The Carrying Capacity of Hunter-Gatherers

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Carrying capacity is defined and an attempt at application on aboriginal Northern California population is made. These people appear to have been at carrying capacity with respect to area, but not with respect to acorns, their staple crop. This finding is analyzed over time and speculations are made about its meaning. [Carrying Capacity, California Indians, Acorns, Population]

The notion of carrying capacity has been used in ecology for a long time. Essentially, carrying capacity is a population density ceiling of an organism related to reproductive capacity of that organism in that environment.

Carrying capacity itself depends on two other quantities. These are r, the rate of increase of any given organism, sometimes called the Malthusian parameter, and N, the population size. In any open population we have:

$$r=(\text{births}+\text{immigration})-(\text{deaths}+\text{emigration})$$

For any r greater than 0 the population growth is exponential in form, as Malthus pointed out. The difficulty with this is that the exponential rapidly goes to infinity, which is not very convenient in practical situations. The classical treatment of this assumes that r is variable and at some point begins to decrease so that at point K it is zero. This leads to the Verhulst-Pearl logistic equation:

$$\frac{dN}{dt}=rN\left(\frac{K-N}{K}\right)$$

K is then the carrying capacity of that population in (or by) that environment.

Although this is clear enough mathematically, and in spite of the fact that the curve often fits actual data quite well, it is not always clear what carrying capacity really represents. The ecologist, Pianka [1978: 117], says "...carrying capacity is ... an extremely complicated and confounded quantity, for it necessarily includes both renewable and nonrenewable resources, as well as the limiting effects of predators and competitors, all of which are variables in themselves. Carrying capacity almost certainly varies from place to place and from time to time for the majority of organisms."

If general ecologists find this difficult to deal with, anthropologists are even more troubled. Cohen [1977: 49] says:

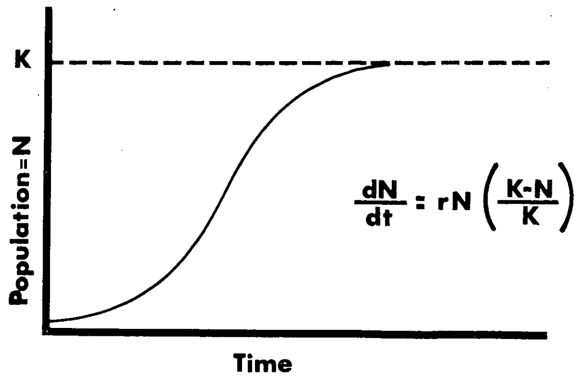

Fig. 1. Graph of the Verhulst-Pearl logistic equation where K is the carrying capacity, N is the population size, r is the rate of increase for a given organism and t is time.

> However, the carrying capacity concept is difficult to apply to human populations and, I believe, may have little relevance to human biology. At best, the concept can be used as a measure of the relationship between a population and its economic strategy at a particular point in time..., but in no case should this measurement be construed as indicating a fixed ceiling on potential consumption or on potential population growth.

Cohen's remarks here are obviously justified in that no one has yet determined a fixed ceiling on population growth even for a limited area, much less for the world as a whole. Yet, although the notion of carrying capacity may have little relevance to human biology, I think it may have a good deal to do with culture and cultural evolution. Indeed Cohen's own argument regarding the origins of agriculture are a sort of carrying capacity argument. I paraphrase it (I hope justly) as follows. It was not until the human population reached its worldwide carrying capacity as *hunter-gatherers* that it took up agricultural ways. Thus, carrying capacity can be regarded as a plateau; if the plateau lasts for a relatively long period of time (as a segment of some longer period), then it might appropriately be called a developmental stage.

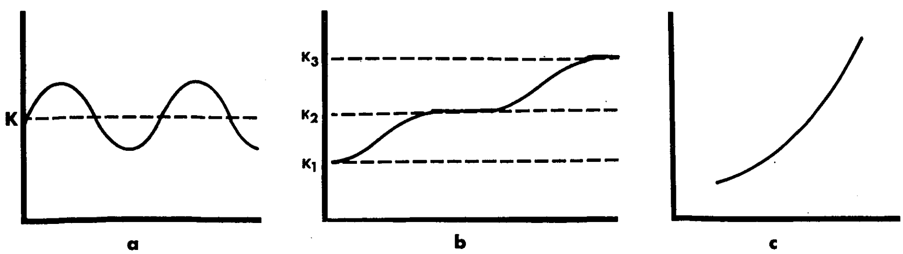

Fig. 2. Three possible curves portraying possible time-density relationships.

