitants, as they contain many bedrock milling features. Two isolated charcoal samples yielded 14 C ages: 2390 ± 80 B.P. (WSU-3190, wood charcoal) at 100 cm depth and 200 ± 90 B.P. (WSU-3191, wood charcoal) at 55 cm depth. Using the radiocarbon timescale calibration of Stuiver and Pearson (1993), the older sample dates to 405 B.C. at 100 cm depth.

For the younger sample at 55 cm depth, calibrated dates of A.D. 1670 and A.D. 1790 are possible, due to oscillations of the timescale calibration curve. These two samples suggest a non-linear deposition rate for the site soils (greater soil deposition during the later periods of site formation), although this cannot be verified with only two dates. We will discuss site formation and potential sources of site disturbance below. A radiocarbon date at 405 B.C. and changes in artifact recovery discussed below are suggestive of two cultural horizons being represented at Wikalokal: an early milling horizon (La Jollan or Amargosan, 400 B.C. to A.D. 600) and a late prehistoric/historic horizon (Patayan/Kumeyaay, A.D. 600-1890).

Site Material Distributions

Ceramics at Wikalokal, shown in Figure 5a by weight, were encountered down to depths of 90 - 100 cm, but the deepest levels yielded such small quantities that their presence probably reflects site disturbance (e.g., rodent activity). Significant quantities (> 60 g/m^3) of ceramics appeared only above 60 cm. The quantities of ceramics recovered at Wikalokal increase linearly above 40 cm; by weight, about 10 times more sherds were recovered in the 0-10 cm level than in the 40-50 cm level. This increase in sherd recovery did not result from excavation procedures: the same ratio is observed when ceramic weight is normalized by the excavated volume for each 10 cm level (Figure 5b).

Groundstone artifacts were encountered as permanent bedrock features (grinding slicks and milling basins) and as portable objects (manos, pestles, and metates). The recovery of portable groundstone displays a pattern similar to that of ceramics. Groundstone manos and pestles, shown in Figure 6 by frequency, were recovered to depths of 70-80 cm. The numbers of manos and pestles recovered at depths below 40 cm was small--seven or fewer were found in each level. Above 40 cm, the numbers of manos and pestles increased significantly; 30 or more were recovered in each of the upper three 10-cm levels. Groundstone metates (Figure 6) were recovered from the surface to a depth of 50-60 cm. The numbers of metates recovered at depths below 20 cm was small--only two were recovered in each level. Above 20 cm, the numbers of metates increased by a factor of four. Portable groundstone manos, pestles, and metates therefore suggest a pattern of increasing use at Wikalokal until the time of site abandonment.

A total of 74 lithic projectile points were recovered at Wikalokal at depths down to 70-80 cm (Figure 7). The number of projectile points recovered at depths below 40 cm was small. The number of projectile points recovered was a maximum of 16 in the 20-30 cm level, and was slightly downward trending at shallower levels, with 13 in the 0-10 cm level.

Lithic tools found at Wikalokal include utilized flakes, unifacially retouched flakes, and unifacially retouched cores (Figure 8). The lithic tools follow a depth pattern somewhat similar to projectile points. Few tools were recovered at levels below 30 cm, with maximum tool recovery in the 10-20 cm level. Despite changes in numbers of tools recovered with depth, no significant changes are observed in the lithic tool assemblage; utilized flakes comprise half or more of the lithic tools recovered in all levels.

Lithic debitage, represented in Figure 9, was recovered to a depth of 110 cm--but only small amounts were recovered below 80 cm. Above 80 cm, debitage was found in increasing amounts; the largest amount was in the 20 -30 cm level. A drop in lithic debitage was observed for the two uppermost levels; half as much by weight in the 0-10 cm level as in the 20-30 cm level.

The Wikalokal faunal material represents mainly small game animals: birds, rabbits, rodents, and tortoises. Although a total of 3,327 bones and bone fragments were recovered, only a small percentage were attributable to large game animals. The faunal sample represents only macro remains (> .25 inch), since micro recovery techniques were not employed. The recovery of faunal material (Figure 8) mirrors the flaked lithic debitage (see Figure 9). The frequency of bone increased steadily from six fragments of bones recovered in the 100-110 cm level to a peak of 783 recovered in the 20-30 cm level; fewer than 300 were found in the 0-10 cm level.

To summarize, the use of ceramic and groundstone artifacts increased through time at Wikalokal, relative to the use of flaked lithic tools, lithic debitage, and faunal remains. The upper levels of the site (0-40 cm) show the weight of ceramic artifacts to have increased by a factor of 10 and the numbers of groundstone artifacts to have increased by a factor of seven relative to the lower levels (40-90 cm), whereas a constant or diminishing recovery of lithic and faunal materials is observed in the upper 20 cm of the site.

Subsistence strategies, gathering and hunting, will guide our discussion of artifact recovery at Wikalokal. As a first approximation, we assume that particular groups of artifacts play dominant roles in each subsistence strategy. The distinction between gathering-related and hunting-related artifacts is admittedly heuristic; multi-function artifacts are probably the rule rather than the exception. The goal of this distinction is simply to reflect general associations of subsistence strategies with their material correlates.

GATHERING STRATEGIES

We identify groundstones and ceramics to pertain primarily to gathering strategies. Artifacts related to gathering strategies were those used to mill plant products--manos, metates, pestles and mortars--and those used to process, cook, and store plant products--ceramics and woven baskets, although we will not consider baskets further, owing to their poor preservation at an exposed site such as Wikalokal.

Ceramics

There is substantial documentation for ceramics usage in the cooking of gathered plant products. Ceramics were mentioned for boiling or cooking acorn mush, amaranth greens, datil seed pods, goosefoot greens, islaya seeds, juniper berries, tuna buds, and yucca flowers. Likewise, ceramics were used for parching seeds and nuts: amaranth, chia, goosefoot, jojoba, pinyon, and saltbrush (Palmer 1878, Barrows 1900, Spier 1923). There is little doubt that ceramics also played a role in boiling small game, particularly lean meat animals such as rabbits. Ceramics also played an important role in plant food storage, although large volume storage was accomplished with outdoor basket granaries. Ceramics were probably little used for food transport during gathering; this job was better done with various kinds of carrying baskets. Water transport and storage were two of the most important functions for ceramics. Ceramics, therefore, were important for food preparation, primarily for boiling, cooking, or parching plant foods, but there were other functions, such as for carrying water or boiling small game, that would also have contributed to the ceramic assemblage.

There are two ceramic wares in the Wikalokal assemblage, both plainwares, Tizon Brown (>98 percent) and Lower Colorado Buff (<2 percent). For this study, we focus on Tizon Brown Ware (Dobyns & Euler 1958, Euler 1959, Lyneis 1988). The beginning of Tizon Brown Ware use on the Colorado River has been dated by association with Lino Black-on-Grey (Schroeder 1961), a tree-ring dated type which spanned A.D. 610-800 (Breternitz 1966:82). The appearance of Tizon Brown Ware in the Peninsular Range has been radiocarbon dated at A.D. 1000 (May 1976).

Increasing ceramic sherd recovery, corresponding to the later occupation of Wikalokal, may reflect increased numbers of people using ceramics. This suggestion is based on archaeological and ethnohistoric documentation of greater population in the Peninsular Range during the late prehistoric period, perhaps related initially to desiccation of Lake Cahuilla and finally to European encroachment. In the first case, desert makers of Tizon Brown Ware may have moved into the Peninsular Range sometime during A.D. 1500-1700 to compensate for dwindling lacustrine resources. In the second case, Kumeyaay impacted by European occupation of the coastal strip after A.D. 1769 may have shifted to inland locations, less accessible to the foreign settlers and better situated for native subsistence activities. Furthermore, Kumeyaay commensal group size may have increased as coastal clan members or clan member claimants opted to join their inland cousins (Luomala 1963).

Another factor influencing ceramic usage may have been an increased reliance on ceramics for cooking and storage (Brown 1989). In particular, the later occupants of Wikalokal may have intensified their use of gathered plant foodstuffs and small game in response to declining large game populations (the result of increased native population density in the Peninsular Range) and to restricted access to native territories (the result of European settlement). Increased numbers of ceramic artifacts would then reflect an increasing need to cook and store gathered plant foodstuffs local to Wikalokal, an area relatively far from Spanish-Mexican settlements. Ceramics may also have played a greater role in processing small game animals, as boiling small game within ceramic vessels is a particularly efficient means of extracting food value by capturing grease from cancellous bone tissue.

Changes in ceramic vessel morphology, suggesting differences in cooking and storage requirements and/or group size, occurred concomitant to their greater level of usage. As a measure of vessel size and shape, we used potsherd curvature to reconstruct average vessel morphology (Hagstrum & Hildebrand 1990). This method was applied to sherds excavated adjacent to a large bedrock milling feature associated with food processing activities. The sherd sample was grouped into three levels: Level I, 0-10 cm; Level II, 10-40 cm; and Level III, 40-90 cm. Within each level, the average vessel rim radius was only slightly smaller than the average vessel body radius, suggestive of hemispheric open-mouthed vessels for cooking, where frequent access was required (Rogers 1936). The average vessel body radius increased with time (Level III = 9.8 cm, Level II = 10.5 cm, and Level I = 12.1 cm). The volume of Kumeyaay pots, therefore, increased by about 35 percent between Levels II and I, although pot shape remained the same. That vessel size increased in the later period of site occupation is supporting evidence for greater emphasis on parched or boiled foods (plant and small game) and/or larger commensal groups. Larger vessel size is also suggestive of greater emphasis on storage.

