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THE EVOLUTION OF PLAGUE CONTROL IN CALIFORNIA

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Bubonic plague no longer is regarded as the dreaded black death of the middle ages. The last great plague pandemic has come to an end. In California, human cases have averaged no more than one every two years for several decades. With modern antibiotics properly administered, recovery is assured. At the same time, there is no doubt that plague is firmly entrenched in the rodent fauna and we should not be lulled even by years of quiescence into assuming that massive epizootics will not break out in the future. There is the un-measurable risk of a quick pneumonic outbreak with tragic results, or the chance that infection may transfer to urban rat populations and thus pose a markedly greater hazard.

No formula can determine the magnitude of these potential hazards, or the intensity of control efforts that should be applied. Reason, both biological and fiscal, dictates that the program should be a modest one. Having reached this conclusion, it behooves us to be sure that this modest effort is applied with the fullest knowledge and understanding to secure the greatest possible benefit.

Let us review briefly the history of sylvatic plague suppression in California. Early in this century, massive epizootics in California ground squirrels were discovered in the San Francisco Bay area. A great campaign of squirrel control was launched, with the purpose of eradicating the infection before it could spread. At one point an official claimed that this goal had been achieved. But new outbreaks appeared, and gradually plague was found to be present throughout most of the west.

Ground squirrels of several species, chipmunks, and marmots were the animals consistently and conspicuously identified in epizootics. Not surprisingly, they were regarded as the reservoirs of plague. Occasional plague-infected mice were thought of as incidental victims. Sites where plague was found were regarded as "foci". Survey workers returned to these sites again and again in succeeding years and often found infected animals or fleas, thus reinforcing the original assumption. It naturally followed that controlling squirrels in these "foci" would control the disease itself. This led to designating a series of plague areas, subject to constant ground squirrel suppression, many of which continue to be observed as geographical control units.

Current knowledge of plague ecology reveals a much different picture. Recent plague studies throughout the world show that the persistent reservoirs of infection are not those susceptible rodent species which Suffer periodic violent epizootics. Instead, they are rodents capable of maintaining a quiet state of infection, with little or no mortality. It is becoming clear that plague persists in relatively small pockets where suitable climate, flea vectors and rodent hosts occur, characteristically in cold mountainous or high plateau regions, or coastal fog belts. From these pockets of enzootic infection, plague may spread periodically through susceptible host populations in epizootic

form. Even when such hosts sustain the disease for a number of years, it must follow an ever shifting epizootic path to survive. Presumably a rather high degree of crowding is required for an epizootic to be sustained.

Although we have learned surprisingly little in 60 years of experience with plague in California, the knowledge we do have fits this interpretation of plague ecology very well. In the hills south of San Francisco, the USPHS San Francisco Field Station finds plague infection year after year in Microtus and Peromyscus populations and their fleas, without decimation of numbers. Ground squirrel populations have been held very low for years. It is notable, however, that this area was the scene of ground squirrel plague in 1916-1920, 1929, 1936 and 1942.

Conversely, there is evidence that plague fails to persist in ground squirrels. For example, a great epizootic swept over the foothills east of Bakersfield, Kern County, in 1934. There were surveys each year from 1935 to 1940, during which approximately 5,300 California ground squirrels (Citellus beecheyi) and 24,000 fleas were found negative for plague. Yet in 1941, massive epizootics again broke out in the surveyed region. There have been similar experiences elsewhere.

We now believe it is essential to reorganize our approach to human plague prevention in the light, of this newer understanding. This will require reliance on a set of unproved assumptions and speculations, considering our incomplete knowledge of plague ecology in California; but plague control in the past has been conducted on the basis of unproved assumptions, and I am confident the new ones have greater validity.

The increased emphasis on smaller rodents as enzootic reservoirs does not alter the fact that epizootic hosts--ground squirrels, marmots, chipmunks, and occasionally rabbits—-have been the principal sylvatic source of human plague infections. Table I shows that in human cases since 1927, these epizootic species have been implicated as the source of infection or at least were plausible alternatives. We have no case in California where the evidence points unequivocally to mice as a source of infection. Thus any preventive measures directed at sylvatic plague hazard to humans should be applied almost exclusively to sciurid rodents.

Drawing a sharp distinction between enzootic and epizootic hosts has profound implications for a plague control program. The "foci" of years past, meaning areas where infected ground squirrels were found, may or may not correspond to foci of persistent plague. One must assume that, during a period of intense epizootic activity plague might progress through ground squirrel populations over many miles. The discovery of even a massive die-off is no proof that plague will be present there during the inter-epizootic period. For example, 1941-1942 were years of exceptionally widespread plague activity, and the disease was found in numerous locations where it was not known before nor observed since. Conversely, where populations have been suppressed, the absence of plague findings in ground squirrels—even for many years--is in itself no basis for denying a potential hazard. This is most clearly seen in San Mateo County where the last recorded plague in ground squirrels was in 1942. Yet the known presence of enzootic reservoirs leaves little doubt that if squirrels were permitted to return to their former prevalence, the epizootic potential would be relatively great.