The curves shown in Figure 2 illustrate a variety of possible time-density relationships with only the center one (Fig. 2b) having apparent carrying capacities. That on the left (Fig. 2a) might represent one of the horizontal segments with a time scale shrunken to make the oscillations visible. The curve on the right (Fig. 2c) may represent only the rising portion of the step-curve. Indeed, it may be the case that any population growth curve can be made to take the form shown in Figure 1 if we are allowed to select the scale and the time segment. That is, a curve will take the form shown in Figure 1 *or* its converse in periods of depopulation. For any given situation we should question the appearance of the growth curve: is it rising, falling, level, oscillating, peaking, and, what is more important, what are the social and cultural effects of the curve?

Some years ago, I wrote on the aboriginal population of California and concluded that the population of the North Coast range was in Malthusian equilibrium with its environment [BAUMHOFF 1963: 204]. By this I meant population was at some carrying capacity plateau. I would like here to carry this argument one step further. In the original argument the equilibrium was posited in terms of population relative to acorns and game, stated as follows [1963: 200]:

$$\text{Population} = 3A + 2G - 210$$

where A is a measure of acorn resources and G a measure of game resources. One difficulty with this formula was that both game and acorns were rough measures of area rather than the resources themselves and I would like here to attempt to refine the measurement procedures.

Let us begin by asking the following question: How many inhabitants would there have been in the North Coast Range of California if they had made optimal use of the acorns there? The question is complicated in several ways. The first concern is for the welfare of the oaks themselves, for if they do not reproduce adequately then the acorn crop is ultimately doomed. The difficulty here is with the dispersal of seeds, the primary agents of which are rodents and woodpeckers, since acorns are not wind transported. Perhaps humans scatter some seeds themselves, but this would be quite minor; so some portion of the crop should be left to the rodents and woodpeckers.

In addition, deer also compete for acorns. Although acorns do not form an important part of deer diet over most of the year, they are critical in their season; this is because in August and September (acorn season) the deer are eating low quality browse and losing weight. In such a condition, they experience a high winter mortality rate. Hence acorns, with their high fat content, are an important element of diet in preserving the size of the deer herd [TABER and DASMANN 1958: 45]. This is, in turn, important to the Indians who depend on deer in their own diet. Thus optimizing from the Indians' standpoint may mean leaving a portion of the acorns for the deer.

These two complications will be borne in mind in our assumptions about carrying capacity, especially as regards classification of vegetation and area computation.

The vegetation types used here are shown in Figure 3; for present purposes I assume that only the oak woodland type produces a significant acorn crop. There are many scrub oaks in the chaparral, and whereas these are good deer fodder, they are not significant for human purposes.[1]

The oak woodland (Fig. 3) is made up of two components; in dividing it thus I follow Griffen [1977], who calls the components the "valley oak phase" (which I will call oak parkland) and the "blue oak phase" (which I will call oak woodland). The dominant tree in oak parkland is the valley oak (*Quercus lobata*). It occurs singly and in small stands of >50 trees/ha. The dominant trees of the oak woodland are blue oak (*Q. douglasii*) and coast live oak (*Q. agrifolia*). These are dense growths of 150–300 trees/ha [GRIFFIN 1977: 109]. My judgment is that in the North Coast Range the higher figure is applicable; at least 60 percent are oaks, half blue oaks and half live oak, the remainder being maples, and the like. In some areas the blue oak is replaced by black oak (*Q. kelloggii*) and coast live oak by interior live oak (*Q. wislizenii*), but the effect on productivity would not change.

The amount of seed produced by these trees is not well-quantified. Harper and White [1974: 138] suggest that most oaks produce only 150 acorns in a good year, but none of their data are from California species. Some estimates and counts in California range as high as 150,000 seeds [WOLF 1945: 21, "half a ton to a ton"]. A more reasonable figure from the same source [WOLF 1945: 230, "160 pounds"] is about 12,000 seeds. Both estimates refer to bumper crops. I make the following assumptions for an average good year seed yield:

Valley oak (*Q. lobata*)	5000
Blue oak (*Q. douglasii*)	2000
Black oak (*Q. kelloggii*)	2000
Coast live oak (*Q. agrifolia*)	1000
Interior live oak (*Q. wislizenii*)	1000

It will be noted that I am not dealing here with starvation years. It is well-known that acorn production of California oaks is uneven, but the causes of the fluctuations are not known. The acorns could have been stored for two years, but it is not known from the literature whether an extra year's supply was maintained.