Groundstone

Groundstones were used to crack, pulverize, or reduce to a paste a wide range of gathered plant products. The ethnohistoric literature is explicit that the Kumeyaay and/or their neighbors used groundstones to process the following fruits, nuts, berries, or seeds: acorns, amaranth, chia, datil, elderberry, goosefoot, islaya, jojoba, juniper, manzanita, pinyon, saltbrush, and prickley pears (Palmer 1878, Barrows 1900, Spier 1923, Meigs 1939)-- which account for the major subsistence plants utilized by the Kumeyaay. There are also reports of the Colorado River Yuman tribes using groundstones to pulverize rodents such as wood rats (Castetter & Bell 1951:217), although this may account for a small percentage of overall groundstone use. Other uses of groundstone may be grinding pigments and processing plant fibers.

Portable groundstone at Wikalokal consisted of manos, pestles, and metates. Manos (used primarily for food grinding) and pestles (used primarily for pounding) were manufactured from conveniently sized river cobbles. Huckell's (1986) summary of ethnographic groundstone production suggests that they were procured at the household level as needed, although production by part-time specialists has been documented for the Mohave on the lower Colorado River. A classification of the Wikalokal groundstone distinguished three basic attributes of tool modification: unshaped, large-grained shaped, and fine-grained shaped (Fink n.d.). These attributes reflect increased labor investment in preparation for use. The unshaped grinding stones required no preparation; they were simply stream-rounded cobbles. The large-grained, shaped grinding stones were prepared from a soft local granitic material which produced an inferior grinding stone because of a tendency to crumble into the prepared food, although these tools required little effort to shape. The fine-grained, shaped grinding stones required the most effort to modify and produced superior tools. This classification illustrates a possible shift in the labor invested in grinding stone manufacture at Wikalokal. Figure 6 plots the frequency of unshaped and large-grained, shaped grinding stones. For levels below 40 cm, only 16 percent (3 of 19) of the grinding stones are unshaped or large-grained whereas for levels above 40 cm the proportion of these stones increases to 33 percent (38 of 116).

We may consider groundstone to be site furniture; owing to their bulk, milling stones are thought to be left at one place and to be used by whoever occupies that place (see Camilli 1989). It has been suggested that labor investment in milling stone production (material selection, shaping, and standardization) is correlated with intended regular use of a site (Nelson & Lippmeier 1993). Casual site use encourages expedient use of unshaped and large-grained milling stones. A proportional increase in unshaped and large-grained milling stones during the later stages of Wikalokal's occupation suggests a shift toward lower labor investment in groundstone production. A substantial increase in late occupation milling stone use may explain their less desirable (large-grained) materials, whereas lowered energy investment in shaping may be explained by less predictable site usage or, alternatively, as a short-term energy/time saving strategy.

To recapitulate, the relative emphasis on gathering-related artifacts increased through timeat Wikalokal. Greater numbers of ceramic vessels were placed in use and they were manufactured to have larger volumes during the later periods of site occupation. More milling stones were employed, with an apparent shift to more expedient milling stone production strategies, such as opportunistic choice of milling stone material.

HUNTING STRATEGIES

We identify flaked lithic tools, lithic debitage, and faunal remains to pertain primarily to hunting activities. There is ample ethnohistoric evidence that flaked lithics were associated with large game hunting: projectile points for arrows and spears, lithic tools for butchering, and lithic debitage as a by product of point and tool manufacture. Flaked lithics were also associated with small game hunting, probably more frequently for animal butchering than for procurement. Both small and large mammal proteins were detected on stone tools from a habitation site in the San Bernardino Mountains (Sutton 1993). On the other hand, small game handling at times involved groundstone usage, as Yohe et al. (1991) and Sutton (1993) demonstrated using immunological techniques. We do not suggest that flaked lithics were used exclusively for hunting; projectile points and lithic debitage were also produced for warfare, and lithic tools probably played a role in plant fiber processing and wooden tool manufacture. That lithic tools were involved in agave/yucca processing has been suggested (see Kowta 1969, Salls 1985), although immunological tests failed to confirm this association (Sutton 1993). In 1913, Isidro Nejo, a northern Diegueno (Mesa Grande) informant of John P. Harrington (1986), gave the Ipai name and function for stone axes as follows: " 'awi aqkwa, stone axe. It had no handle. They made them of blue--sometimes of pure white rock. They trimmed them up by knocking. They never used them for chopping wood--they got fire wood by burning off branches, etc., by means of fire. They used 'awi aqkwa for skinning deer, etc. They had no axes with handle."

At Wikalokal, artifacts related to hunting strategies are flaked lithics (projectile points, lithic tools, and lithic debitage), and faunal materials. A classification of Wikalokal projectile points identified three major types: triangular with straight base, triangular with concave base, triangular with concave base and side-notches (Bull n.d.). The triangular point with straight base is the simplest form. The presence of a concave base or side notches may be related to point-toshaft hafting; their presence improves point attachment. Early occurrence of side-notched points and late occurence of non-side-notched points is the pattern observed at Wikalokal (Figure 7). The side-notched point is a time marker in southern California prehistory; this point style is thought to have originated after A.D. 1100-1200 and continued to be manufactured and used throughout the late prehistoric (Baumhoff & Byrne 1959, Kowta 1969, Heizer and Hester 1978). For levels between 20 cm and 80 cm, side-notch points are 70 percent of all diagnostic points, whereas for levels between 0-20 cm, the figure is 41 percent. Experimental study of dart point manufacture (Elko Corner-notched) reveals that most manufacture breakage is associated with notching (Titmus & Woods 1986), and this pattern also probably holds for smaller projectile points, suggesting that some triangular points may be blanks for side-notched points that were broken during manufacture. For the late period at Wikalokal, a larger proportion of triangular points (and/or blanks) may imply that a greater percentage of points were being manufactured on-site. The use of these broken side-notch blanks as points and/or the explicit manufacture of triangular points to reduce point breakage during manufacture would suggest that less labor was being invested in projectile point manufacture during the late occupation of Wikalokal.

To the extent that lithic tools are primarily used for animal butchering, and lithic debitage is a by-product of tool manufacture, the recovery of these materials should be correlated with faunal remains. A strong correlation between lithic debitage and faunal remains is observed at Wikalokal (compare Figures 8 and 9); the correlation of these materials with lithic tools (Figure 7) is less convincing. Ignoring the uppermost, 0-10 cm site level, recognizing that this level may be biased or disturbed, lithic tools show a steadily increased recovery at Wikalokal. However, lithic tools are subject to greater curation than lithic debitage or faunal remains; both spatially and temporally, lithic tools are more likely to be displaced from the location of their production and deposited at a location of use. The pattern for constant or decreasing lithic debitage and faunal remains (even discounting the 0-10 cm site level) suggests decreased processing of hunted products at Wikalokal. Either tool manufacture (debitage) and animal butchering (faunal remains) were increasingly conducted off-site, or the overall reliance on hunting was diminishing. More regional data are needed to test these hypotheses.

One alternative explanation for decreasing lithic debitage would be the introduction of metals or other European objects to replace lithic production. However, the recovered pattern of European objects argues against this explanation: (1) a porcelain projection point, indicating continued lithic production; (2) crockery fragments replacing ceramics, not lithic tools; and (3) no metal objects.

To summarize, a constant or diminishing recovery of hunting-related artifacts (projectile points, lithic debitage, and faunal remains) is observed in the upper 20 cm of the site. Projectile points represented in the later periods of site occupation suggest a diminishing relative reliance on large game. An apparent shift away from side-notched points may represent a greater percentage of on-site point manufacture and/or labor savings in point manufacture. On the other hand, on-site lithic debitage, a by-product of point and tool manufacture, decreased during the later period of site occupation. The faunal remains indicate that fewer animals, large or small, may have been butchered at Wikalokal during the latest stages of occupation.

The constant or lowered recovery for hunting-related artifacts in the later site occupation complements the increased recovery for gathering-related artifacts, suggesting an intensification in subsistence strategies related to plants and plant products, perhaps additionally a greater reliance on small game relative to large game. These complimentary data sets are consistent with a modified Kumeyaay subsistence procurement strategy during the latest occupation of Wikalokal. Bettinger and Baumhoff (1982) have suggested that a similar pattern of subsistence changes occurred in the Great Basin beginning about 700 B.P., with decreased importance for hunting of large game and increased importance for gathered resources, grass seeds in particular.

SITE DISTURBANCE

Artifact distribution patterns at Wikalokal will reflect both depositional and post-depositional processes; we consider what patterns are expected from these processes to differentiate them. Applicable site disturbance sources include erosion, plants, and animals (Wood & Johnson 1978). Erosion and downslope soil movements tend to mix archaeological materials (Rick 1976); for slopes of 10-44 degrees, large objects show greater displacement than small objects. The average slope of Wikalokal is less than 10 degrees, and a pattern of larger materials on the downslope side of the site is not observed. Mixing from downslope movement is unlikely to explain the distribution of materials with depth.

