MIWOK BALANOPHAGY: IMPLICATIONS FOR THE CULTURAL DEVELOPMENT OF SOME CALIFORNIA ACORN-EATERS

By

Peter J. Mayer

Archaeological Research Facility
Department of Anthropology
University of California
Berkeley, CA 94720
1976

Facsimile Reprint by

Coyote Press
P.O. Box 3377
Salinas, CA 93912

http://www.coyotepress.com

MIWOK BALANOPHAGY:

Implications for the Cultural Development of Some California Acorn-Eaters

by

Peter J. Mayer

ARCHAEOLOGICAL RESEARCH FACILITY
University of California
Department of Anthropology
Berkeley
1976

TABLE OF CONTENTS

This paper presents an investigation into the subsistence behavior of the Miwok Indians who inhabited the Sierra Nevada Mountains. It focuses primarily upon the acorn as a food resource, and upon the possible dependence of Miwok aboriginal groups on this source of nourishment. It further relates population phenomena with cultural development, and attempts to integrate population, culture and environment into a meaningful explanation of the subsistence lifestyle of the aboriginal Sierra Miwok.

INTRODUCTION

The Miwok Indians of California were aboriginally located in a number of geographically distinct areas. The Coast Miwok inhabited Marin County which forms the northern border of San Francisco Bay; the Lake Miwok were located proximate to Clear Lake, an inland region north of San Francisco Bay; and the Interior Miwok (Kroeber 1923) ranged east of the bay (the Bay Miwok and the Plains Miwok) and south along the Sierra Nevada Mountains (the Sierra Miwok). All of these groups spoke dialects of the Penutian language family (Callaghan 1967) and thus enjoyed a certain degree of cultural unity. On the basis of linguistic evidence it seems probable that these groupings are the scattered descendants of a once unified ancestral population. However, changes in subsistence and material culture since the time of that ancestral unity have become more significant than the remains of linguistic similarity.

The Coast Miwok were able to exploit the Pacific maritime resources and their cultural adaptations were like those of their northern neighbors, the Pomo. The Lake Miwok, in an analogous situation, subsisted primarily on the fish and waterfowl of Lake Clear. They, too, shared many similarities with the Pacific Pomo culture, indicating, perhaps, a fairly recent common heritage with the Coast Miwok. The Interior Miwok, who "constituted by far the largest portion of the stock" (Kroeber 1923:442), can be conveniently divided into three regional groups, Bay, Plains and Sierra. The Bay Miwok settled in the area of Saclan, south of Suisun Bay. Together with the Plains Miwok they occupied the delta region of the central California valley, a lush, marshy habitat formed by the Sacramento River flowing down from the north and the San Joaquin River coming up from the south. Large land fauna supplemented the water dependent resources of fish and fowl for these valley people, and their subsistence activity was much like that of the neighboring Wintun to the north and of the Northern Yokuts to the south. Thus three of the four Miwok groups subsisted primarily by fishing and hunting, meeting their nutritional needs with rich animal protein.

The Sierra dwelling members of the Miwok Indians stand in marked contrast to those just described. Principally, they lived at higher elevations, ranging from the limits of the winter snow cap and timberline down to the gently sloping foothills to the west. The extent of their western habitation is a somewhat controversial but significant point. Merriam (1907:338) divides the Interior Miwok into "two principal parts, which may be known as the Me'-wok or Mountain people, and the Mew'-ko or Valley people". Barrett seems to agree with Merriam, for he describes, "this main Miwok area (as) extending from the crest of the Sierras westward into San Joaquin valley itself" (1908:335). However, he emphasizes that the Miwok inhabited the higher altitudes and subsequently modifies his position: "The only exception to this mountain habitat of the Miwok is the northwestern extremity of their territory, which extends down into the broad plain of the San Joaquin valley... (This conclusion is based upon) statements made by certain Miwok informants to the effect that the edge of the San Joaquin plains was the western limit of Miwok territory" (Barrett, 1908).

Kroeber reaches a similar conclusion on the basis of linguistic and ethnographic evidence from earlier work. He ascribes "the whole valley east of the San Joaquin" to the Yokuts and states, "that the Miwok habitat on the plains was confined to the region north of the Calaveras" (1908:375), that is, to the delta region. In Kroeber's later work (1923, 1962a, b) and in that of others (Barrett and Gifford 1933, Cook 1941, Baumhoff 1963), this distinction of Plains and Sierra Miwok, with the latter excluded from the San Joaquin valley, is accepted without question.

The importance of distinguishing valley from foothill residents is threefold, with the three axes of distinction representing the major foci of this paper. First of all, the size and destiny of the populations of the two regions differ. According to Kroeber (1923:442), "The Interior Miwok constituted the largest portion of the stock... The bulk of the group were a true foothill people, without claims to the floor of the valley, and moving into the higher Sierra only for summer residence of hunting". More will be said about population size and density later.

Second of all, the resources of the valley were (aboriginally) sufficiently distinct from those in higher elevations such that groups of people with a shared history (i.e., the Miwok) nevertheless developed different patterns of culture in adaptation to different environments. This is especially true in terms of subsistence activity, as a comparison of the following reports makes clear. First, the delta region:

> The early accounts make few direct statements as to native food supplies... But the immense herds of deer, elk, and antelope are spoken of a number of times, and later writers are astonished at the superabundance of these animals and of water fowl. It is probably impossible for us to conceive the quantity of such game and the ease with which it could be procured. Kotzebue stated that one could ride among the herds of deer without frightening them. Geese and ducks could be knocked over with a stick.
>
> (Schenck 1926:143)

Then the western slope of the Sierras:

> The foot-hill region, however, was not at all lacking in its food supply, particularly in the higher foot-hills. Here conifers were chiefly lacking, but there were various species of oak. There were also many smaller berry and nut bearing trees and shrubs, which, when combined with acorns, always the chief resource, and the bulbs, tubers, and grass seeds of the open meadows and hillsides, provided an abundance of vegetable foods... many of the animals and birds were driven from the high Sierras by the winter snows to the foot-hills and to the plains of San Joaquin valley, where they furnished a good supply of game during that season. Fish were, of course, abundant in the many rivers and creeks which water this portion of the area.
>
> (Barrett 1908:336)

Thus in general terms the hunting and fishing activities of the valley dwellers is replaced by the gathering, especially acorn-gathering, of their foothill "cousins".

Third of all, the importance of a valley-foothill dichotomy is reinforced in theoretical considerations of cultural development. As Barrett and Gifford (1933:274) put the matter:

> In short, although the dwellers of the delta region (among whom some Plains Miwok were doubtless included) had one of the richest cultures of central California, the Sierra Miwok were relatively primitive in culture. This situation conforms to what is generally observable in California; namely, that valley dwellers have a richer culture than mountain dwellers.

It is important to realize, however, that this is not an explanation but merely the application of an accepted generalization. Ultimately I shall suggest an explanation that will be based primarily upon the role of acorns in Sierra Miwok cultural development.

In summary and conclusion to this introduction, then, consider the following: not enjoying direct and permanent access to vast herds of deer, to yearly migrating flocks of geese, or to swarming schools of salmon, the Sierra Miwok emphasized an alternative food resource -- they exploited the abundant and numerous species of California oaks, utilizing acorns as the staple of their diet. The term emphasized is important here, for I do not wish to imply that the Sierra Miwok were dependent solely upon acorns to the exclusion of all other foods. Patently this wasn't so. Indeed, it is the effect of the very richness and variety of their diet which I hope to explain. But I choose to do so by first examining, in some detail, the extent to which they could have relied entirely on almost nothing but acorns.

SUBSISTENCE TECHNOLOGY AND NUTRITION

Monophagy: Acorns

In 1936 Gifford employed the phrase "California Balanophagy" to describe the typical complex of behaviors which centered around acorns in the far west. It is interesting to note that other regions of North America elicited other technological responses to the local abundance of oak trees (Driver 1953, Yanovsky 1936). For instance, the Iroquois in the northeast (and other groups clear west to Minnesota and Wisconsin) added lye, and alkalai, to boiling acorns in order to neutralize the tannic acid; and in the southeast acorns were boiled whole, and the valuable oil was skimmed off the top of the hot liquid. These processes were unique to these areas. Similarly, there existed a combination of procedures and products which was particular to the California aboriginal inhabitants. The routine of this "industry", as it was employed by the Sierra Miwok, can be summarized as follows.