Certain region's have a relatively prominent history of recurring epizootics or repeated positive findings in sciurid rodents or fleas. Until more is learned about sources of infection, we must assume that under these circumstances an enzootic reservoir is not far away, and assign to these areas the highest plague potential. The principal regions of recurrent epizootic plague are in northeastern California, along the east side of the Sierra Nevada, along the central coast, in the Tehachapi Mountains and southernmost Sierras, and in the San Bernardino Mountains (Fig. I). Generally, these regions are within or immediately adjoin mountain ranges, high plateaus, or the humid coast where sources of enzootic plague might logically be sought.

No explanation is available for the apparent absence of plague in the north coastal region. One outbreak among meadow mice and domestic rats in southernmost Marin County in 1942 might have resulted from an introduction of the disease. The Central Valley has had only a minor history of plague, apparently limited to the fringes of epizootics; there is little likelihood that plague exists permanently on or near the valley floor. On the west slope of the Sierras (except the extreme south end) the sporadic and localized occurrence of plague episodes suggests that the disease may have migrated periodically from the east side in epizootic trails. In southern California there hat been a prominent history of recurrent epizootic plague in the San Bernardino Mountains and in and near the mountains 61 Ventura and Kern counties. South of there, plague records are sporadic and nearly all occurred in 1942, again suggesting the absence of a permanent plague reservoir.

Our aim has been to develop a flexible approach to plague suppression based on this newer view of its ecology and distribution. The first step was to zone the state according to degrees of epizootic hazard (Fig. 2). Once again it must be emphasized that this process is heavily based on unproved assumptions, and may even appear to invoke a measure of divine judgment. Nevertheless, it relieves us of a sense of statewide helplessness that results from assuming that since plague has been detected in most parts of the state, it may appear almost anywhere with equal probability. Certainly the zoning should be only a tentative guide, subject to constant revision as more becomes known.

We propose that any plague surveillance or suppressive measures applied to reduce the epizootic hazard be confined to the two highest priority zones. Within these zones, control measures are justified only where human exposure is high—in urban, suburban, and recreation areas. The important issue of plague transfer from sylvatic rodents to domestic rodents should be acknowledged by special emphasis on domestic rodent and ectoparasite control in the two highest priority zones.

Permanent suppression of sciurid rodents can be justified only in a few areas within Zone 1, namely, where there is strong probability of enzootic plague in close proximity to high human exposure. Otherwise we should be prepared to reduce squirrel numbers in appropriate areas when they become dense enough to afford an epizootic potential. In recreation areas, flea control is a who\1y suitable alternative. This calls for the development of an adaptable control program to replace our present system of rigid plague control areas and improved methods for routine measurement of rodent densities.

These proposed program changes mainly concern plague prevention and surveillance. We must, of course, be prepared to deal with epizootics whenever they occur--even if they should violate our zoning. Efforts to obtain reports from competent observers of mortality in small mammal populations has been fairly successful and will continue to be the foundation of our intelligence program designed to detect epizootics in their early stages. The intensity of control measures applied, once an epizootic is detected, will be governed by the degree of human exposure. In any event, the response to an epizootic will, under most circumstances, be ectoparasite control rather than squirrel eradication.

Finally, we will not be satisfied to proceed for another 60 years by creating a revised dogma of plague control. Only by locating enzootic plague sites and identifying their ecological characteristics can a meaningful program be devised. Serological and other refined techniques are available for that purpose and the Bureau of Vector Control has recently begun such an investigation in cooperation with the USPHS San Francisco Field Station.

TABLE 1.—Human Plague Cases in California Since 1927
and their Probable Source of Exposure

YEAR	LOCATION	EXPOSURE
1927	Near Clayton, Contra Costa County	Plague-infected ground squirrels found in vicinity. (16% of 147)
1928	Fort Ord, Monterey County	Soldier camped where plague found earlier in ground squirrels.
1928	Near Santa Ynez, Santa Barbara County	Evidence of ground squirrel epizootic.
1928	Santa Cruz County	?
1933	Big Bear, San Bernardino County	Man had visited cabin; evidence of ground squirrels. Epizootic possible.
1934	Poso Creek, Tulare County	Boy visited ranch where plague-infected ground squirrels found.
1936	Lake Tahoe, Placer County	Woman buried dead chipmunk week before.
1936	28 mi. N. San Simeon, Monterey County	Boy cut hand while cleaning brush rabbit.
1936	Santa Rosa, Sonoma County	No evidence of sylvatic origin.
1937	Huntington Lake, Fresno County	Girl bitten by chipmunk.
1941	Near Montague, Siskiyou County	*C. beecheyi* population in area had been heavy, almost disappeared just before onset.