Plant disturbance results from tree fall when uprooted trees bring masses of earth to the surface, mixing the upper tens of centimeters (Wood & Johnson 1978). The dry climate and scarcity of trees at Wikalokal argue against this disturbance process; although a few oaks are located close to the site, it does not appear to have been thickly covered by trees. Animal disturbance is a possibility, more likely by rodents (Erlandson 1986; Bocek 1986) than by earthworms (Stein 1983) because of the dryness of the site soil. The pattern expected from pocket gopher disturbance is that smaller materials (0.6-3.5 cm) should be concentrated near the site surface, whereas larger materials (5.0+ cm) should be concentrated at depths between 30 cm and 60 cm (Bocek 1986:600). This pattern is at odds with the pattern observed at Wikalokal, where some classes of materials both small (lithic debitage and faunal remains) and large (lithic tools) are concentrated at depth and other classes of material, both of mixed size (ceramics) and large size (groundstones), are concentrated near the surface. Although gopher disturbance may explain some of the mixing of materials within the site (e.g., presence of ceramics below 60 cm), it does not explain the overall patterning of the artifact types. Alternatively, Baker (1978) has discussed the tendency for objects to be relatively more abundant at the surface of sites, suggesting artifact reuse and site deflation as possible explanations. This effect may explain the recovery of groundstone from the surface and upper-most levels of Wikalokal.

However, less than 10 percent (18 of 135) of the recovered groundstones were whole and, therefore, desirable for reuse, and these were distributed roughly equally with depth. Since site disturbance and reuse do not account for the primary patterning within the archaeological deposit at Wikalokal, we propose that this patterning reflects changes in cultural practices.

DISCUSSION AND SUMMARY

The archaeological data from Wikalokal suggest shifts in foraging practices during the latest period of site occupation, about A.D. 1700-1890. Artifacts related to gathering, ceramics and groundstone, became more heavily used. The density of ceramic artifacts increased, as did ceramic vessel size, perhaps reflecting an intensification in cooking and storing gathered plant foodstuffs or in boiling small game animals, and/or changes in commensal group size and greater emphasis on food storage. The frequency of groundstone artifacts also increased during this period, suggesting an increased importance for plant gathering in meeting Kumeyaay subsistence needs. Both archaeological and ethnohistoric evidence point to a late prehistoric/historic Kumeyaay subsistence economy primarily dependent upon plant gathering strategies and hunting strategies focused on small game. Reflecting this trend, projectile points for large game hunting became a smaller portion of the archaeological assemblage.

Ethnohistorically documented social responses undertaken by the Kumeyaay involved extensive residential mobility and expanded networks of kin-based subsistence resource sharing. By occupying territories that covered a wide-ranging and vertical landscape, the risk of poor food resources within the band territory, due to little rainfall or other natural variation, was diminished. Extensive kin-based sharing networks were another mechanism to buffer risk (Loumala 1963). The kin ties between the mountain Kumeyaay and the river-valley farming Kamia exemplifies a strategy of maintaining a sharing network with a group whose food production is environmentally decoupled from the local group, since Kamia agricultural production depended on river valley flooding, rather than on local rainfall.

These shifts in Kumeyaay social and foraging activities at Wikalokal may reflect an economic trajectory of adaptation to food stress. With the loss of lacustrine resources from Lake Cahuilla and increasing territorial encroachment by Europeans, traditional Kumeyaay subsistence strategies may have accommodated to a deteriorating resource base. Kumeyaay adaptation followed predictions whereby their procurement strategies show intensification in plant gathering and small game hunting, decrease in large game hunting, and environmental modification by burning, along with social strategies for residential mobility and kin-based sharing networks.

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REFERENCES

Arnold, J. E. (1992) "Complex Hunter-Gatherer-Fishers of Prehistoric California: Chiefs, Specialists, and Maritime Adaptations of the Channel Islands." *American Antiquity* 57:60-84.

Aschmann, H. (1959) *The Central Desert of Baja California; Demography and Ecology.* University of California Press, Berkeley.

--------------- (1986) Review of "Massacre on the Gila: An Account of the Last Major Battle between American Indians, with Reflections on the Origins of War" by C. Kroeber and B. L. Fontana. *Journal of California and Great Basin Anthropology* 8:138-140.

Baker, C. M. (1978) "The Size Effect: An Explanation of Variability in Surface Artifact Assemblage Content." *American Antiquity* 43:288-293.

Barrows, D. P. (1900) *The Ethno-Botany of the Coahuilla Indians of Southern California.* Chicago: University of Chicago Press.

Basgall, M. E. (1987) "Resource Intensification among Hunter-Gatherers: Acorn Economies in Prehistoric California." Pp 21-52 in B. L. Isaac (ed.) *Research in Economic Anthropology*, vol. 9, London: JAI Press.

Baumhoff, M. A. and J. S. Bryne (1959) "Desert Side-Notched Points as a Time Marker in California." *University of California Archaeological Survey Reports* 48: 32-65. (Berkeley).

Bean, L. J. (1974) *Mukat's People*. Berkeley & Los Angeles: University of California Press.

Bean, L. J., and H. W. Lawton (1973) "Some Explanations for the Rise of Cultural Complexity in Native California with Comments on Proto-Agriculture and Agriculture." Pp. v-xlvii in H. Lewis, *Patterns of Indian Burning in California: Ecology and Ethnohistory*. Ramona, CA: Ballena Press.

Bean, L. J., and K. S. Saubel (1972) *Temalpakh*. Morongo Indian Reservation, CA Malki Museum Press.

Belovsky, G. E. (1987) "Hunter-Gatherer Foraging: A Linear Programming Approach." *Journal of Anthropological Archaeology* 6:29-76.

Bentley, G. R. (1985) "Hunter-Gatherer Energetics and Fertility: A Reassessment of the !Kung San." *Human Ecology* 13:79-109.

Bettinger, R. L., and M. A. Baumhoff (1982) "The Numic Spread: Great Basin Cultures in Competition." *American Antiquity* 47:485-503.

Bocek, B. (1986) "Rodent Ecology and Burrowing Behavior: Predicted Effects on Archaeological Site Formation." *American Antiquity* 51:589-603.

Breternitz, D. A. (1966) *An Appraisal of Tree-Ring Dated Pottery in the Southwest*. Tucson: Anthropological Papers of the University of Arizona 10.

Brown, J. A. (1989) "The Beginnings of Pottery as an Economic Process." Pp. in S. E. van der Leeuw & R. Torrance (eds.) *What's New? A Closer Look at the Innovation Process*. London: Unwin Hyman.

Bull, C. S. (n.d.) "A Look at Projectile Points, and Other Flaked Lithic Materials from a Pre-Contact Diegueno Site: Buckman Springs Archaeological Project." Manuscript on file, Laboratory of Anthropology, San Diego State University.

Camilli, E. L. (1989) "The Occupational History of Sites and the Interpretation of Prehistoric Technological Systems: An Example from Cedar Mesa, Utah." Pp. 17-26 in R. Torrence (ed.) Time, Energy, and Stone Tools. Cambridge, ENG: Cambridge University Press.

Castetter, E. F., W. H. Bell, and A. R. Grove (1938) *Ethnobiological Studies in the American Southwest: VI. The Early Utilization and the Distribution of Agave in the American Southwest.* Albuquerque: University of New Mexico Bulletin, Biological Series, Vol 5, No.4.

Castetter, E. F., and W. H. Bell (1951) *Yuman Indian Agriculture.* Albuquerque: University of New Mexico Press.

Castillo, E. D. (1978) "The Impact of Euro-American Exploration and Settlement." Pp. 99-127 in R. F. Heizer (ed.) *Handbook of North American Indians, vol. 8, California*, (William G. Sturtevant, gen. ed.).Washington, DC: Smithsonian Institution.

Christenson, Lynne E. (1992) "The Late Prehistoric Yuman Settlement and Subsistence System: Coastal Adaptation." Pp. 217-230 in Terry L. Jones (ed.) *Essays on the Prehistory of Maritime California.* Davis, CA: Center for Archaeological Research at Davis.

Cline, Lora L. (1984) *Just Before Sunset*. Jacumba, CA: J and L Enterprises.

Colton, H. S. (1945) "The Patayan Problem in the Colorado River Valley." *Southwestern Journal of Anthropology* 1:114-121.

Cook, J. R., and S. G. Fulmer (1981) *The Archaeology of the McCain Valley Study Area in Eastern San Diego County*, California. Riverside, CA: Bureau of Land Management.

Costanso′, Miguel (1911) *The Portola expedition of 1769-1770, diary of Miguel Costanso.* (Tr. by F. J. Teggart). Berkeley: University of California.

Dobyns, H. and R. Euler (1958) "Tizon Brownware, a Descriptive Revision." in H. S. Colton (ed.) *Pottery Types of the Southwest: Ware 15, No. 3D*. Flagstaff: Northern Arizona Society of Science and Art.

Drucker, P. (1937) "Culture Element Distributions: V. Southern California." *Anthropological Records* 1:1-52.

------------ (1941) "Culture Element Distributions: XVII. Yuman-Piman." *Anthropological Records* 6:91-230.

Dwyer, P. D. (1983) "Etolo Hunting Performance and Energetics." Human Ecology 11:145-174.

Earle, T. K. (1980) "A Model of Subsistence Change." Pp. 1-29 in T. K. Earle & A. L. Christenson (eds.) *Modeling Change in Prehistoric Subsistence Economies.* New York: Academic Press.

Erlandson, J. M. (1986) "A Case Study in Faunalturbation: Delineating the Effects of the Burrowing Pocket Gopher on the Distribution of Archaeological Materials." *American Antiquity* 49:785-790.

Euler, R. (1959) "Comparative Comments on California Pottery." Pp. 41-42 in C. W. Meighan (ed.) *University of California, Los Angeles, Archaeological Survey Annual Report* 1958-1959.

Farris, G. J. (1980) "A Reassessment of the Nutritional Value of Pinus Monophylla." *Journal of California and Great Basin Anthropology* 2:1-31.