The utilization of acorns by the foothill-dwelling Miwok required four separate activities. Each of these activities involved both a negative factor (i.e., limiting to the total output) and a positive factor (i.e., contributing to the final product). Actual disucssion of these activities will help to clarify the benefits and costs of each.

1. Collecting

Collecting the acorns was a simple, annual event and in almost all Miwok groups it was initiated with a first acorn ceremony in the fall (Aginsky 1943). "The acorn harvest lasted many days, perhaps as long as a month (Gayton 1948:178), until enough nuts had been picked up to last over the winter, when food was scarce" (Baumhoff 1963:162). Both men and women engaged in acorn-gathering, with the males climbing the trees to shake the nuts down and the females retrieving the falling and already fallen acorns (Willoughby 1960).

As a rough measure of the effort required to obtain acorns, the author was able to pick up more than three pounds of acorns in less then 15 minutes. This was done at night, with no previous experience, and the total represents only whole, uncracked nuts as produced by one tree, Wolf (1945) was able to land harvest 30-50 pounds in an hour. As a conservative estimate, then, one family of six persons (Cook and Heizer 1965) could easily gather sixty pounds in an hour, or more than 700 pounds during twelve hours of daylight. Therefore, even allowing extra time for relocation to previously untouched trees, it is quite reasonable to accept Chesnut's statement that "as much as 7 or 8 large basketfuls -- some 400 to 500 pounds -- may thus be gathered by one family for a year's supply" (1902:335). The existence of conical baskets that large, and even larger, able to hold perhaps 100 pounds, has been reported by many ethnographers. Leaving aside the question of settlement patterns for the moment, it thus appears that gathering and transporting acorns were factors not limiting to Miwok subsistence. But what of their supply?

At least three types of evidence can be marshalled in order to answer this question. The first and most direct is by gauging the productivity of oak trees. A general way to do this involves examining the cyclicity of acorn production for each species in California: Quercus garryana (Oregon oak), Q. dumosa (scrub oak), Q. durata (leather oak), Q. agrifolia (coast live oak or live oak), Q. lobata (valley oak or California white oak), and Q. douglassii (blue oak or mountain white oak) are all known to mature acorns the first year, i.e., annually; Q. chrysolepis (maul oak or mountain live oak), Q. palmeri, Q. vaccinifolia (huckleberry oak), Q. wislizenii (interior live oak or highland oak) and Q. kelloggii (black oak) produce nuts the second year, i.e., biennially (Jepson 1910). The last two species mentioned in each list (valley oak, blue oak, interior live oak and black oak) are those used most commonly and preferred by the Sierra Miwok (Barrett and Gifford 1933:142). These Indians thus adjusted their taste, their social values, so as to be able to maintain a generally even balance of supply year to year in accordance with the annual abundance of their staple food.

This observation is in agreement with Cook's principle of socio-cultural adaptation to the more available food (1941).

A second way to gauge the direct evidence for acorn abundance is to turn to some quantitative figures collected by Baumhoff (1963) and by Wolf (1945). According to their data, the valley oak could average 350-500 pounds or more, the blue oak averages at least 160 pounds, the interior live oak has a maximum crop yield in excess of 200 pounds, and the black oak average production is between 200 and 300 pounds. These figures are average yields per tree so that once an acorn-gathering group arrived at an oak grove or stand, it would take but a few trees to provide their daily 400-500 pound capacity (as calculated above). Movement between trees, therefore, was a relatively minor percentage of the total energy expended in order to obtain acorns.

To make these figures more meaningful, however, one would have to calculate the density of each species and then correlate that with aboriginal population and territory information. Unfortunately, exact data on the distribution of oak trees in the Sierra Nevada Mountains is extremely hard to come by. The only available approximation to such data relies upon individual report and subjective evaluation. A qualitative statement such as this one by Cook (1941:32) is representative: "For an Indian family to obtain wild subsistence it was necessary to travel some distance, albeit a short distance, because the oak trees supplying acorns grow in a rather scattered fashion over the hills and canyons". It is important to realize that this statement includes more than the distance moved to obtain sustenance: it implies travel from somewhere and thus refers to Miwok mobility and lifestyle. This significant question of nomadic or seasonal or occasional migrations will be considered in due course.

One piece of indirect evidence on the nature of acorn abundance comes from a study on the geographical ecology of the acorn woodpecker. Bock and Bock (1974:696) explain that, "it is probable that acorn woodpeckers living in areas with fewer than four oak species are subject to random but frequent acorn crop failures... By contrast, in areas above the 'resource diversity threshold' (i.e., oak species greater than four)... acorn crops occur virtually every year". Therefore the continued presence of populations of acorn woodpeckers, implying their long-term survival, is a very good indicator of continuing production of acorn crops by diverse oak species. Evidence of the "continued presence of populations" of these birds in the Sierras is provided by the ethnographic record: "Especially in times of shortage, the trees in which the California woodpecker had drilled holes and stored acorns, were examined and the fresh acorns

pried out with a pointed instrument of deer antler" (Barrett and Gifford 1933:143). And though Barrett and Gifford refer to a time of shortage, it would seem that swings of relatively more or less abundant years, rather than the boom and bust cycles of feast and famine, are indicated by this indirect evidence.

One final piece of evidence depends upon a technological or material cultural means of coping with occasional vagaries of supply, namely, storing a good year's crop against a future bad year. Assuming that whole acorns can last indefinitely (and I have found no evidence to contradict the assumption), calculation of storage capacity is important because it could act as a factor limiting dependence upon acorns. Indeed, the fourth activity of acorn utilization is storage, and a detailed consideration of that factor is presented below. But leaving that aside for the moment, we can summarize the discussion of gathering and transportation: An average family of six could easily obtain 300 pounds of acorns in a day. This is a very conservative figure, based on the assumption that not all the members of the family would be able to carry fully laden baskets and that only one trip to and from the trees was made per day. The limiting factors here could be the size of the baskets, their strength, or the strength of the people carrying them. In addition, a relatively poor crop, due to fire, disease, or weather conditions, could be limiting (but then this limitation could be overcome by storage).

Allied to the possibility of storage is trade, an adaptation not yet mentioned. Trade could act to even out local variations in supply over the long run, and its role in Sierra Miwok culture will be more fully considered below. Last of all, in order to balance out the picture, it should be stated that the positive gain of acorn gathering lies in their availability and in the technologically, as well as energetically, undemanding nature of the endeavor.

2. Processing

Many general (Gifford 1936, Merriam 1918, Driver 1953, Grinnell 1958, Kroeber 1923, 1925) as well as specific (Barrett and Gifford 1933, Merriam 1955, Aginsky 1943, Baumhoff 1963) studies have detailed the procedures involved in preparing acorns for consumption. The following account draws upon these sources, and others, in order to describe the particular methods which the Sierra Miwok employed. All of these tasks were performed by females (Grinnell op cit., Willoughby op cit.).

First, the shell must be removed. Even squirrels, though they may lack further sophistication, don't eat the shells. Two methods

have been reported for shell-removal. One, squirrel-like, involves the use of teeth and jaws (Grinnell 1958, Merriam 1967). Although this method is slow and hard on the dentition, one can nevertheless free the nut meats from their shells in a mildly efficient, if crude, manner. More common, however, and more efficient, was the use of a hand held stone and rock platform. Crushing the nuts in this manner is presumably less strenuous, and decidedly less deleterious to one's fitness and future consumption (i.e., masticatory ability).

Once shelled the nut meats were ground to a fine powder or flour. This was accomplished by the use of a mano and metate (Bennyhoff 1956) or a pestle and mortar, the latter rarely made from oak wood, nearly always composed of stone. The stone mortars, moreover, were of two types: a more ancient portable model, "often weighing a hundred pounds" (Barrett and Gifford 1933:272), and a more recent bedrock type (Bennyhoff 1956). This change in style may indicate a change in other aspects of cultural adaptation, a possibility to be considered below. With the use of either type of processing tool, though, it appears that vegetable material was not infrequently included:

> The pulverized root of peltiphyllum peltatum... was sometimes mixed with acorn meal to whiten it. The green leaves of Spanish Clover (Lotus americanus) were pounded with acorns that were too oily, to absorb some of the oil. They did not alter the flavor of the acorn meal. A third plant which was at times pulverized and mixed with acorn meal intended for "bread" making was the root of either a pond lily or a rattail.
>
> (Barrett and Gifford 1933:144-145)

This may have been a very important source of vitamins in the diet, for as Chesnut (1902:360) remarks about clover, "according to chemical analysis the leaves contain most of the essential food ingredients". As an indication of the importance of acorn meal to the diet, it is reported that Sierra Miwok sometimes constructed a small conical slab house over the bedrock mortar so that grinding could continue in bad weather (Barrett and Gifford 1933).