Let us make some additional assumptions:

Parkland

40 trees/ha
5,000 seeds/tree
5 g/seed
giving 1000 kg/ha

1) A significant element I have omitted is the tan oak (*Lithocarpus densiflora*) found among the redwoods (*Sequoia sempervirens*). I cannot quantify it at present and will leave it for the future.

Oak Woodland

100 blue or black oaks/ha	100 live oaks/ha
2000 seeds/tree	1000 seeds/tree
3 g/seed	2 g/seed
giving 600 kg/ha	giving 200 kg/ha

For present purposes I lower the parkland figure to 800 kg/ha. There are about 5,000 calories/kg of acorns (this should be determined in more detail). If we assume an average daily caloric requirement of 2400, then it takes about 175 kg/yr/person if he eats nothing else. This yields the figures shown in Table 1.

Two self-cancelling adjustments could be made immediately. First, nobody would (or could) have a 100 percent acorn diet, so let us assume that 50 percent of calories come from acorns. The second or canceling adjustment would derive from optimizing considerations. I assume that if more than half the acorns were eaten by the people it would be hard on oak propagation and on the deer herd as well. The figures on Table 1 therefore stand as before.

Note that the figures for possible population in Table 1 are about 65 times as large as the population. This means that even if production assumptions are considerably optimistic, the native Californians were by no means making full use of the acorn crop. This does not in itself mean they were below carrying capacity relative to acorns. It could be that they are at carrying capacity relative to a minimum year rather than an average year. There is no reason, in principle, to preclude adjustment to an average year provided they had storage capacity for a two years supply as a cushion against the bad years; it is not known at present what causes bad years. Of

Table 1. Summary of resources of California Province, North Coast Range.[a]

		Population	Area Km^2	Woodland Km^2	Acorns $Kg \times 10^3$	Possible Population
1.	Wailaki	2760	1050	521	41, 680	238, 000
2.	Coast Yuki	750	452	19	1, 520	8, 685
3.	Yuki	6880	2953	942	75, 360	430, 000
4.	N. Pomo	7010	3017	770	61, 600	352, 000
5.	E. Pomo	1410	719	216	17, 280	99, 000
6.	C. Pomo	3440	1750	458	36, 640	209, 000
7.	S.E. Pomo	1070	248	91	7, 280	42, 000
8.	S.W. Pomo	1480	694	134	10, 720	61, 000
9.	Wappo	4600	1311	815	65, 200	372, 000
10.	Lake Miwok	900	499	302	24, 160	138, 000
	Total	30300	12676	4268	341, 440	1, 949, 685
	Avg.	3030	1267. 6	426. 8	34, 144	194, 968. 5

[a] These figures are taken from my notes made in preparing Baumhoff [1963]. I found on going back over them that the figures shown in Table 8, p. 199 have two errors. For Southeastern Pomo the area should be 96 sq.mi. rather than 206.6 sq.mi. For Lake Miwok the area figure should be 193 sq.mi. rather than 93.2 sq.mi.