Fink, G. R. (n.d.) "Ground, Battered, and Core Stone Analysis of the Buckman Springs Site, San Diego County, California." Manuscript on file, Laboratory of Anthropology, San Diego State University.

Forbes, J. D. (1965) *Warriors of the Colorado: The Yumas of the Quechan Nation and Their Neighbors.* Norman: University of Oklahoma Press.

Gastler, G. F., A. L. Moxon, and W. T. McKean (1951) "Composition of Some Plants Eaten by Deer in the Black Hills of South Dakota." *Journal of Wildlife Management* 15:352-357.

Gifford, E. W. (1931) *The Kamia of Imperial Valley.* Washington, DC: Smithsonian Institution, Bureau of American Ethnology Bulletin 97.

Gladwin, W. and H. S. Gladwin (1930) *The Western Range of the Red-on-buff Culture.* Globe, AZ: Gila Pueblo, Medallion Papers 5.

Greene, R. A. (1936) "The Composition and Uses of the Fruit of the Giant Cactus (*Carnegia Gigantea*) and Its Products." *Journal of Chemical Education*13:309-312.

Hagstrum, M. B. and J. A. Hildebrand (1990) "The Two-Curvature Method for Reconstructing Vessel Morphology." *American Antiquity* 55: 388-403.

Harner, M. J. (1958) "Lowland Patayan Phases in the Lower Colorado River Valley and Colorado Desert." *University of California Archaeological Survey Annual Report* 42:93-97. (Berkeley).

Harrington, John P. (1986) "John P. Harrington papers, Vol. 3: Southern California/Basin. Diegueno Field Notes." National Anthropological Archives, Smithsonian Institution (Microfilm edition: Reel 169, Frame 20).

Hawkes, K. and J. O'Connell (1992) "On Optimal Foraging Models and Subsistence Transitions." *Current Anthropology* 33:63-66.

Hedges, K. (1975) "Notes on the Kumeyaay: A Problem of Identification." *Journal of California Anthropology* 2:71-83.

Heizer, R. F. and T. R. Hester (1978) *Great Basin Projectile Points: Forms and Chronology.* Socorro, NM:Ballena Press.

Heizer, R. F. and W. C. Massey (1953) "Aboriginal Navigation off the Coasts of Upper and Baja California." Bureau of American Ethnology, Bulletin 151:289-311.

Hicks, Frederic N. (1963) *Ecological Aspects of Aboriginal Culture in the Western Yuman Area.* Ph.D. dissertation, University of California, Los Angeles.

Hill, K., K. Hawkes, A. M. Hurtado, and H. Kaplan (1984) "Seasonal Variance in the Diet of Ache′ of Eastern Paraguay." *Human Ecology* 12:145-180.

Holsworth, W. N. (1973) "Hunting Efficiency and White-Tailed Deer Density." *Journal of Wildlife Management* 37:336-342.

Hooper, L. (1920) "The Cahuilla Indians." *University of California Publications in American Archaeology and Ethnology,* 16:316-379.

Huckell, B. B. (1986) *A Ground Stone Implement Quarry on the Lower Colorado River, Northwestern Arizona.*Phoenix, AZ: Bureau of Land Management, Cultural Resource Series, No. 3.

Jochim, M (1983) "Optimization Models in Context." Pp. 157-170 in J. A. Moore & A. S. Keene (eds.) Archaeological Hammers and Theories. London: Academic Press.

Kowta, M. (1969) *The Sayles Complex.* Berkeley & Los Angeles: University of California Press,

Kroeber, A. L. (1925) *Handbook of the Indians of California.* Washington, DC: Smithsonian Institution, Bureau of American Ethnology, Bulletin 78.

Langdon, M. (1970) *A Grammer of Diegueno: The Mesa Grande Dialect.* Berkeley: University of California Publications in Linguistics, Vol. 66.

Lawton, H. W. (1976) "History and Ethnohistory of the Yuha Desert (1769-1865)." Pp. 43-72 in P. J. Wilke (ed.) *Background to Prehistory of the Yuha Desert Region.* Ramona, CA: Ballena Press, Anthropological Papers, No. 5 (L. J. Bean, gen. ed.).

Laylander, D. (1994) *Phase III Data Recovery at the Elmore Site (CA-IMP-6427) Imperical County, California.* San Diego: California Department of Transportation.

Lee, R. B. (1968) "What Hunters Do for a Living, or, How to Make Out on Scarce Resources." Pp 30-48 in R. B. Lee & I. DeVore (eds.) *Man the Hunter.* New York: Aldine.

--------- (1969) "!Kung Bushman Subsistence: An Input-Output Analysis." Pp. 47-79 in A. P. Vayda (ed.) *Environment and Cultural Behavior.* Garden City, NY: Natural History Press.

---------- (1979) *The !Kung San: Men, Women and Work in a Foraging Society.* Cambridge, ENG: Cambridge University Press.

Lewis, Henry T. (1973) *Patterns of Indian Burning in California: Ecology and Ethnohistory.* Ramona, CA: Ballena Press.

Luomala, K. (1963) "Flexibility in Sib Affiliation Among the Diegueno." *Ethnology* 2:282-301.

----------- (1978) "Tipai-Ipai." Pp. 572-609 in R. F. Heiser (ed.) *Handbook of North American Indians, vol. 8, California* (William G. Sturtevant, gen. ed.). Washington, DC: Smithsonian Institution.

Lyneis, M. M. (1988) "Tizon Brown Ware and the Problems Raised by Paddle-and-Anvil Pottery in the Mojave Desert." *Journal of California and Great Basin Anthropology* 10:146-155.

McCarthy, Helen (1993) "Managing Oaks and Acorn Crops." Pp. 213-228 in Thomas C. Blackburn & Kat Anderson (eds.) *Before the Wilderness, Environmental Management by Native Californians.* Menlo Park, CA: Ballena Press.

May, R. V. (1976) "An Early Ceramic Date Threshold in Southern California." *Masterkey* 50:103-107.

Meigs, Peveril, III. (1939) The Kiliwa Indians of Lower California. Berkeley: University of California, *Ibero Americana 15.*

Minnis, P. E. (1985) *Social Adaptation to Food Stress.* Chicago: University of Chicago Press.

Nelson, M. C., and H. Lippmeier (1993) "Grinding-Tool Design as Conditioned by Land-Use Pattern." *American Antiquity* 58:286-305.

O′Connell, J. F. (1971) "Recent Prehistoric Environments in Interior Southern California." University of California Archaeological Survey Annual Report 13: 175-185. (Los Angeles).

Palmer, Edward (1878) "Plants Used by the Indians of the United States." *American Naturalist* 12:593-606, 646-655. (Philadelphia).

Phillips, G. H. (1975) *Chiefs and Challengers.* Berkeley & Los Angeles: University of California Press.

Press, W. H., B. P. Flannery, S. A. Teukolsky, and W. T. Vetterling (1986) *Numerical Recipes: The Art of Scientific Computing.* Cambridge, ENG: Cambridge University Press.

Rick, John (1976) "Downslope Movement and Archaeological Intrasite Spatial Analysis." *American Antiquity* 41:133-144.

Rogers, M. J. (1936) *Yuman Pottery Making.* San Diego: San Diego Museum Papers No. 2.

------------ (1939) Early Lithic Industries of the Lower Basin of the Colorado River. San Diego: San Diego Museum Papers No. 3.

------------ (1945) "An Outline of Yuman Prehistory." *Southwestern Journal of Anthropology* 1:167-198.

------------ (1966) *Ancient Hunters of the Far West.* San Diego: The Union-Tribune Publishing Company.

Salls, Roy (1985) "The Scraper Plane: A Functional Interpretation." *Journal of Field Archaeology* 12:99-106.

Schroeder, A. H. (1957) "The Hakataya Cultural Tradition." *American Antiquity* 23:176-178.
------------- (1961) *Archaeological Excavations at Willow Beach, Arizona.* Salt Lake City: University of Utah Anthropological Papers, no. 50.
------------ (1979) "Prehistory: Hakataya." Pp. 100-107 in A. Ortiz (ed.) *Handbook of North American Indians, vol. 9, Southwest* (William G. Sturtevant, gen. ed.). Washington, DC: Smithsonian Institution.

Shipek, F. C. (1970) *The Autobiography of Delfina Cuera: A Diegueno Indian.* Ramona, CA: Ballena Press.
----------- (1978) "History of Southern California Mission Indians." Pp. 610-618 in R. F. Heiser (ed.) *Handbook of North American Indians, vol. 8, California* (William G. Sturtevant, gen. ed.). Washington, DC: Smithsonian Institution.
----------- (1981) "A Native American Adaptation to Drought: The Kumeyaay as seen in the San Diego Mission Records 1770-1798." *Ethnohistory* 28:295-312.
----------- (1985) "Kumeyaay Socio-Political Structure." *Journal of California and Great Basin Anthropology* 4:296-303.
----------- (1987) *Pushed into the Rocks.* Lincoln: University of Nebraska Press.
----------- (1993) "Kumeyaay Plant Husbandry: Fire, Water, and Erosion Management Systems." Pp. 379-388 in Thomas C. Blackburn & Kat Anderson (eds.) *Before the Wilderness, Environmental Management by Native Californians.* Menlo Park, CA: Ballena Press.

Simms, S. R. (1987) *Behavioral Ecology and Hunter-Gatherer Foraging.* Oxford, ENG: British Archaeological Research International Series, 381.