Perhaps the most widely known step in acorn preparation is leaching. Due to the presence of tannic acid (6.6% by weight according to Merriam 1918), raw California acorns taste very bitter. Although this doesn't seem to have bothered squirrels (or woodpeckers for that matter), and even though this concentration of

tannin is not actually poisonous, California Indians devised a process for removing much of this bitter substance. The Sierra Miwok made a depression in the sand by a stream and lined the hole with grape leaves or pine needles. They then placed the acorn meal on top of the leaves and covered it over with pine or other boughs. Water is repeatedly poured over the entire pile, slowly percolating through the meal and thereby leaching out the bitter acid.

Either hot or cold water was used for leaching, the former acting more efficiently and quickly, the latter being less destructive of nutritional value. In connection with this dichotomy it is significant that whereas the Sierra Miwok leach black oak acorn meal (fat content 18.0%) with hot water, they use cold water for blue oak acorn meal (fat content 8.1%) (Merriam 1955). The significance of this practice illustrates a trade-off between loss of tannin and loss of food energy. Molecular lipids (fats) which are leached out along with the tannin by the hot water would be removed in lesser amounts by cold water. Thus to use the more wasteful process on the nutritionally inferior food might render it useless; yet the benefits of speed and efficiency can accrue to processing of the superior food source using hot water. When the meal no longer tasted bitter (usually after about ten dousings with cold water) it was ready to be cooked.

An alternative container to the sand basin was employed when smaller amounts of meal were to be processed. In that case, the meal was placed in a sifting basket which was lined with Lupinus latifolius (Barrett and Gifford 1933). Water was poured over the flour and, as before, leaves were used in order to keep the ground acorn particles from leaking out. In cases of both sand and basket leaching, moreover, the leaves (and boughs) may have performed an even more important function than that of containment: they most likely supplied vitamins to the meal. For just as tannic acid (and fats) were liberated by the leaching, vitamins too would have diffused out from the green plants.

In sum, then, the objectionably bitter tannin was removed from the acorn meal by leaching. Accompanying this removal was the probably unnoticed but nonetheless significant loss of calories in the form of fats (a negative factor) and gain of vitamins from the leaf linings (a positive factor). The fact that the Miwok used both hot and cold water may indicate the continuation of a cultural trait founded in social tradition but with important adaptive biological consequences.

3. Cooking and Eating

There were essentially four products which the Sierra Miwok made from acorn meal. When dumped into a basket full of water and heated by dropping hot stones into the liquid, the meal became a thin soup. If the consistency was thicker it became a mush and was called "nu'pah" (Merriam 1955:61). Both of these were eaten with relishes or condiments of steamed clover which again provided a source of vitamins. In addition, all of the Sierra Miwok groups stored mushrooms and tree fungi for the winter when they were added to flavor the soup (Aginsky 1943) and presumably supplied additional nutrients. Furthermore, "Seed meal was regarded as particularly fine eating. Visitors were given it to eat along with their acorn mush, which was regarded as insipid without such accompaniment" (Barrett and Gifford 1933:141). The result of this supplement was undoubtedly an increase in the protein value of both foods due to the benefit gained from combining complementary amino acids found in each food. And in terms of economy, a little went a long way, since two quarts of meal yielded from ten to twelve quarts of mush (ibid).

If the thick mush was formed into biscuits or cakes and put into the stream to cool and harden, it was called "oo-la" (Merriam 1955). If, instead, the meal or mush was shaped into thick pancakes or loaves, with the addition of bits of clay, and then baked on hot rocks or in an earth oven, the food was named "ma-soo'-tah" (ibid). According to Merriam (1955:67), "The ma-soo'-tah are sweet, whereas the oo-la' is slightly sour". The Miwok say they add clay to the dough for taste since it sweetens the bread by absorbing excess tannic acid still in the meal. Of greater nutritional importance, though, is the fact that the clay undoubtedly also supplied essential minerals which might otherwise be lacking in the diet. Thus we see once more how aboriginal social tradition and technological procedures contribute, perhaps unbeknownst to their practitioners, to the biological benefit of the group. The only limiting factor here is the technological skill involved, something which developed in an as yet unknown manner and rapidly spread throughout the central California aboriginal populations.

4. Storage

The final, and for all intents and purposes crucial, factor in assessing the possibility of total dietary dependence on acorns is that of storage. As we have already seen, during the month or so of the harvest season, the Sierra Miwok were readily capable of

gathering and transporting at least 300 pounds of acorns per family per day. They had developed the technology for processing the raw acorns so as to render them more palatable. Furthermore, they possessed the ingenuity for preparing the meal in a number of forms, to each of which accrued various "hidden" nutritional benefits. The only limit to subsistence on acorns, then, which has not yet been fully explored, is that of year to year fluctuations in supply, specifically as related to demand. "Thus the quantity of stored food that could be carried over the winter would have been a crucial factor in determining population size" (Baumhoff 1963:161).

Some qualitative answers to the question of supply can be gleaned from the literature. First of all, the Sierra Miwok did construct acorn granaries or storage caches. As a matter of fact, "so tightly were these caches built, that they were used for the storage of grass seeds" (Barrett and Gifford 1933:207). In addition, the technique was exported to the north, as Kroeber (1923:410) explains: "The acorn cache or granary of the type described for the Miwok was used by the Maidu of the valley as well as the foothills".

As to their capacity, Barrett and Gifford state that, "The nuts kept for months and were stored whole in outdoor granaries...a water-tight storehouse where a whole winter's supply of acorns or seeds could be kept. Nearly every family had at least one of these caches, and a man of importance who must provide for feasts required several" (1933:142...208). Merriam (1905:596) is not nearly so conservative: "But acorns were rarely wanting, for it was the universal practice to gather and store each fall enough to last 2 years, so that if a bad year came the people would not suffer...". All writers claim that enough could be put by to last at least through the fall and winter seasons. But can we be more precise? Can we calculate the actual nutritional value of a stored amount of acorns and then, on the basis of population data, conclude whether or not total dependence on acorns was a viable possibility for the Sierra Miwok?

Given certain assumptions, the answer to this question is "yes!".

Table 1 presents the food composition of various species of acorns in various stages of processing. The data are presented as percentages, presumably based on weight (a common standard in the assessment of nutritional value) rather than on volume. The last two columns are the most important for the following discussion.

Table 1

CHEMICAL COMPOSITION OF ACORNS (%)

Species or Form	Water	Fats	Carbohydr.	Ash	Protein	Kcalories per pound
Q. lobata (Valley)	9.0	5.5	69.0	2.1	4.9	--
Q. garryana (Oregon)	9.0	4.5	68.9	1.8	3.9	--
Q. douglasii (Blue)	9.0	8.1	65.5	2.1	5.5	--
Q. chrysolepis (Maul)	9.0	8.7	63.5	2.0	4.1	--
Q. agrifolia (Coast Live)	9.0	16.8	54.6	1.8	6.3	--
Q. Kelloggii (Black)	9.0	18.0	55.5	1.6	4.6	--
Average of six above (air-dry storage)	9.0	10.3	62.8	1.9	4.9	2718
Meal	8.7	18.6	65.0	2.0	5.7	2265
Flour (leached)	11.3	19.8	62.0	.29	4.5	--
Bread	60.3	9.9	27.0	0.6	2.2	2347

Sources: Baumhoff 1963:162, Chesnut 1902:339, Merriam 1918:135, Wolf 1945:62-63, Woods and Merrill 1899:80.