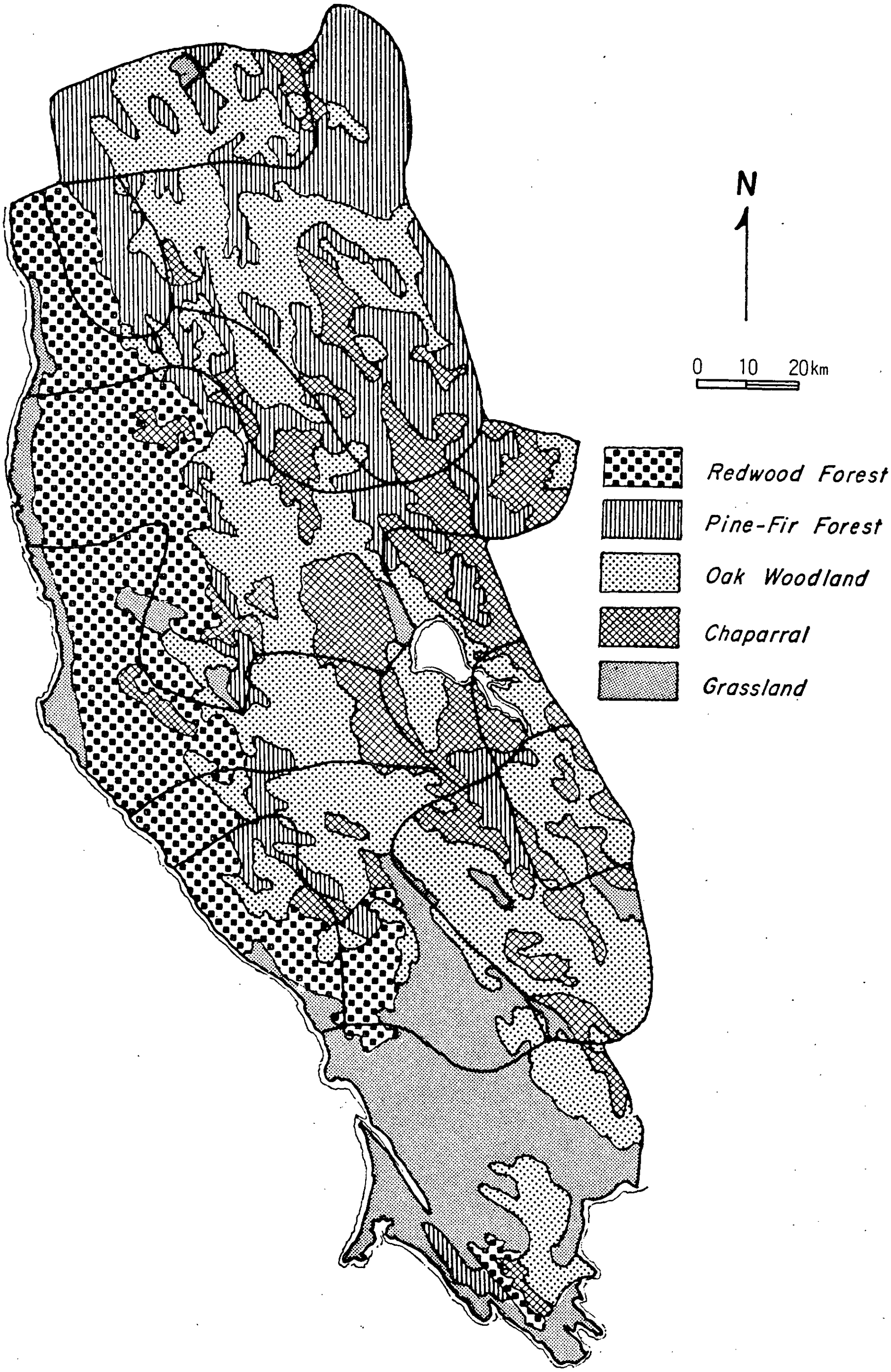

Fig. 3. Vegetation types of the North Coast Range, California.