Smith, E. A. (1983) "Anthropological Applications of Optimal Foraging Theory: A Critical Review." *Current Anthropology* 24:625-651.
---------- (1988) "Risk and Uncertainty in the 'Original Affluent Society': Evolutionary Ecology of Resource-Sharing and Land Tenure." Pp. 222-251 in T. Ingold, D. Riches, & J. Woodburn (eds.) *Hunters and Gatherers.* Oxford, ENG: Berg Publishers.

Speth, J. D. and K. A. Spielmann (1983) "Energy Source, Protein Metabolism, and Hunter-Gatherer Subsistence Strategies." J*ournal of Anthropological Archaeology* 2:1-31.

Spier, L. (1923) "Southern Diegueno Customs." University of California Publications in American Archaeology and Ethnology 20:297-358. (Berkeley).

Stein, J. K. (1983) "Earthworm Activity: A Source of Potential Disturbance of Archaeological Sediments." *American Antiquity* 48:277-289.

Stuiver, M., and G. W. Pearson (1993) "High-Precision Bidecadal Calibration of the Radiocarbon Time Scale, AD 1950-500 BC and 2500-6000 BC." *Radiocarbon* 35:1-23.

Sutton, M. Q. (1993) "On the Subsistence Ecology of the 'Late Inland Millingstone Horizon' in Southern California." *Journal of California and Great Basin Anthropology* 15:134-140.

Timbrook, J., J. R. Johnson, and D. D. Earle (1982) "Vegetation Burning by the Chumash." *Journal of California and Great Basin Anthropology* 4:163-186.

Titmus, G. L., and J. C. Woods (1986) "An Experimental Study of Projectile Point Fracture Patterns." *Journal of California and Great Basin Anthropology* 8:37-49.

Treganza, A. E. (1947) "Possibilities of an Aboriginal Practice of Agriculture Among the Southern Diegueno." *American Antiquity* 12:169-173.

True, D. L. (1970) *Investigation of a Late Prehistoric Complex in Cuyamaca Rancho State Park, San Diego County, California.*Los Angeles: University of California, Department of Anthropology, Archaeological Survey Monograph.

Van Etten, R. C., D. F. Switzenberg, and L. Eberhardt (1965) "Controlled Deer Hunting in a Square-Mile Enclosure." *Journal of Wildlife Management* 29:59-73.

Wallace, W. J. (1962) "Prehistoric Cultural Development in the Southern California Desert." *American Antiquity* 28:172-180.

Warren, C. N. (1968) "Cultural Tradition and Ecological Adaptation on the Southern California Coast." Pp. 1-14 in C. Irwin-Williams (ed.) *Archaic Prehistory in the Western United States.* Las Vegas, NM: Eastern New Mexico University Contributions in Anthropology, 1(3).

Waters, M. R. (1982) "The Lowland Patayan Ceramic Tradition." Pp. 275-298 in R. H. McGuire & M. B. Schiffer (eds.) *Hohokam and Patayan: Prehistory of Southwestern Arizona.* New York: Academic Press.

----------- (1983) "Late Holocene Lacustrine Chronology and Archaeology of Ancient Lake Cahuilla, California." *Quaternary Research* 19:373-387.

Weber, C. W., H. S. Gentry, E. A. Kohlhepp, and P. R. McCrohan (1991) "The Nutritional and Chemical Evaluation of Chia Seeds." *Ecology of Food and Nutrition* 26:119-125.

Weide, M. L. (1976) "A Cultural Sequence for the Yuha Desert." Pp. 81-94 in P. J. Wilke (ed.) *Background to Prehistory of the Yuha Desert Region.*Ramona, CA: Ballena Press Anthropological Papers, No. 5 (L. J. Bean, gen. ed.).

Wilke, P. J. (1971) "Late Prehistoric Change in Land-Use Patterns at Perris Reservoir." *University of California, Los Angeles, Archaeological Survey Annual Report* 13:155-167.

----------- (1978) *Late Prehistoric Human Ecology at Lake Cahuilla, Coachella Valley, California.* Berkeley: Contributions of the University of California Archaeological Research Facility, No. 38.

Wilke, P. J., and H. W. Lawton (1975) "Early Observations on the Cultural Geography of the Coachella Valley." *Ballena Press Anthropological Papers* 3:9-43. (L. J. Bean, gen. ed. Ramona, CA: Ballena Press).

Winterhalder, B. (1981) "Optimal Foraging Strategies and Hunter-Gatherer Research in Anthropology: Theory and Models." Pp 13-35 in B. Winterhalder & E. A. Smith (eds.) *Hunter-Gatherer Foraging Strategies: Ethnographic and Archaeological Analyses.* Chicago: Univ. of Chicago Press.

Winterhalder, B., and C. Goland (1993) "On Population, Foraging Efficiency, and Plant Domestication." *Current Anthropology* 34:710-715.

Wood, W. R., and D. L. Johnson (1978) "A Survey of Disturbance in Archaeological Site Formation." Pp. 315- 381 in M. B. Schiffer (ed.) *Advances in Archaeological Method and Theory, vol. 1.* New York: Academic Press.

Yohe, R. M., II, M. E. Newman, and J. S. Schneider (1991) "Immunological Identification of Small Mammal Proteins on Aboriginal Milling Equipment." *American Antiquity* 56:659-666

Table 1. Distribution and Seasonal Availability of Native Plants Important to the Kumeyaay Subsistence Economy (adapted from Hicks 1963)

Plant Zone	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Sage-Scrub	-	-	-	Chaparral yucca	Chaparral yucca	Chia	Chia Cactus pear	Cactus pear	Cactus pear	-	-	-
Oak-Chaparral	-	-	-	Chaparral yucca	Chaparral yucca	-	-	-	-	Acorns	Acorns	Acorns
Interior Uplands	-	-	-	Agave	Agave	-	-	Cactus pear Datil	Cactus pear Datil	-	-	-
Desert Foothills	-	-	Agave	Agave	Agave	-	Mesquite	Mesquite	-	-	-	-

Table 2. Search, Handling, and Energy Estimates

Resources	*Search*[a] *(hr/kg)*	*Handling*[b] *(hr/kg)*	*Energy Density (kcal/kg)*	*Energy Return (kcal/hr)*	*Reference*
Hunted Resources					
!Kung average	3.3	2.1	3000	556	Lee 1968
Deer	5.0	2.1	1258	177	Simms 1987
Jackrabbit[c]	1.7	2.1	1078	284	Simms 1987
Cottontail Rabbit[d]	2.4	2.1	1078	240	Simms 1987
Ground Squirrel	2.2	2.2	1078	245	Simms 1987
Duck	3.8	2.5	948	150	Simms 1987
Gathered Resources					
!Kung average	1.3	5.7	3220	460	Lee 1968
Mongongo (nuts)	2.0	5.7	6400	830	Lee 1968
Oak (acorns)	1.7	3.4	5000	980	Simms 1987
Pinyon (nuts)	2.5	4.5	4880	697	Simms 1987
Atriplex sp. (seeds)	1.3	2.6	2900	743	Simms 1987
Bluegrass (seeds)	5.0	6.8	3340	283	Simms 1987
Saltgrass (seeds)	10.0	15.8	2540	100	Simms 1987

[a] When a range of search rates were given, highest value was selected.

[b] Cooking (0.7 hr/kg) and tool maintenance (1.3 hr/kg) are added to Simms' estimates.

[c] Communal drive hunting.

[d] Encounter hunting.

Table 3. Nutritional Compositions for Gathered Foods

Food Name	*Protein (%)*	*Fat (%)*	*Carbohydrates (%)*	*Energy Density (kcal/kg)*	*Reference*
Oak (acorns)	4.5	19.8	64.1	5000	Farris (1980)
Pinyon (nuts)	9.5	23.0	54.9	4880	Farris (1980)
Cactus (fruit)	13.1	9.9	66.3	4170	Green (1936)
Arctostaphylos sp. (berries)	3.3	4.7	66.0	3270	Gastler et al. (1951)
Chia (seeds)	19.3	31.5	43.8	5360	Weber et al. (1991)
Atriplex sp. (seeds)	7.7	0.0	69.3	2900	Simms (1987)
Bluegrass (seeds)	10.9	0.4	73.5	3340	Simms (1987)
Saltgrass (seeds)	6.2	0.4	58.0	2540	Simms (1987)