Table 2 is an abbreviated version of the 1974 Canadian recommended daily nutrient intakes (Pike and Brown 1975:916-917, Table 25.4). The adjusted protein requirements have been scaled down 6% for males and 4% for females. This was done because the average stature for living Miwok Indians is 166 cm. for males (aged 19-60 years) and 154 cm. for females (aged 17-60 years) (Gifford 1926b--see Appendix A for details). Calorie requirements were not similarly reduced since, as we shall see, more than enough energy was available from acorns.

Finally, we come to the actual storage data and calculations derived therefrom. I was able to find only three descriptions of the Sierra Miwok acorn caches which included quantitative measurements. According to Barrett and Gifford (1933:207-208), there were two different sized granaries, the bottoms of both of which stood a foot above the ground: "The smaller of the two... stood originally six feet high... The larger was nearly twelve feet high... five feet in diameter and its conical bottom was about three and a half feet deep". Kroeber (1923:447) describes a cache he saw which was "...a yard or so in diameter, a foot or two above the ground, and thatched over beyond the reach of a standing person, after it was filled". Grinnell (1958:42) mentions acorn bins which "hold perhaps fifty bushels": "From the point of beginning the basket rounds outward until it becomes five feet in diameter, and is then carried to a height of ten feet or more..." (ibid). Appendix B details the methods used to calculate the volumes of all four types of containers.

The only missing piece of data is one that can relate the composition by weight of Table 1 to the storage capacity by volume of Table 3. This information was supplied by the author from the afore-mentioned 15 minute collection of Colorado acorns. On the basis of twenty separate fillings and weighings, one liter of Colorado acorns weighed an average of 507 grams, with a range of from 490 to 520. This is an underestimate of the actual amount of California acorns and thus the results of the following calculations are conservative (see endnote 1).

Doing the best possible under the circumstances, then, the author calculated the amount of energy and protein available daily per person. The assumptions of one cache for each family (Barrett and Gifford 1933) and an average of six persons per family (Cook and Heizer 1965) were gleaned from the literature. The results are displayed in Table 3; the relevant mathematics have been included as indicated.

Table 2

1974 CANADIAN RECOMMENDED DAILY NUTRIENT INTAKES

Age (Years)	Sex	Weight (kg)	Height (cm)	Energy (kcal)	Protein (gm)	Adjusted Protein (gm)[a]
1-3	Both	13	90	1400	22	21
4-6	Both	19	110	1800	27	26
7-9	M	27	129	2200	33	31
	F	27	128	2000	33	32
10-12	M	36	144	2500	41	39
	F	38	145	2300	40	38
13-15	M	51	162	2800	52	49
	F	49	159	2200	43	41
16-18	M	64	172	3200	54	51
	F	54	161	2100	43	41
19-35	M	70	176	3000	56	53
	F	56	161	2100	41	39
36-50	M	70	176	2700	56	53
	F	56	161	1900	41	39
51+	M	70	176	2300	56	53
	F	56	161	1800	41	39

Adapted from Pike and Brown 1975:916-917, Table 25.4.

[a] See Appendix A for details.

Table 3

FOOD ENERGY AVAILABLE FROM STORED ACORNS

Volume of cache (cubic feet)	(kilo-liter)	W Weight (lb)	X W x 2300[e] (kcal/yr)	Y X ÷ 365 (kcal/day)	Z Y ÷ 6 people[f] (kcal/day/person)
170[a]	4.8	5366	12,341,800	33,813	5636
98[a]	2.8	3099	7,127,700	19,528	3255
94[b]	2.7	2975	6,842,500	18,747	3124
196[c]	5.6	6246	14,365,800	39,358	6560
140[d]	4.0	4442	10,216,600	27,991	4665

PROTEIN AVAILABLE FROM STORED ACORNS

Volume of cache (cubic feet)	(kilo-liter)	W Weight (kg)	X W x 4.5%[g] (gm/yr)	Y X ÷ 365 (gm/day)	Z Y ÷ 6 people[f] (gm/day/person)
170[a]	4.8	2439	109,755	301	50.1
98[a]	2.8	1409	63,405	174	29.0
94[b]	2.7	1352	60,852	167	27.8
196[c]	5.6	2839	127,764	350	58.3
140[d]	4.0	2028	91,260	250	41.5

[a] Barrett and Gifford 1933:207-208, as calculated in Appendix B.

[b] Kroeber 1925:447, as calculated in Appendix B.

[c] Grinnell 1958:42, as calculated in Appendix B.

[d] The average of 170, 98, 94 and 196.

[e] Based on 2300 kilocalories per pound, Table 1.

[f] Based on six persons per family, Cook and Heizer 1965.

[g] Based on 4.5% protein by weight, Table 1.

NOTE: The lowermost figures in Column Z are the most important for the purposes of the following discussion.

As was stated earlier, average calorie requirements, even on the basis of a (Canadian) population with larger average size, could have been easily met by the amount of acorns contained in any of the granaries. With the technology which the Sierra Miwok developed, meeting energy needs on a diet consisting entirely of acorns was very much within the realm of possibility. The case for protein requirements is not quite as clear.

Based on the above tables, only the two largest reported granaries would definitely be able to supply sufficient protein to an average family of six. The Canadian levels of recommended dietary intake, however, are purposely high, the government wisely preferring to err on the positive side. Moreover, total grams of protein is a misleading criterion since it is the quality of protein, that is, the degree to which the eight essential amino acids are present in "ideal" proportion, which ultimately determines the utilization of that food by the body. Thus, in order to be as precise as possible, we must readjust the assessment of Sierra Miwok Indian protein requirements in light of these facts.

Table 4 presents minimum protein levels for the world's populations (not just the affluent West) on a compared basis relative to the "ideal" sources of milk or eggs. The columns with scores of 70 or 80 are included because protein analyses of nuts and seeds fall within this range (Lappe 1971). Unfortunately, to the best of my knowledge, acorns have never been analyzed for these specific data.

Even these corrected and readjusted figures, though, are too high. For one thing, a footnote to the table states that, "The correction may overestimate adult protein requirements" (Pike and Brown 1975:925). For another, once again the body weight estimates are too high for the average stature of living Sierra Miwok Indians. Therefore, given an average family of six (as constituted in Table 4, footnote b), possessing an average granary with 140 cubic foot capacity, an average of 42 grams of protein would be available per person per day for the entire year. This supply of protein, like the supply of calories, places the total dependence of Sierra Miwok Indians on acorns easily within the realm of possibility.

In summary and conclusion to this rather lengthy discussion, then, let me present a very brief answer to the question posed earlier. The nutritional requirements of any population include sufficient amounts of quality-protein for growth and body maintenance, ample calories for energy expenditure, and smaller quantities of vitamins and minerals in constant, if not daily, supply. The technological and traditional practices of the Sierra Miwok enabled these Indians to fully exploit essentially one food resource in order

Table 4

Age Group	Body Weight (kg)	Safe Level of Protein Intake (gm protein/person/day)	Adjusted Level for Proteins of Different Quality (gm/person/day) Score[a] 80	Score[a] 70
Children				
1-3 years	13.4	16	20	23
4-6 years	20.2	20	26	29
7-9 years	28.1	25	31	35
Average[b]			26	29
Male Adolescents				
10-12 years	36.9	30	37	43
13-15 years	51.3	37	46	53
16-19 years	62.9	38	47	54
Average[b]			43	50
Female Adolescents				
10-12 years	38.0	29	36	41
13-15 years	49.9	31	39	45
16-19 years	54.4	30	37	43
Average[b]			37	43
Adult Man	65.0	37	46	53
Adult Woman	55.0	29	36	41
Average Family of Six[b]			36	41

Adapted from FAO/WHO, "Energy and Protein Requirements," WHO Tech. Rep. Ser., No. 522:74 (1973).

[a]Scores are estimates of the quality of the protein usually consumed relative to that of egg or milk.

[b]Average family consists of 2 children, 1 male adolescent, 1 female adolescent, 1 male adult, 1 female adult.

to meet their nutritional needs. It appears that the Sierra Miwok could have enjoyed an almost unheard-of luxury: a month's worth of collecting for a year's worth of living.

Polyphagy: Other Foods

The Sierra Miwok could have sustained themselves almost entirely on acorns, but they didn't. Not aboriginally, anyway, although in more recent times they have had almost no other choice, as Merriam (1967:333) reports from a visit made in August of 1900:

> The Mew-wah Indians are living in filth and squalor... They had a few peaches, but appeared to be living almost wholly on acorns of the black oak which is common in this locality. They also eat the nuts of the digger pine which is also common here. But they cannot begin to get the pine nuts in the quantity they need, while the acorns are inexhaustible.