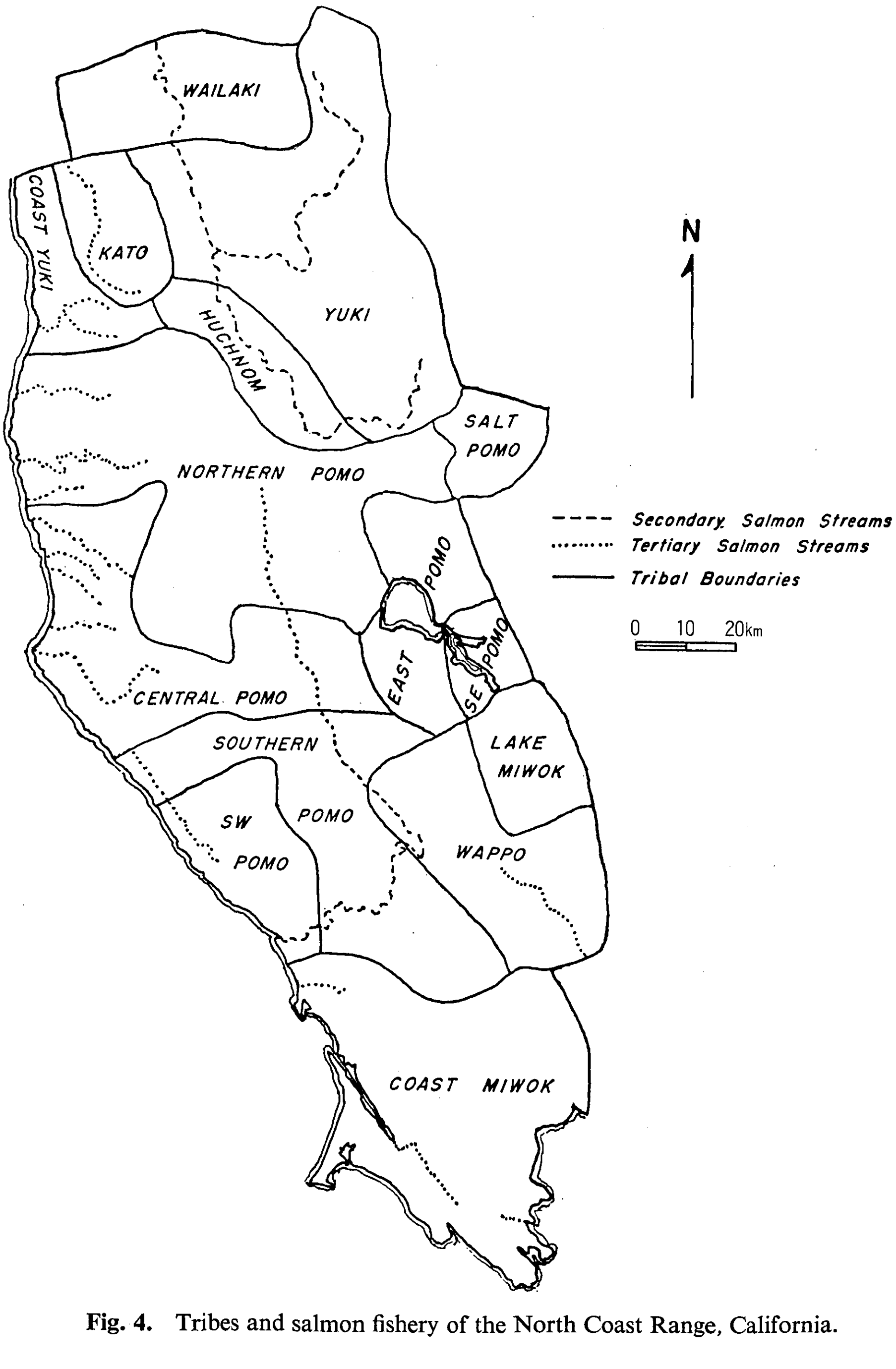

Fig. 4. Tribes and salmon fishery of the North Coast Range, California.

the oaks listed here two have a two-year ripening period (*Q. kelloggii* and *Q. wislizenii*) whereas the others ripen in one year. Therefore if there had been poor water conditions or drought, this would not result in uniformly bad crops. In any case it is known that production is uneven.

It is also known that the native Californians were able to store very large quantities of these nuts, and it may not have been impossible to maintain a two years' supply [see BARRETT 1916 for data on acorn granaries]. But we do not know whether they tried to do this; my guess is that they did not. We must therefore address the question of whether population was being maintained at a minimum crop carrying capacity. If so, we would expect that the amount of oak woodland would be directly reflected in population. Table 2 gives population density relative to oak woodland. There is considerable variation in those densities, and it is evident they do not reflect "carrying capacity" with any precision, if at all.[2)]

If the oak woodland densities are inconsistent with notions of carrying capacity, the straight area densities are not (Table 2). These figures show a very consistent density throughout the region. In fact, if we plot population against total area, we get a very tight linear regression witha correlation coefficient of 0.97; almost perfect. I suggest that these figures argue strongly that these people had reached carrying capacity. Just what the components of this quantity are is another matter. Since the figures are based on area alone, the component must be complex, but I can say no more than that.

Table 2. Population density by area and oak woodland.

	Area (Km^2)	Oak Woodland (Km^2)
Wailaki	2.63	5.30
Coast Yuki	1.66	39.47
Yuki	2.33	7.30
N. Pomo	2.32	9.10
E. Pomo	1.96	6.53
C. Pomo	1.97	7.51
S.E. Pomo	4.40	11.76
S.W. Pomo	2.13	11.04
Wappo	3.51	5.64
Lake Miwok	1.85	2.98
Average	2.47	10.66
Standard Deviation	0.68	6.29

Calculated from figures in Table 1.

2) There is an error in computing acorn production on Table 1 that I am not able to overcome. The problem is with the computations for tan oak (*Lithocarpus densiflora*), which occurs in the redwood forest. This no doubt accounts for the fact that the Coast Yuki density is so high.

The next question concerns the duration of time these people were at carrying capacity. We have only recently obtained data that can begin to answer this question. Most archaeological work does not involve excavation of large numbers of archaeological sites in a single area, so that if we have sites of periods A, B, and C, it is difficult to determine which periods have the largest and most numerous sites. Because of this, Cohen was forced to adopt indirect ways of identifying population pressure. But more recently, we have been under a legal mandate to deal with all archaeological material from an entire region, and the situation has changed. I will give two examples, one from the North Coast Range of California and one from the Sierra Nevada.