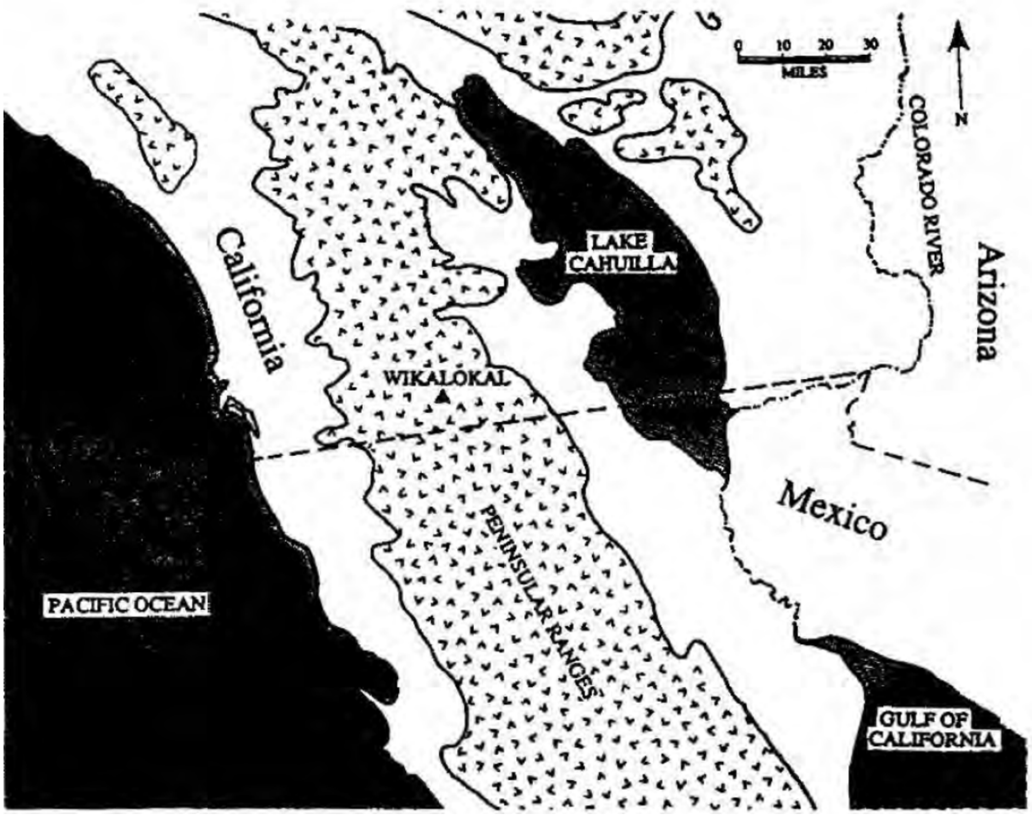

Figure 1. Regional Setting for Prehistoric Southern California, Showing Lake Cahuilla at Its Maximum Extent

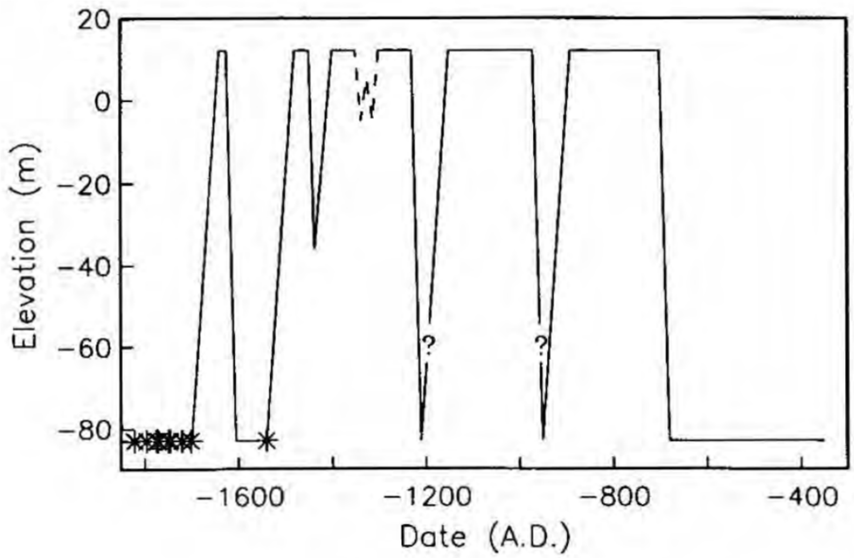

Figure 2. A Proposed Lacustrine Chronology for Lake Cahuilla, Represented by Water Level, where Maximum Water Level is +12m Elevation and Dry Lake Is -83m Elevation. (Historic confirmations of dry lake intervals are given by asterisks [*]. Complied from Waters (1983) and Laylander (1994))

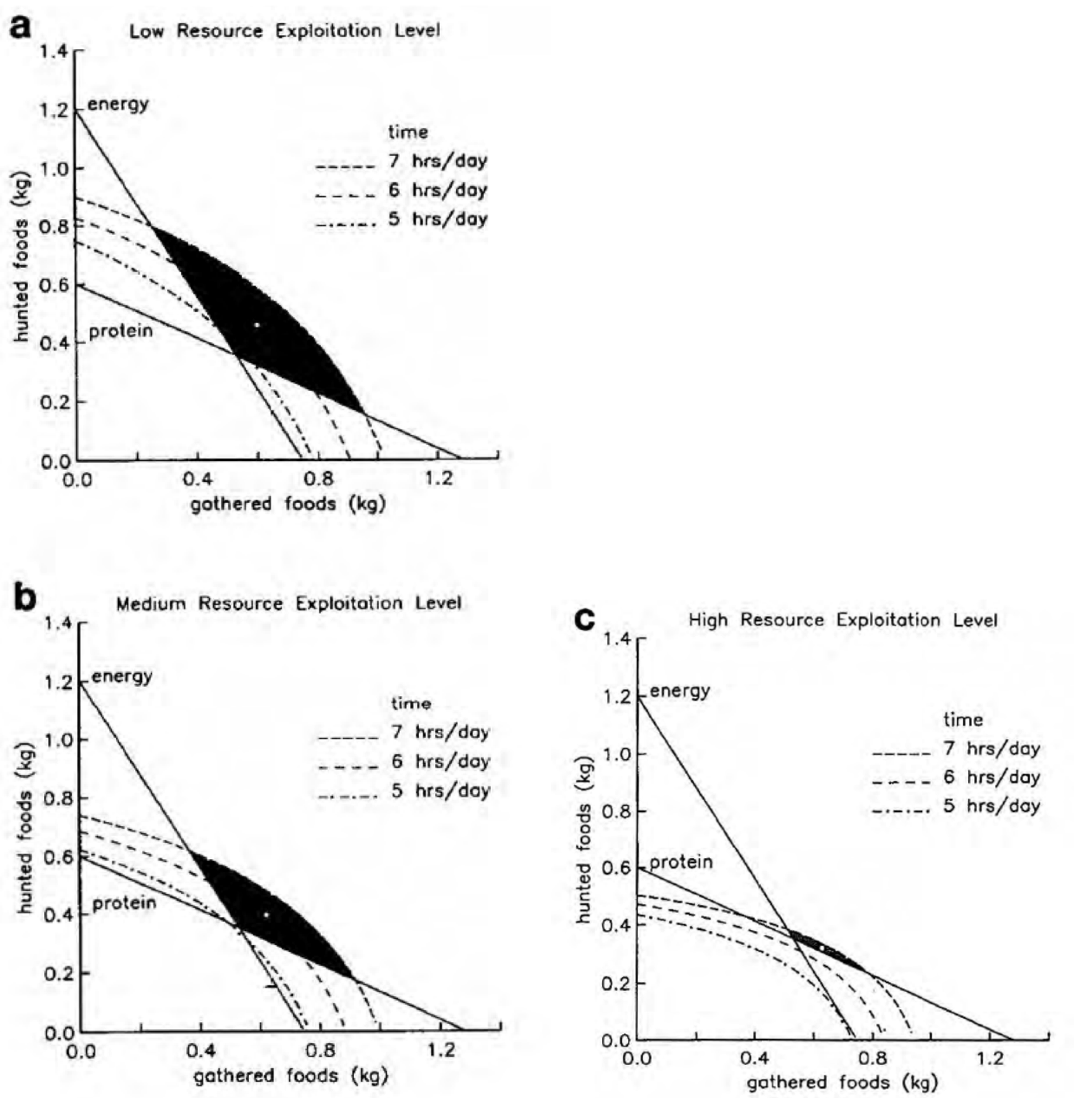

Figure 3. Foraging Model Based on Time (dashes), Energy (line) and Protein (line)