In a similar vein, according to Chesnut (1902:334), it is possible for a group to be monophagous and not tire of its sole source of sustenance. "The Concows especially, who are not used to eating much meat, claim that they never get sick from eating the mush and bread made from acorns". The Sierra Miwok, however, were highly polyphagous.

Barrett and Gifford (1933:137) provide a good general description of the highly varied Miwok dietary:

> Nearly all the mammals, birds, reptiles, and fishes which could be caught, served as food, as did several kinds of insects... Of vegetable foods manzanita berries were the "cheapest" and least desirable. Bulbs, corms, and mushrooms were next highest in ascending order of esteem. Certain seeds came next, but were considered luxuries. Acorns were regarded as the finest vegetable food. The people who had a sufficiency of both acorns and venison was considered well off... Deer meat was the most highly regarded flesh, with the meat of the California Gray Squirrel a close second. In the lower foothills salmon was the most prized fish, in the mountains trout. The principal crops were as follows: mushrooms in winter, clover in spring, seeds in summer, acorns

> in fall. Plums and cherries were gathered in the spring. In winter the diet was more largely of meat than at other times of the year. The mammals, especially squirrels, were fat and nice to eat at this season.

To this list can be added: worms, larvae, lamprey eels, crickets, locusts, mussels, (Kroeber 1923), deer tripe, honey, digger and sugar pine nuts (Merriam 1967), hazel nuts, buckeyes, tree fungi (Aginsky 1943), bear, beaver, rats, quail, pigeons, woodpeckers, and dogs (Barrett and gifford 1933).

Over 37 species of greens were consumed, "usually eaten as accompaniment to acorn soup" (Barrett and Gifford 1933:158), as well as 28 different varieties of bulbs and corms (ibid). As mentioned previously, the former provided a valuable supply of vitamins and the latter undoubtedly helped to complete the acorn as a protein source by providing missing essential amino acids. Grasshoppers, which are complete animal protein in and of themselves, "are eaten after being mixed with pounded acorns, and constitute one of the national dishes... by the Diggers of California and the Plains. Grasshoppers are sometimes gathered into sacks saturated with salt, and placed in a heated trench, covered with hot stones, for fifteen minutes, and are then eaten as shrimps or they are ground and put into soup or mush" (Palmer 1871:415).

In addition to this vast wealth of local food resources, the Sierra Miwok traded with neighboring culture groups. The nutritionally most significant trade items was salt, a mineral which was found in abundance east of the Sierras. This territory was inhabited by the Mono, whom the Miwok call the "salt people" (Kroeber 1923). With the Mono the Miwok also exchanged acorns, squaw berries, elderberries, manzanita berries and material goods for pine nuts, pandora moths, caterpillars, fly larvae, pinon nuts and animal skins (Davis 1961). The Northern (Sierra) Miwok traded acorns and baskets for salt from the Washo (to the northeast), and provided digger pine nuts and salt to the Plains Miwok in exchange for grass seeds and fish (ibid). The Central (Sierra) Miwok traded baskets and bows and arrows for dogs with the valley living Yokuts. Finally, all of the Sierra Miwok groups exchanged different species of acorns amongst themselves and with the inhabitants of the San Joaquin valley. In addition, "acorn flour was also an item of trade between interior and coastal tribes" throughout California (Downs 1971:293).

In general, then, the Sierra Miwok enjoyed a rich and varied diet. Between local collection, trade, and storage[2] it is not surprising that neither the reality nor the mythic tradition of famine

is present. "The Miwok by no means lived from hand to mouth, but preserved and stored large quantities of food. Acorns and seeds were stored without special preparation. Greens and grasshoppers were steamed and dried before packing away. Meat and fish were dried and stored" (Barrett and Gifford 1973:139). Even surplus acorns, that is, those not traded with another village, were given to the needy of one's own village (Aginsky 1943). One gets the impression that the Sierra Miwok had little to trouble them in the way of subsistence. "People ate when they felt hungry. Visitors were fed immediately upon their arrival" (Barrett and Gifford 1933:138).

SOCIOCULTURAL ADAPTATION AND POPULATION

Given the wealth of nutritional resources detailed above, it is not surprising that Kroeber (1925:523) would write: "The California Indians are perhaps the most omnivorous group of tribes on the continent". I prefer to use the term polyphagous, for whereas omnivorous implies the capacity to eat many different foods, polyphagy implies the actual practice thereof. Either way, an important consideration of the anthropological aspects of a varied diet is the way in which a population organizes itself in reference to the ecological determinants of that diet.

Many different lifestyles are compatible with polyphagy, as the global range of human cultural variations amply demonstrates. It is therefore worthwhile to try to explain the specific pattern of Sierra Miwok subsistence within the larger context of their particular cultural development. As Baumhoff (1963:158) puts it, "subsistence efficiency has important effects on population size, density, and aggregation, each of which has important social correlates". Add to this a description (or partial reconstruction) of cultural history and the smaller, more detailed image of acorn-staple polyphagy resolves itself into the broader picture of sociocultural adaptation through time. The remainder of this paper, then, focuses upon the larger question of culture-population-environment interactions. It will conclude with reasoned speculation about the role of populational and environmental determinants in aboriginal Sierra Miwok lifestyle.

Land Use and The Social System

The Miwok concept of nena combined the social awareness of membership in a male lineage with the territorial idea of an ancestral

home. As Gifford (1926a:389) explains it, "The lineage was a landowning group, the limited real estate which was held by it being used in common by all members of the lineage". At its head was a chief or patriarch of the lineage, whose position was inherited by the eldest son in the patrilineal family. Lineage exogamy was the rule since each nena "is composed of such a small group of closely related people that marriage within it is inconceivable" (ibid). Moiety exogamy, based on the common west coast pattern of a land-water dichotomy, was also recognized. But as Downs (1971: 294) points out, this supra-local system was relatively insignificant: "The availability of food and the relative productivity in the several food categories, within small areas, may be one of the main underlying causes of an almost universal California pattern of social atomism, with little organization beyond the village level and few structural links with other such units".

Indeed, in pre-contact times the nena "was an independent autonomous political unit" (Gifford 1926a:389). It wasn't until European influence exerted itself that an ancient settlement pattern was forced to change:

> Caucasian pressure brought about true village life among the Miwok, in which a number of unrelated lineages, often of different moieties, came to form a new political body, the village community... From the small size of the settlements in the mountainous... portions of the state, it would seem likely that each autonomous hamlet in most cases comprised but a single lineage. (ibid).

Without regard to consideration of population numbers, then, we can assume that congregation into larger, more densely populated areas was a relatively recent phenomenon.

Before describing the use of land by Sierra Miwok groups, it might be useful to briefly examine two other cultures. Among the Karok, a northern California population living near the Coast Mountain range, "Acorns are gathered in early fall. When gathering each family has a special place where they 'pick up' fallen acorns; there is no trouble between families" (Schenck and Gifford 1952: 381). At an opposite extreme in terms of gathering-group size, stand the Yahi group of the Yana Indians of north central California. "The harvest time was the most social season of the year for the Yana. Acorns were ripe, ready for picking, shelling, drying, and storing as were buckeye, and pine and hazel nuts. Everyone took part in the harvesting, villages coming together in temporary

camping places, as many as two or three hundred or more people in a single camp" (T. Kroeber 1961:37).

In between the single family unit on the one hand and the multi-group unit on the other was the collecting-group pattern of the Sierra Miwok. Gifford's (1926a:390-391) description of their land use is the most detailed available:

> Each nena held a small tract of land about its hamlet. There was always a spring or stream within the tract. The bulk of the country, however, was unclaimed by the nena and was regarded as "no-man's-land", or more correctly "every-man's-land", upon which people from any nena might seek vegetable foods and hunt animals. This rather unusual arrangement in which much of the land was unclaimed is better understood when it is realized that each summer the Miwok moved into the higher mountains, so that practically every nena had occasion to travel and had occasion to collect food and other materials away from its fixed place of habitation. It is quite possible that these periodic movements into the higher mountains on the part of all nena shaped the ideas as to land ownership and resulted in only limited holdings which were jealously guarded because of their proximity to the ancestral dwelling, while there was mutual recognition of the international rights of all nena to gather vegetable products and hunt animals in the remainder of the country.