The first archaeological example is from Dry Creek, a tributary of the Russian River (the Warm Springs Project). A testing phase has already been carried out and full-scale excavation is now proceeding. We have determined the following phases:

	A.D. 1800
Phase 4	
	A.D. 1200
Phase 3	
	500 B.C.
Phase 2	
	3000 B.C.
Phase 1	
	5000 B.C.

We find in this area a full complement of sites by at least 500 B.C., and probably by 3000 B.C. In other words I am arguing that, if these people were at carrying capacity in ethnographic times, they must have been that way for more than 2000 years.

A contrary example is taken from the west slopes of the Sierra Nevada, as reported by Moratto, King, and Woolfenden (1978). They report the following three phase sequence from the Buchanan Reservoir Project:

A.D. 1800		
	Dense population Extensive settlements	Status differentiation Complex political organization
A.D. 1500		
	Depopulation Small, dispersed settlements	Little status differentiation Simple political organization
A.D. 500		
	Large population in villages	Status differentiation Complex political organization
1000 B.C.		

This sequence shows a very different situation from the one I describe in the North Coast Range. The archaeological record at Buchanan Reservoir is one of fluctuating populations, which these authors believe is due to climatic fluctuations (the middle period here is evidently drier than the first or last periods).

I do not presume to pass judgment now on the correctness or accuracy of either of these schemes. I know that the Warm Springs sequence is quite tentative and the one given by Moratto *et al.* for Buchanan Reservoir will, I think, be quite controversial. Nevertheless, the two situations, one of fairly long equilibrium and the other of oscillation or fluctuation, no doubt existed at one time or another, and we want to ask what they mean culturally.

The period of depopulation in the Moratto scheme is seen as one of decreasing social complexity, and these authors also see a decline of trade and craft specialization at that time. One supposes that a declining population for whatever reason, at least a radically declining population, is likely to be associated with some social dislocation and perhaps a general cultural decline.

Increasing population is often thought of as "progressive." From the present point of view it can be seen that there may be too much "progress" with regard to total world resources. But aside from this, it seems clear that increasing population in a given area is bound to change economic and ecological relationships and to force changes unwelcome at the time (even when beneficial from a longer perspective). In fact I take it that this is Cohen's argument on the origins of agriculture.

What are we to say with regard to a period of population stability or equilibrium? Viewing it as the population itself might, this could appear to be a good thing. Social and economic relations would remain stable and predictable and many of us existing in what we perceive as a rapidly changing world would regard this as an ideal condition. But this utopian vision is doubtless less perfect in practice. The competition of individuals, families, and subgroups seems inevitably to lead to conditions of instability for the people, even when it is stable for the population as a whole.

One of the things that might be thought of as a bad aspect of population stability would be the possibility of its being associated with cultural stagnation. Although there is now a considerable literature concerning the effect of population growth on culture, especially agriculture [SPOONER 1972], there seems to be little on the effects of stability. We might take as a period of cultural stagnation that of Western Europe between late Roman times and the beginning of the high Medieval Period, say from A.D. 100–300 to A.D. 1000. Certainly these "Dark Ages" cannot be regarded as a period of great inventiveness. This period may also have been one of substantial population stability [WAILES 1972: 169]. This is, however, presumably a down period of stability, following a period of depopulation.

One other possible effect during a period of population stability might be the formation of regional culture types. In periods of population change, we expect rapid culture change; but there would still be some culture change even in periods of no population change. The cultural changes that occurred in such periods might be expected to be more specifically adaptive to the local situation, to be less revolutionary than those happening in periods of demographic stress. Thus one would see more continuities than discontinuities in an archaeological sequence. I would also expect to see more of what used to be called *survivals*, cultural items existing in one period when, in reality, they are more relevant to an earlier period.

This may be one process which leads to relatively well-defined culture areas, and particularly, to what Kroeber called *culture climaxes*, which in California he saw in terms of religious systems [KROEBER 1948: 566]. As a matter of fact, Kroeber perceived such a climax in the North Coast Range, the area analyzed here. I see it as a result not of stagnation but of culture change, increment by increment, which did not upset any social or ecological balance, but ultimately resulted in a very distinct configuration.

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Part II

The Hida Project:

An Exercise in Mid-Range Theory

(Courtesy of Kiyoshi Sonobe)