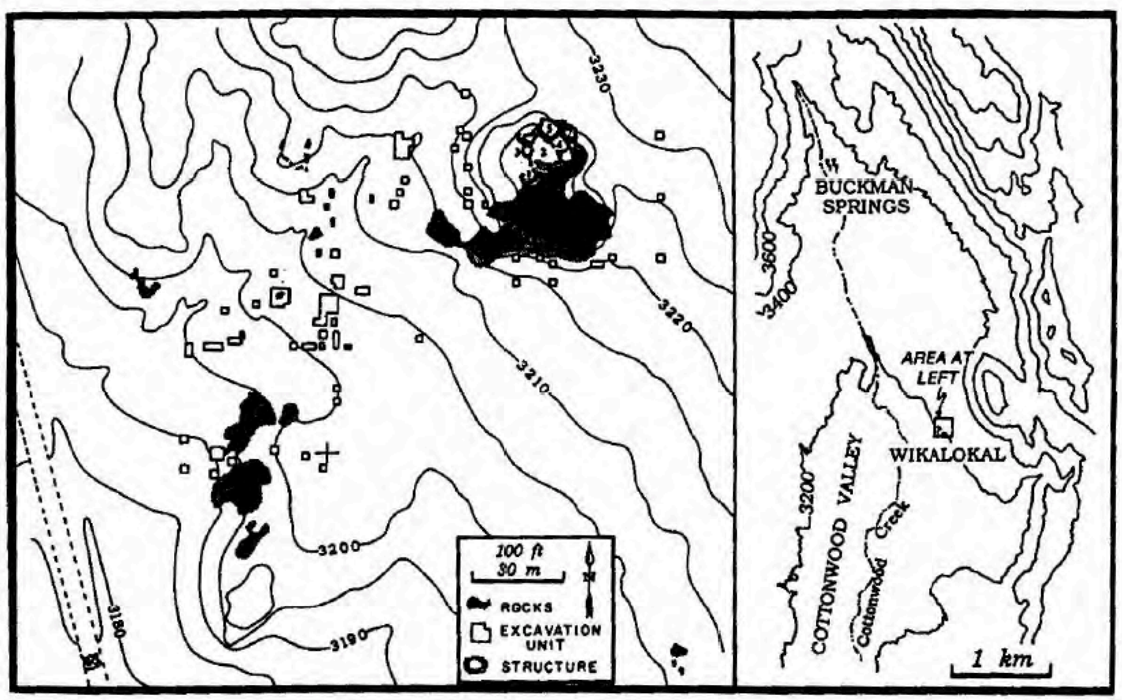

Figure 4. Wikalokal Site Map with Regional Contexts

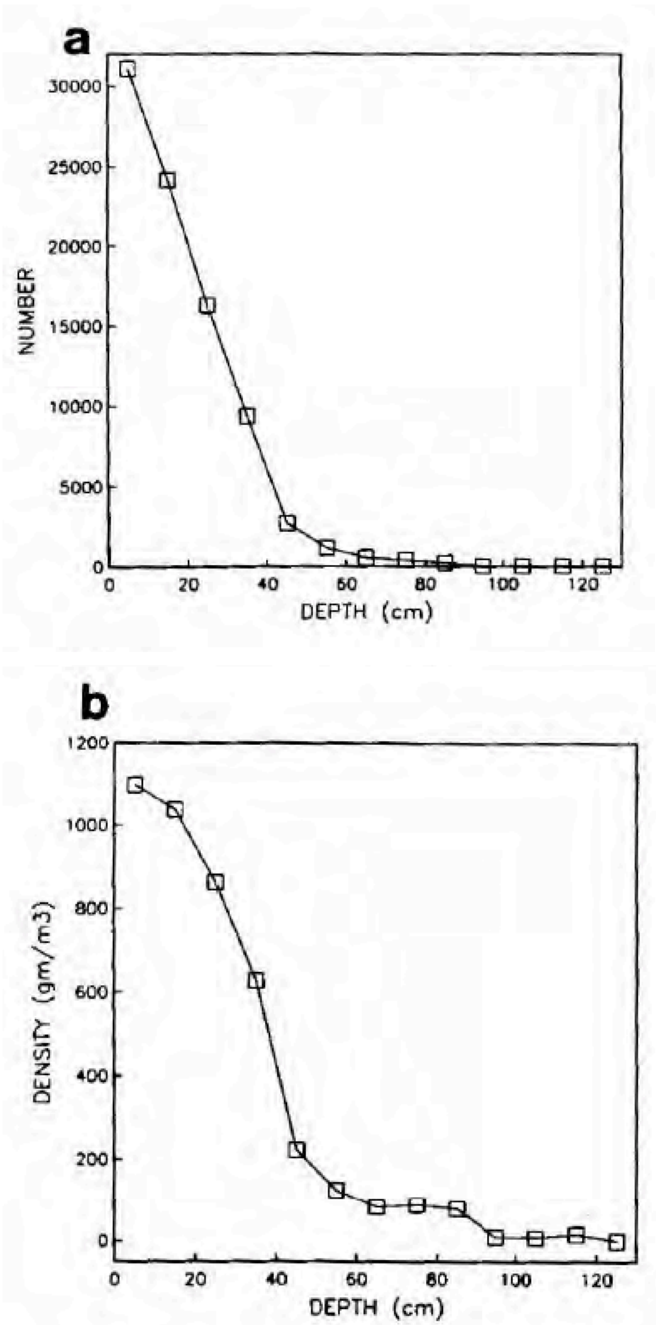

Figure 5. Tizon Brown Ware Sherds Recovered in 10 cm Depth Levels, Plotted by (a) Weight and (b) Density (weight ÷ excavation volume) (Includes all excavated units except the stone structures.)

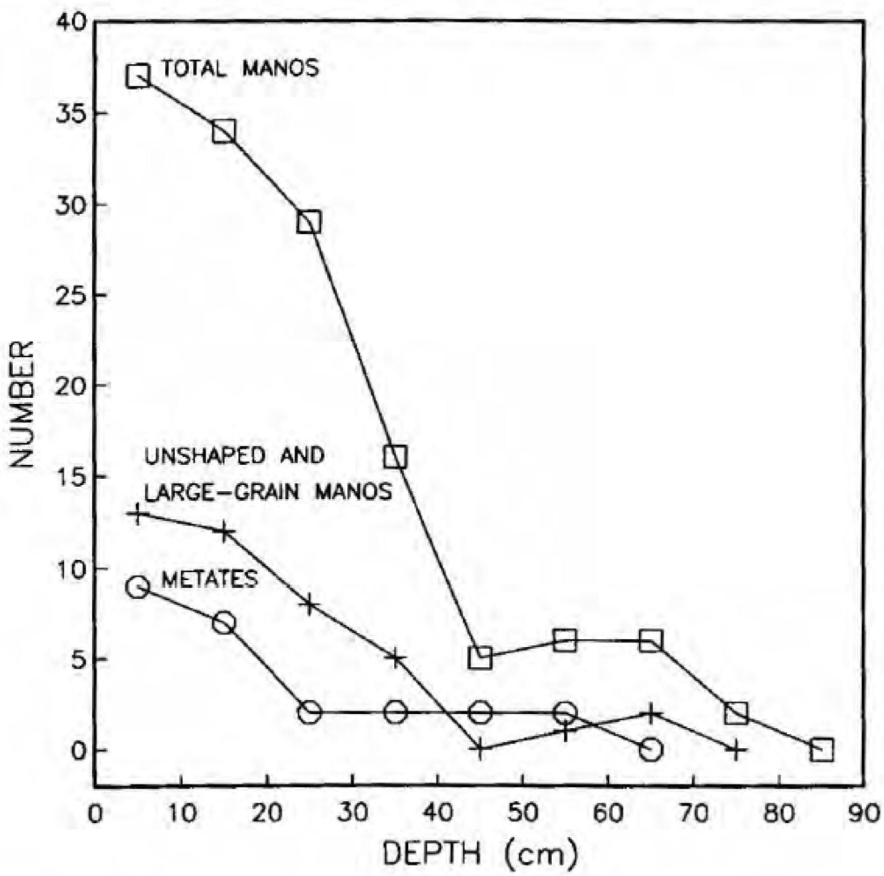

Figure 6. Portable Groundstone (including fragments), Plotted by Frequency in 10 cm Levels for Total Manos, Unshaped and Large-grained Manos, and Metates (Includes all excavated units except the stone structures.)

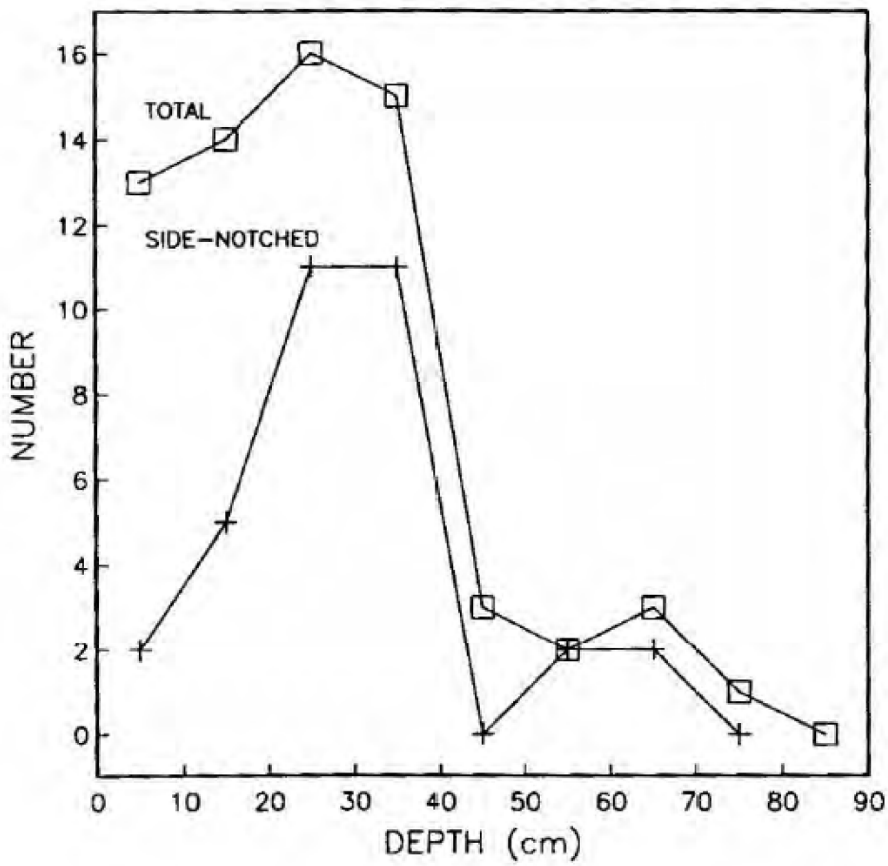

Figure 7. Projectile Points (including fragments), Plotted by Frequency in 10 cm Levels for Total Projectile Points and Side-notched Points (Includes all excavated units except the stone structures.)