TABLE 1 (Continued)

1941	Mt. Shasta, Siskiyou County	Squirrels and chipmunks in area; dead squirrel seen week before. No obvious epizootic.
1942	Near Yreka, Siskiyou County	Child played in hay hauled in from area of prior ground squirrel plague. Mouse carcasse found in hay. Marmots had disappeared in vicinity.
1943	Near Ft. Jones, Siskiyou County	Boy killed and skinned ground squirrels and chipmunks; was bitten.
1947	Fitzhugh Ranger Station, Modoc County	Boy had handled sick marmot.
1949	Jess Valley, Modoc County (not confirmed by laboratory)	Girl had handled sick marmot.
1956	Upper Cuyama Valley, Ventura County	Man visited site of ground squirrel epizootic.
1959	Yosemite Park, Mariposa County	Boy camped where a ground squirrel and chipmunk epizootic apparently had occurred.
1959	Sonora, Tuolumne County	Evidence of ground squirrel epizootic behind residence.

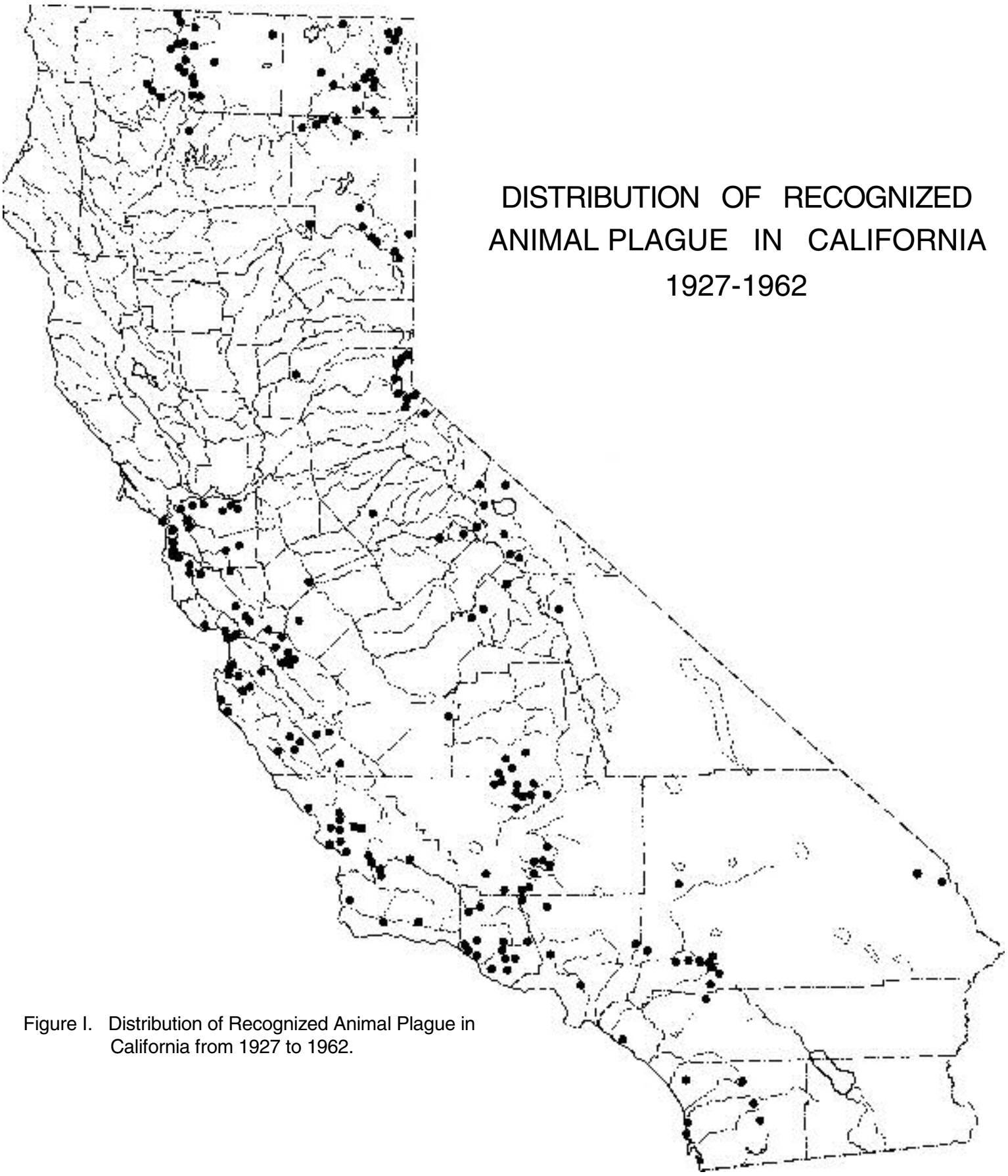

Figure I. Distribution of Recognized Animal Plague in California from 1927 to 1962.