Here then is an example of extra-local or regional organization based on a tacit understanding between groups. Such a tradition of nonhostility seems to be characteristic of the Sierra Miwok. Warfare is not mentioned by any ethnographers, an impression which is supported by Kroeber's (1923:451) observation: "By impulse, the native is thoroughly peaceable". So perhaps this tendency towards cooperation, as further highlighted by the mutually beneficial activity of trade (whether of material or matrimonial value), has an economic as well as a social foundation.

Surely the abundance of natural resources, most especially a wide variety of foods, helps to explain the ease with which neighboring groups got along. Competition for scarce resources is a basic and often primary cause of intergroup conflict. But in order to fully explain the total pattern of Sierra Miwok adaptation of subsistence lifestyle, three variables must be considered. The quality of the environment and its possible limitations have been

detailed; sociocultural adaptation, including technological and territorial traditions, has been explored; what is left to be discussed is population size.

Population Density and Settlement Patterns

As the previous discussion suggests, the concept nena represents what might be termed a socio-ecological solution of Miwok culture to the problem of population dispersal and resource exploitation. It combines land use (especially acorn utilization) with a kinship based social system so that both population density and settlement patterns are determined. An illuminating discussion of this adaptive complex, this cultural solution, is presented by Kroeber (1926b:30-32). He compares the foothills dwelling Miwok to a generalized southern California desert pattern,

> where conditions of life were not too abundant and where it was necessary for the group to be not too large in order that it would not eat itself out of food in its territory...
>
> The territory of the nena was perhaps as large as in the southern desert because, the natural resources of the country being greater, it was possible either for the groups to grow larger or for their territories to be smaller than in the southern desert. The former was the way it had worked out among the Yokuts farther south in the San Joaquin valley; the latter was the case among the Miwok. The territory of the Miwok nena was likely to be perhaps some 10 miles wide and 5 miles long, more or less, possibly following a stream, with the population averaging one per square mile, again more or less. This ratio seems to have given the proper balance between food supply and population in this area.

This density of about one person per square mile, though still perhaps high for any area of similar size in aboriginal North America, is low when compared to the figures of other researchers.

Although I will cite only a few studies concerned with population size and density in aboriginal central California (not that more than a half dozen have been attempted), they will suffice to indicate the trend in this line of research. As more

sophisticated methods and more complete knowledge became available, estimates of pre-contact population size have continually and substantially increased.

In 1925 Kroeber estimated that the total population of both Plains and Sierra Miwok, as of 1770, was about 9000. Although he feels that this may be too high, his "opinion is the formulation of years of attention to all possible aspects of the question" (1925:70). Thirty years later Cook (1955) calculated that for the foothill strip alone, in the period circa 1850, the figure would be about 4150. At first glance this estimate appears to support that of Kroeber. However, the Plains area, which Kroeber included but Cook excluded, is known to have been significantly more densely settled than the foothills region. Furthermore, Cook assumes that his estimate is conservative since Indian populations had been continually decreasing since first contact with Europeans. In addition, his method involved multiplying the number of villages times an average of 21 persons per village, this latter ratio coming from Gifford's work. But Cook and Heizer (1965) recently changed that ratio to an average of 33 persons per village, a 65% adjustment which would increase Cook's earlier estimate to 6848, again only for the foothill dwellers.

Finally we come to Baumhoff's (1963) detailed calculations which were based upon the subsistence efficiency (the "resource index") of California Indians. Estimating the utilization of game and acorns by the Miwok, Baumhoff formulates the following figures:

	Population	Area	Density
Central Miwok	4,410	2870	1.54
Southern Miwok	5,766	1905	3.03
Plains Miwok	14,350	1290	11.12
Totals	24,526	6065	4.04-5.23 (avg.)

Adapted from Baumhoff (1963:231)

We can thus see that the most recent estimate of aboriginal Miwok population (even excluding the Northern Sierra Miwok) is between two and three times greater than Kroeber's earliest speculations.

More relevant, though, to the present discussion, is the substantial increase in density calculations. This increase lends strong support to the notion, perhaps first enunciated by Merriam

(1905:594), that in California "...the aboriginal systems based on hunting and gathering supported the greatest density of population found anywhere in North America north of Mexico, not excluding the eastern and southeastern agricultural regions" (Downs 1971:293). A brief consideration of this notion, with respect to an explanation of the cultural development of the Sierra Miwok, will conclude this paper.

CULTURAL DEVELOPMENT OF SIERRA MIWOK LIFESTYLE

The following generalization can serve as both a summary to what has preceded and an introduction to what will follow: "That small groups could sustain themselves for many generations within circumscribed territories and without appreciable outside contact suggests the bountiful nature of the habitat and successful and widespread techniques for exploiting it" (Newcomb 1974:189). Before we explore that success, however, a word of warning is due: "The civilization of the Miwok is imperfectly known" (Kroeber 1923:445). Though this caveat was issued over fifty years ago, it can still serve as a helpful reminder that present speculation is based on far from complete evidence and information.

The detailed, original calculations of this paper focus upon balanophagy. That a population (or, more generally, a group of populations) would develop the technology necessary to utilize such a dependable food resource as acorns has been recognized for some time. That a population could subsist almost entirely and solely on acorns has not been as obvious a proposition. Nevertheless it is this hypothesis which helps to explain the adaptive advantage of balanophagy and is useful in analyzing the subsistence lifestyle which surrounded this resource.

Data from prehistory add support to an understanding of the Sierra Miwok orientation to their ecological situation. "In the records of the University of California Archaeological Survey are literally dozens of bedrock mortar sites situated above the 6000 foot level. Bennyhoff (1956:19) notes that thirteen sites recorded at elevations between 6500 and 7500 feet in Yosemite National Park have from 1 to 52 mortar holes in association" (Elsasser 1958:29). Now since pulverized meal cannot be stored for any significant amount of time, and since altitudes higher than about 6000 feet are too cold and snowbound in winter for year-round habitation (Barrett and Gifford 1933), there are two alternative explanations for these artifacts. Either a lot of people assembled simultaneously, for a relatively short time span, in order to grind their meal; or else

fewer people habitually used and reused the same bedrock mortars. On the basis of the present archaeological analysis one cannot conclusively decide between these two possibilities. Nevertheless, data from the excavation reports of Bennyhoff (1953, 1956) strongly suggest "the reoccupation season after season of many of these sites." And if we supplement these facts with ethnographic evidence, a picture of habitual, seasonal movement begins to emerge.

The development of the concept nena among the Sierra Miwok may very well have been an adaptive response to increasing numbers of people attempting to share a fixed resource. This concept combines cultural control of land with social regulation of the people depending on that land. Fixed access to stationary and limited but abundant oak trees developed into a more or less tacit understanding in Miwok tradition. It defined land use, so far as we can tell, only in terms of acorns, for reciprocal exploitation via hunting, snaring, collecting and, to a lesser extent, fishing, was indeed allowed (Kroeber 1962b). But why did such a "policy" develop in the first place?

Although a strongly supported answer to this question is beyond the present scope, there are archaeological studies of central California which begin to shed some light. According to Beardsley (1948), from the early horizon (about 5000 years ago) through historical times, there is an increasing emphasis on vegetable foods, a decreasing emphasis on hunting, and a rise and then fall in dependence on fishing. Let us assume for the sake of argument that a similar trend occurred among the foothills as in the valley. Add to this trend a small but general population increase, or at least no decrease in size and density. This second assumption is based on the facts of an abundance of food, more permanent settlement (see below), and more highly successful subsistence adaptation (this last due to familiarity with the environment, intergroup contact and diffusion of ideas and techniques, and improvements in acorn processing).[3] We then have a situation in which regulation of access to certain parts of the environment becomes advantageous to all. Under these circumstances cooperation holds greater survival value than does competition.

Not that all the Sierra Miwok groups got together, discussed the matter as I have just done, and decided what the best course of action would be. Obviously they didn't. But as A.I. Richards (1939:34) has explained it: "In any society, living on a subsistence level, the preparation of the staple food must determine the routine of the household". The routine of the household, in turn, reflects the subsistence lifestyle of the culture. Furthermore, as far as

acorn preparation is concerned, we know that there was a change from portable to stationary implements (Bennyhoff 1956).