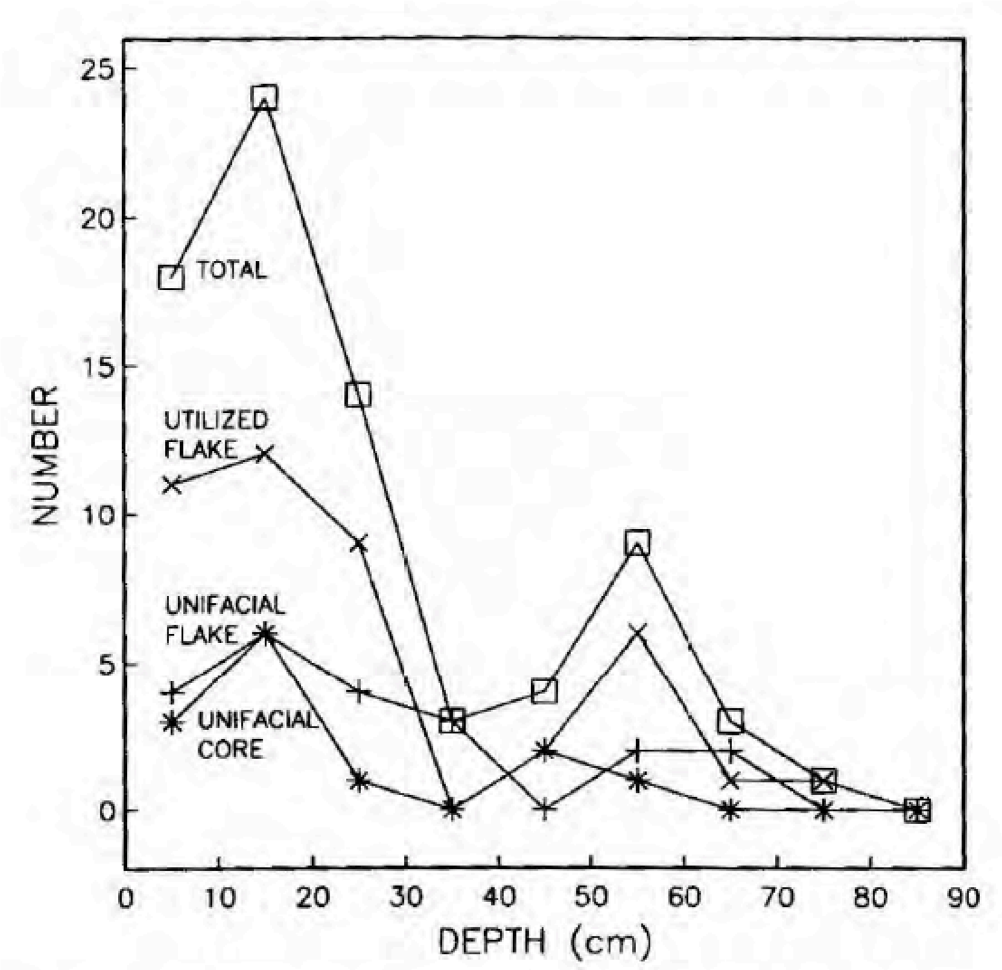

Figure 8. Lithic Tools, Plotted by Frequency in 10 cm Levels for Total Tools, Utilized flakes, Unifacial Flakes, and Unifacial Cores (Includes all excavated units except the stone structures.)

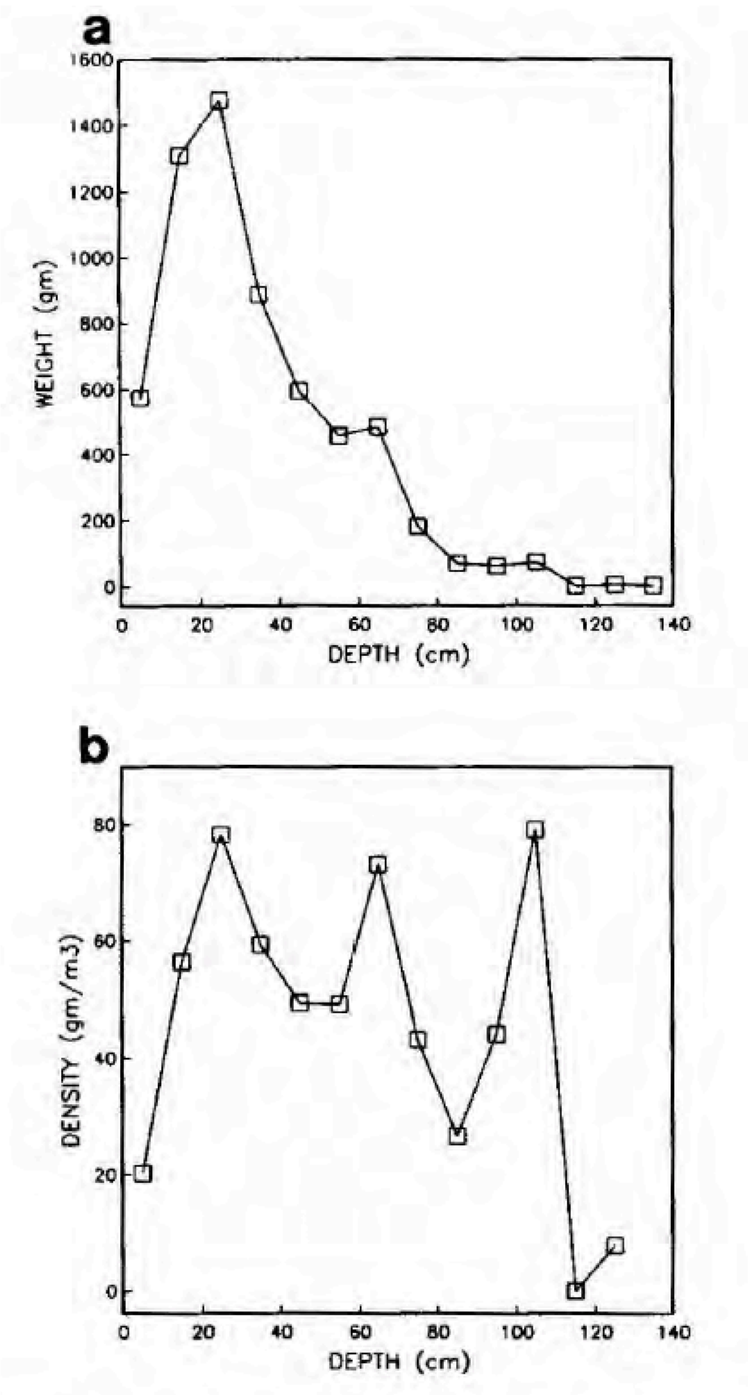

Figure 9. Lithic Debitage Recovered in 10 cm Depth Levels, Plotted by (a) Weight and (b) Density (weight ÷ excavation volume) (Includes all excavated units except the stone structures.)

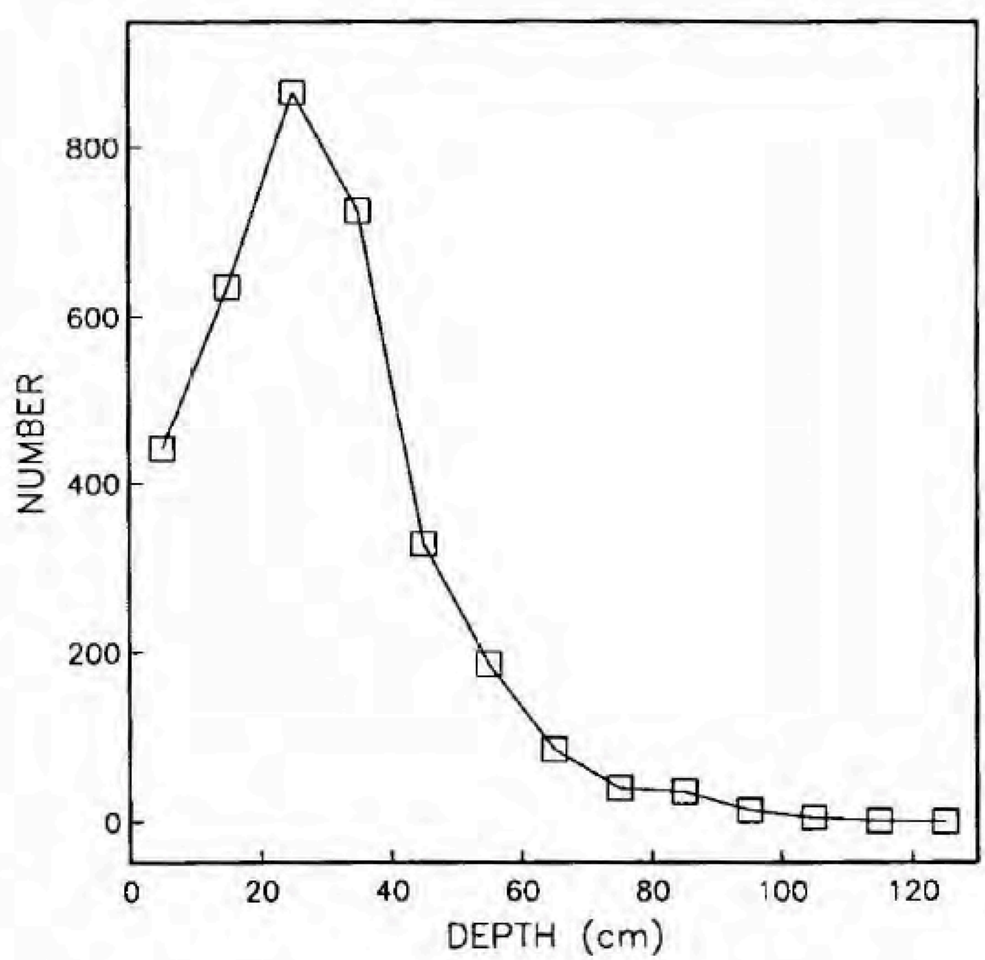

Figure 10. Faunal Remains, Plotted by Frequency in 10 cm Levels (Includes all excavated units except the stone structures.)