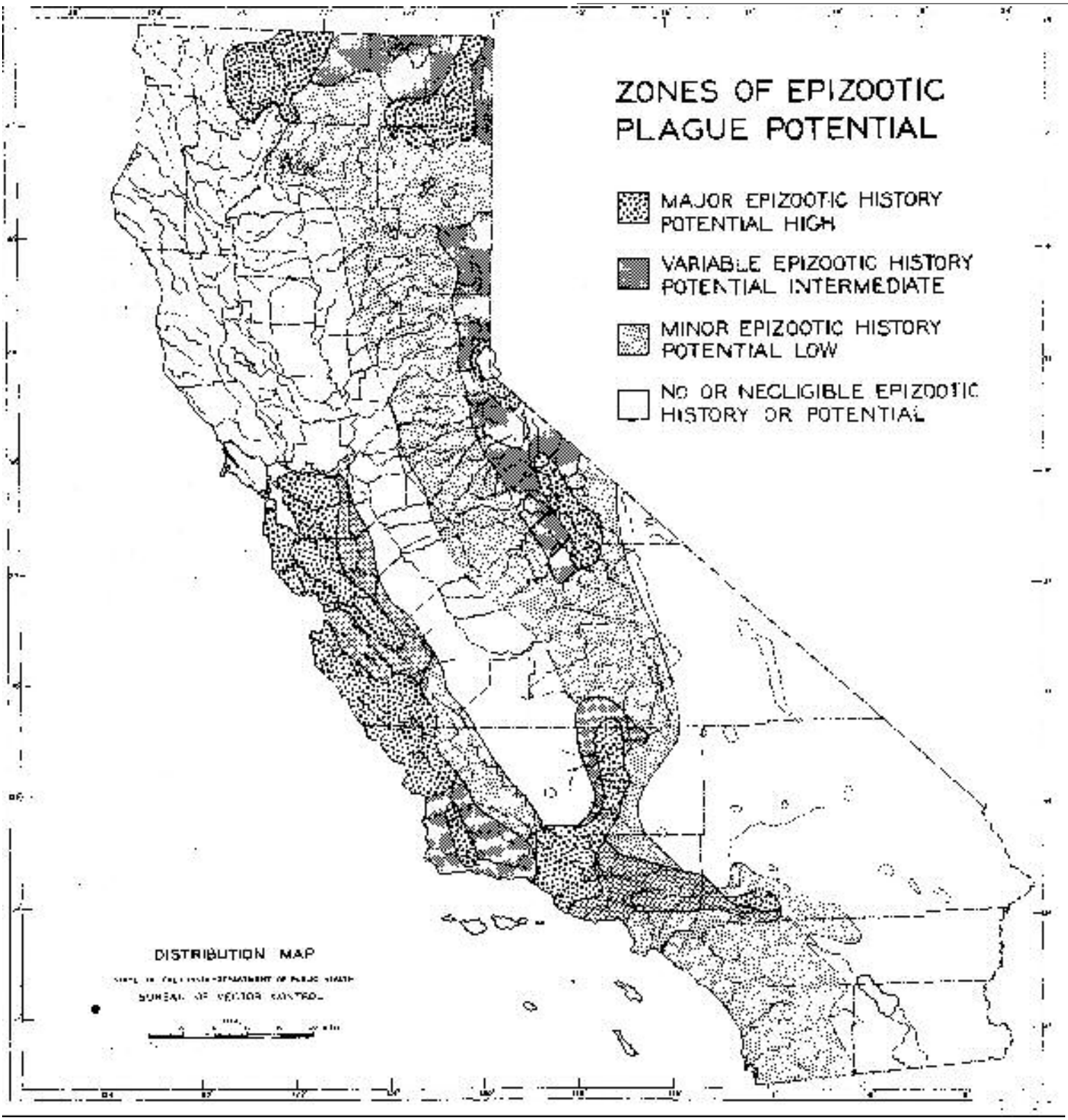

Figure II. Designated Zones of Epizootic Plague Potential in California.