> What brought about the change from portable bowl to stationary bedrock mortars is unknown. The hypothesis suggests itself, however, that the seasonal movements to higher and lower altitudes may have led to the invention of the bedrock mortar as a temporary convenience. Transportation of the heavy portable mortars, often weighing a hundred pounds, would have been a difficult and wasteful proceeding, when the available transport was needed for the food products gathered. Thus the bedrock mortar may gradually have come into use. The bedrock mortar is formed by use and does not have to be laboriously pecked out as do the finished portable mortar. Moreover the bedrock mortars served a social purpose. Those for a hamlet were often all situated in a single granite outcrop. This meant that the matrons gathered there, instead of each preparing her acorns separately at home in a portable mortar.
>
> (Barrett and Gifford 1933:272)

Once they had begun to fully exploit acorns, the subsistence life-style of the Sierra Miwok came to be one of seasonal movement between permanent settlements. The archaeological survey of the Yosemite region completed by Bennyhoff (1956) supports this notion. His data indicate a dichotomy between higher elevation "campsites" and lower elevation "villages". Obsidian flakes (and lack of mortars) in the former show evidence of hunting activity; number and depth of mortar holes in the latter bespeak habitual nut and seed grinding.

Wherever the knowledge of processing acorns, especially leaching, spread, it invariably improved the local diet. One way to view this improvement is in terms of a great increase in caloric input (in the form of food) for a relatively minor increase in output (in the form of work). This surplus energy, in turn, could very easily have generated a population increase. It certainly doesn't appear to have produced the elaborate and sophisticated material culture found among many of the aboriginal inhabitants of the Pacific Northwest Coast.

Baumhoff (1963:230), relying upon the concept of a land's carrying capacity, concluded that population had reached a maximum: "The central Californians...had evidently reached about the limit

of productivity, given a non-agricultural economy, and therefore could have progressed no further unless they abandoned their economy and started on a new track". Conclusive evidence for this position will be provided when a diachronic archaeological analysis reveals little or no change in size, density and distribution of habitation sites. The apparent shift to a permanent settlement pattern will make such an analysis both easier and more valid.

On the other hand, such an analysis might indicate, for the reasons stated above, that populations of Sierra Miwok groups were on the increase. Population growth may have continued right up until contact with Europeans when disease took such a heavy toll throughout the New World (Dobyns 1966). If this were the case, the traditional concept of nena may have been initially strengthened under the resulting population stress which threatened it. Population increase without the occurrence of warfare would be one way to guage the degree of success promoted by a continuation of nena. Conversely, more recent erosion of the efficacy of this concept developed under the influence of European domination (see Gifford 1926a above). Ultimately, culture clash and subordination disrupted the traditional relationship between Miwok socio-cultural adaptation and population increase.

In general, there seems to be a correlation between numbers of people and the development of social systems. Baumhoff presents the logic and the evidence as applied to a number of California groups including the Miwok:

> Goldschmidt (1948) indicated that the unilineal organization was most strongly developed among (other groups and)... the Miwok. One cause of the development, he mentioned, was the high population densities in central California. In areas of dense populations one could not have intimate knowledge of everyone with whom one came into frequent contact. Therefore it was necessary to formalize relationships between people, and this was most easily done along family lines. Goldschmidt's hypothesis is substantially supported by the present population data: the tribes with strongest lineage organization are in the most densely populated areas - the north Coast Range - Sierra Foothills zone...
>
> (Baumhoff 1963:228)

Thus adjustment to population pressure is often regulated by social institutions. Moreover, in the case of the Sierra Miwok this adjustment included additional regulatory factors.

Based on the nutritional content of acorns, on their easy collection and storage as well as the added nutritional benefits gained from techniques of processing and preparation, it is clear that they are a highly valuable food resource. Aboriginal groups of the California Sierras who exploited this resource were well adapted to conditions of hardship and shortage; they were also able to greatly expand their dietary so that it included a wealth of highly varied foods. Balanophagy provided a secure and dependable subsistence base. Once it began to be successful, adaptation to acorn-eating acted as an essential and focal organizing cultural element.

The establishment of permanent villages at lower elevations permitted full exploitation of acorns; it also required assured access to stands of oak trees. Need for this assurance contributed to the development of the concept nena. Relatively high population density further supported the benefits of a regulated land use policy. In both social and economic terms, however, cooperation prevailed over competition. This attitude was integral to nena. Finally, this concept reduced the possibility of over-exploitation of an abundant but ultimately finite resource. For the Sierra Miwok, nena provided a successful cultural solution to many of the social, populational, environmental, and economic problems posed by balanophagy.

SUMMARY AND CONCLUSIONS

I have tried to demonstrate, with as much detail and as completely as possible, that dependence upon acorns alone was by no means impossible for the Sierra Miwok. It was necessary to demonstrate this in order to assess the nutritional status and technological capabilities of an assumed typical family unit. To this calculation of the minimum supply must be added a variety of foods which, though deprecated by some (see the Foreward to this paper), is quite remarkable for its wealth and nutritional value. The richness of the Sierra Miwok diet made possible one of the highest population densities in aboriginal North America.

These conclusions as regards subsistence, which had been reached in the first part of the paper, were then applied to a more general discussion of sociocultural adaptation. The Miwok concept nena was analyzed in the light of subsistence activity, population density and social relationships. It was shown that this "socio-ecological" concept had developed as a highly effective means of spacing apart groups which might otherwise have been in competition

for a fixed resource base. The effectiveness of this cultural solution was demonstrated in part by the interrelationships between improved efficiency of acorn processing, permanent settlement patterns, and probable population increase. Finally, the subsistence history and prehistory of the Miwok were briefly explored in an attempt to explain their particular "policy" of land use. The practice of seasonal migration to higher altitudes may explain in part why these foothill and mountain dwelling Miwok were "relatively primitive in culture": built into their concept of territory or home base was a recognition of the necessity of seasonal movement for food-gathering. They were mobile and therefore the development of elaborate material culture was impossible.

The importance of the acorn to the Sierra Miwok has been noted by many writers in their recognition of its having been a "staple" in the aboriginal diet. This is certainly true, but it also had significant impact on population phenomena. Furthermore, it was a primary factor determining cultural development. This is not to say that the abundance of oak trees dictated the human response to their presence. But what is suggested is that utilization of the acorn had a profoundly orienting effect upon cultural adaptation. Aboriginal balanophagy among the Sierra Miwok was truly a matter of lifestyle.

APPENDIX A

These are the calculations of the percent reduction in daily protein needs. They are based on the reduced height of living Sierra Miwok (Gifford 1926b) as compared to the average of a standard population (modern Canadians) whose dietary requirements have been assessed.

GROUP	COMPARATIVE AVERAGE HEIGHTS			
	N	Males aged 19-60 (cm)	N	Females aged 17-60 (cm)
Northern Miwok	1	173	1	151
Central Miwok	4	165	1	152
Southern Miwok	4	166	4	155
Weighted average		166		154
Standard population		176		161

For males the reduction is $\frac{10}{176} = 6\%$.

For females the reduction is $\frac{7}{161} = 4\%$.

APPENDIX B

These are the calculations for the volumes of the four acorn storage caches. (The symbol π means "pi", i.e., 3.14).

1. The larger granary from Barrett and Gifford (1933:207-208) is composed of a cylinder plus a cone.

Cylinder: height = 7-1/2 ft. (Total height 12 feet minus 1 foot above the ground minus 3-1/2 feet conical bottom)

radius = 2-1/2 ft.

$V = \pi r^2 h$ $V = (3.14)(2.5)^2(7.5)$ 147 cu. ft.

Cone: height = 3-1/2 ft.
radius = 2-1/2 ft.

$V = 1/3\ \pi r^2 h$ $V = (.33)(3.14)(2.5)^2(3.5)$ 23 cu. ft.

Total volume 170 cu. ft.

2. The smaller granary from Barrett and Gifford (1933:207-208) is composed of a cylinder:

height = 5 ft. (Total height 6 feet minus 1 foot above the ground)

radius = 2-1/2 ft. (Assumed same as above)

$V = \pi r^2 h$ $V = (3.14)(2.5)^2(5)$ Total volume 98 cu. ft.

3. The granary described by Kroeber (1923:447) is assumed to have a height somewhere between the two above, 9 feet being a reasonable guess. It is a cylinder:

height = 7-1/2 ft. (Total height 9 feet minus 1-1/2 feet above the ground)

radius = 2 ft.

$V = \pi r^2 h$ $V = (3.14)(2)^2(7.5)$ Total volume 94 cu. ft.

4. The granary described by Grinnell (1958:42) is a cylinder, the height of which is "ten feet or more":

height = 10 ft.

radius = 2-1/2 ft.

$V = \pi r^2 h$ $V = (3.14)(2.5)^2(10)$ Total volume 196 cu. ft.

ENDNOTES

1. For the purposes of the present discussion, it is important to note that Colorado acorns are not the same as California acorns and it is the volume or mass of the latter in which we are interested. But since volume increases faster than surface area (to the cube of the dimension as opposed to the square), and since storage capacity is a function of both volume and surface area, California acorns, being larger than Colorado acorns, will allow more volume (or mass) to be stored for the same granary space. To put it another way, due to the superior size of California acorns, storing them as compared to storing Colorado acorns would result in a smaller increase in surface area relative to a larger increase in volume (or mass). In other words, the capacity to store California acorns is being underestimated when Colorado acorns are used in the calculations.

2. Acorn bins also stored: California laurel, pinion pine and chinquepin nuts as well as grass seeds, wild rye or oats, dried worms, scorched grasshoppers and dried insect larvae (Bunnell 1880).

3. Improved subsistence adaptation is suggested by the archaeological record in the change from mano and metate at lower levels to bedrock mortar at more recent occupations (Bennyhoff 1956). The change is in efficiency, not only from portable (thus relatively frail) to stationary (thus relatively durable) but also from a planar surface to a deep volume. This change in shape of working area is important because grinding acorns in a bowl allows the finer flour to settle to the bottom (to be made into cakes) while the coarser particles can be scooped off the top for mush (Grinnell 1958). Cakes made from finer flour, in turn, can be dried more thoroughly and cooked more completely, thereby decreasing the possibility of spoilage. Since these cakes were taken on hunting trips (Barrett and Gifford 1933), their durability might well have meant the difference between a successful and an unsuccessful food gathering excursion.

BIBLIOGRAPHY

Aginsky, B.W.
1943 Culture element distributions: xxiv Central Sierra Anthropological Records 8(4):393-468.

Barrett, S.A.
1908 The geography and dialects of the Miwok Indians. University of California Publications in American Archaeology and Ethnology 6:333-368.

Barrett, S.A. and E.W. Gifford
1933 Miwok material culture. Bulletin of the Public Museum of the City of Milwaukee 2:117-376.

Baumhoff, Martin A.
1963 Ecological determinants of aboriginal California populations. University of California Publications in American Archaeology and Ethnology 49:155-236.

Beardsley, Richard K.
1948 Culture sequences in central California archaeology. American Anthropologist 14:1-28.

Bennyhoff, James A.
1953 High altitude occupation in the Yosemite Park region. University of California Archaeological Survey Report 21:31-32.

1956 An appraisal of the archaeological resources of Yosemite National Park. University of California Archaeological Survey Report 34.

Bock, Carl E. and Jane H. Bock
1974 Geographical ecology of the acorn woodpecker: diversity versus abundance of resources. American Naturalist 108:694-698.

Bunnell, L.H.
1880 Discovery of the Yosemite and the Indian War of 1851. Chicago, Fleming H. Revell.

Callaghan, Catherine A.
1967 Miwok-Costanoan as a subfamily of penutian. International Journal of American Linguistics 33:224-227.

Chesnut, V.K.
1902 Plants used by the Indians of Mendocino County, California. U.S. National Museum Contributions to the U.S. National Herbarium 7:295-408.

Cook, S.F.
1941 The mechanism and extent of dietary adaptation among certain groups of California and Nevada Indians. Ibero-Americana 18.

1955 The aboriginal population of the San Joaquin Valley, California. Anthropological Records 16:31-80.

Cook, S.F. and R.F. Heizer
1965 The quantitative approach to the relation between population and settlement size. University of California Archaeological Survey Report 64.

Davis, James T.
1961 Trade routes and economic exchange among the Indians of California. University of California Archaeological Survey Report 54.

Dobyns, Henry F.
1966 Estimating aboriginal American population: An appraisal of techniques with a new hemispheric estimate. Current Anthropology 7:345-416.

Downs, James F.
1971 California. In E.B. Leacock and N.O. Lurie (eds.) North American Indians in Historical Perspective. New York, Random House:289-316.

Driver, Harold E.
1953 The acorn in North American Indian diet. Proceedings of the Indiana Academy of Sciences 62:56-62.

1969 Indians of North America. Chicago, University of Chicago Press (Second Edition).

Elsasser, A.B.
1958 Aboriginal use of restrictive Sierran environments. University of California Archaeological Survey Report 41:27-33.

Gifford, Edward Winslow

1926a Miwok lineages and the political unit in aboriginal California. American Anthropologist 28:389-401.

1926b Californian anthropometry. University of California Publications in American Archaeology and Ethnology 22:217-390.

1936 California balanophagy. In Essays in Anthropology Presented to A. L. Kroeber. Berkeley, University of California Press:87-98.

Grinnell, Elizabeth

1958 Making acorn bread. University of California Archaeological Survey Report 41:42-45 (From The Youth's Companion 66-67:559, 1893).

Jepson, Willis Linn

1910 The Silva of California. Memoirs of the University of California 2.

Kroeber, A. L.

1908 On the evidences of the occupation of certain regions by the Miwok Indians. University of California Publications in American Archaeology and Ethnology 6:369-380.

1923 Handbook of the Indians of California. Berkeley, California Book Company.

1925 The native population of California. In R. F. Heizer and M. A. Whipple (eds.) The California Indians. Berkeley, University of California Press; 1970: 68-81.

1962a The anthropology of California. University of California Archaeological Survey Report 56:1-18.

1962b The nature of land-holding groups in aboriginal California. University of California Archaeological Survey Report 56:19-58.

Kroeber, Theodora

1961 Ishi in Two Worlds. Berkeley, University of California Press.

Lappe, Frances Moore
1971 Diet for a Small Planet. New York, Ballantine Books.

Merriam, C. Hart
1905 The Indian population of California. American Anthropologist 7:594-606.

1907 Distribution and classification of the Mewan stock of California. American Anthropologist 9: 338-357.

1918 The acorn, a possibly neglected source of food. National Geographic 34:129-137.

1955 Studies of California Indians. Berkeley, University of California Press.

1967 Ethnographic notes on California Indian tribes III. Ethnological notes on Central California Indian tribes. University of California Archaeological Survey Report 68, Part III.

Newcomb, William M., Jr.
1974 North American Indians: An Anthropological Perspective. Pacific Palisades, California, Goodyear Publishing Company.

Palmer, E.
1871 Food products of the North American Indians. Report of the Commissioner of Agriculture for the Year 1870:404-428.

Pike, Ruth L. and Myrtle L. Brown
1975 Nutrition: An Integrated Approach. New York, John Wiley and Sons (Second Edition).

Richards, Audrey I.
1939 Land, Labour and Diet in Northern Rhodesia. London, Oxford University Press.

Schenck, W. Egbert
1926 Historic aboriginal groups of the California delta region. University of California Publications in American Archaeology and Ethnology 25 (2):123-146.

Schenck, Sara M. and E.W. Gifford
1952 Karok ethnobotany. Anthropological Records 15 (6).

Willoughby, Nona Christensen
1960 Division of labor among the Indians of California. University of California Archaeological Survey Report 60:7-80.

Wolf, Carl Brandt
1945 California Wild Tree Crops. Rancho Santa Ana Botanic Garden.

Woods, Charles D. and L.H. Merrill
1899 Nuts as food. Maine Agricultural Experiment Station Annual Report 15:71-92.

Yanovsky, E.
1936 Food plants of North American Indians. U.S. Department of Agriculture Miscellaneous Publications 237.

Yanovsky, E. and R.M. Kingsbury
1938 Analysis of some Indian food plants. Journal of the Association of Official Agricultural Chemists 21:648-665.