

# Historical Mortality of Valley Oak (*Quercus lobata*, Née) in the Santa Ynez Valley, Santa Barbara County, 1938-1989<sup>1</sup>

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**Abstract:** The range and abundance of valley oak (*Quercus lobata*, Née) have steadily decreased in the last 100 years due to low rates of regeneration during this period. Documented low rates of sapling recruitment must be compared to adult mortality rates in order to evaluate the severity of this decline. The purpose of this research is to measure and analyze the mortality rate of established valley oaks in different habitat types over the past 51 years. Valley oak stands of the Santa Ynez Valley in Santa Barbara County were mapped and stratified into three major habitat types: valley floor alluvium, lower hillslopes and swales, and rolling uplands. Mortality rates of canopy individuals in each habitat type were determined for a sample of 600 valley oaks censused in 1938 aerial photography and re-censused in 1954, 1967, 1978, and 1989. 125 of 600 (20.8 percent) sampled individuals disappeared during the 51 year period. No new individuals were recruited into the canopy layer during this time. The average mortality rate between 1938 and 1989 was 0.45 deaths/100 trees/year. Mortality rates were highly variable within and among habitat types, and were not strongly associated with precipitation or human population increases in the Santa Ynez Valley during the study period. High mortality between 1967 and 1978 coincides with the lowest groundwater levels in the 51 year study period.

Jepson (1910) and other botanists in the early 1900's first noted that the valley oak produced the most abundant crops of acorns of the western oaks, yet was the least successful in regeneration. The reasons proposed for this failure are varied and complex, and will not be reviewed in this paper (see Borchert and others 1989, Dutzi 1979, Griffin 1971, 1976 & 1980, and Rossi 1979). Whatever the causes for low sapling recruitment rates of the valley oak, these rates must be compared to the rates of adult mortality in order to evaluate whether the species is declining within its range, and if so, to measure the rate of decline. Valley oak stands in the Santa Ynez Valley, like many others statewide, exhibit a skewed size distribution. Populations are dominated by scattered large individuals (which we refer to as "established trees"). Rare saplings tend to occur at the margins of stands, in fence rows, or neighboring shrublands (Bolsinger 1988, Calloway 1990). Mortality of established trees

thus represents, at least for the present, a thinning process ultimately resulting in a treeless grassland.

Scheidlinger and Zedler (1980) used aerial coverage from 1928 and 1970 to measure change in canopy cover of coast live oak stands in southern San Diego County. We have analyzed historical aerial photography to measure the mortality rates of valley oaks in different habitat types over the past 51 years and to investigate how mortality varies among sites, habitats, and time periods.

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## METHODS

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Valley oak stands of uniform vegetation composition and environmental conditions in the upper Santa Ynez Valley of Santa Barbara County were first identified and mapped on U.S. Geological Survey 1:24,000 7.5 minute quadrangle maps using 1:24,000 color and 1:40,000 color infrared air photos from 1978. We used recent photography to delineate stands in order to exclude areas converted to other land use or land cover types. The mortality rates reported here are thus conservative and assumed to be due to natural death rather than removal by humans. All areas mapped as valley oak stands from the air photos were verified in the field. Only pure valley oak stands were retained in the analysis.

The non-contiguous study area encompassed 3,171 hectares located on the following four topographic quadrangles: Figueroa Mountain, Lake Cachuma, Los Olivos, and Santa Ynez. Stand density varied from a high of 1.40 trees/acre to a low of 0.23 trees/acre. This study area contained several habitat types including valley floor alluvium, lower hillslopes and swales, and rolling uplands. Elevations ranged from 158 m to 427 m. Most of the area is underlain by Quaternary deposits dominated by alluvium, terraces, and Paso Robles conglomerates (Dibblee 1950, 1966).

We used a stratified random design to sample 600 trees in 12 stands. The study area was divided into the three habitat types of valley floor alluvium, lower hillslopes and swales, and rolling uplands. Plastic overlays were made for the photos from the 1938 base flight (Fairchild Aerial Surveys flight C-4950, 1938, 1:24,000 black and white paper prints) and the study area outline was transferred to these overlays. Twelve stands were sampled at random, including five in valley floor alluvium, four in lower hillslopes and swales, and three in rolling uplands. Three stands

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in the valley floor alluvium were cultivated cropland, and two were used for pasture.

We identified and mapped the 50 valley oaks closest to a point located randomly in each stand (the minimum size of trees that could be reliably detected was between 10 and 15 meter crown diameter). Once trees were mapped in the 1938 images, frame overlays were constructed for the 1954 photos (U.S. Department of Agriculture flight BTM-PMA-6-53-DC item 3, 1954, 1:20,000 black and white paper prints, flown by Pacific Air Industries). Each sampled individual from the 1938 flight was noted as alive or dead/missing in 1954.

The above procedure was repeated using photos from 1967 (U.S. Department of Agriculture flight BTM, invitation #ASCS 9-67 DC item 6, 1967, 1:20,000 black and white paper prints, flown by Western Aerial Contractors, Inc.), 1978 (U.S. Department of Agriculture flight USDA-24-615070, solicitation #ASCS/FS-11-78 SLC item 3, 1978, 1:24,000 natural color paper prints, flown by Pacific Aerial Surveys; and U.S. Department of Agriculture flight USDA-40-06083, invitation #ASCS 12-78 SLC item 1, 1978, 1:40,000 color infrared positive transparencies, flown by Pacific Aerial Surveys), and 1989 (Pacific Western Aerial Surveys flight PW-SB 7, 1989, 1:24,000, natural color positive transparencies, flown by I.K. Curtis).

Mortality rates were expressed as deaths per 100 trees per year. We calculated mortality rates for each period by dividing the number of deaths by the number of individuals at the start of the census period and by the number of years in the period, and multiplying that number by 100 (this is a conservative estimate of mortality, as the denominator neglects the decrease in number of trees over the census period). Two models of mortality were used to project future decreases in population: 1) mortality independent of population size, in which the number of survivors was modeled as a linear function of time ( $N_t = N_0 - d \cdot t$ , where  $N_t$  is the number of survivors at time  $t$  years from the 1938

census,  $N_0$  is the number of individuals at the start of the period, and  $d$  is the decrease in number of remaining individuals per year). This model implies an increasing mortality rate as the number of remaining individuals decreases linearly through time; 2) constant mortality rate ( $N_t = N_0 \cdot \exp(-rt)$ ). This model implies a curvilinear decrease in trees through time.

The Kruskal-Wallis non-parametric statistic was used to test for significant differences in mortality rates among time periods and habitat types. Also, mortality rates for each period were qualitatively compared to precipitation, ground water and Bureau of Census population data.

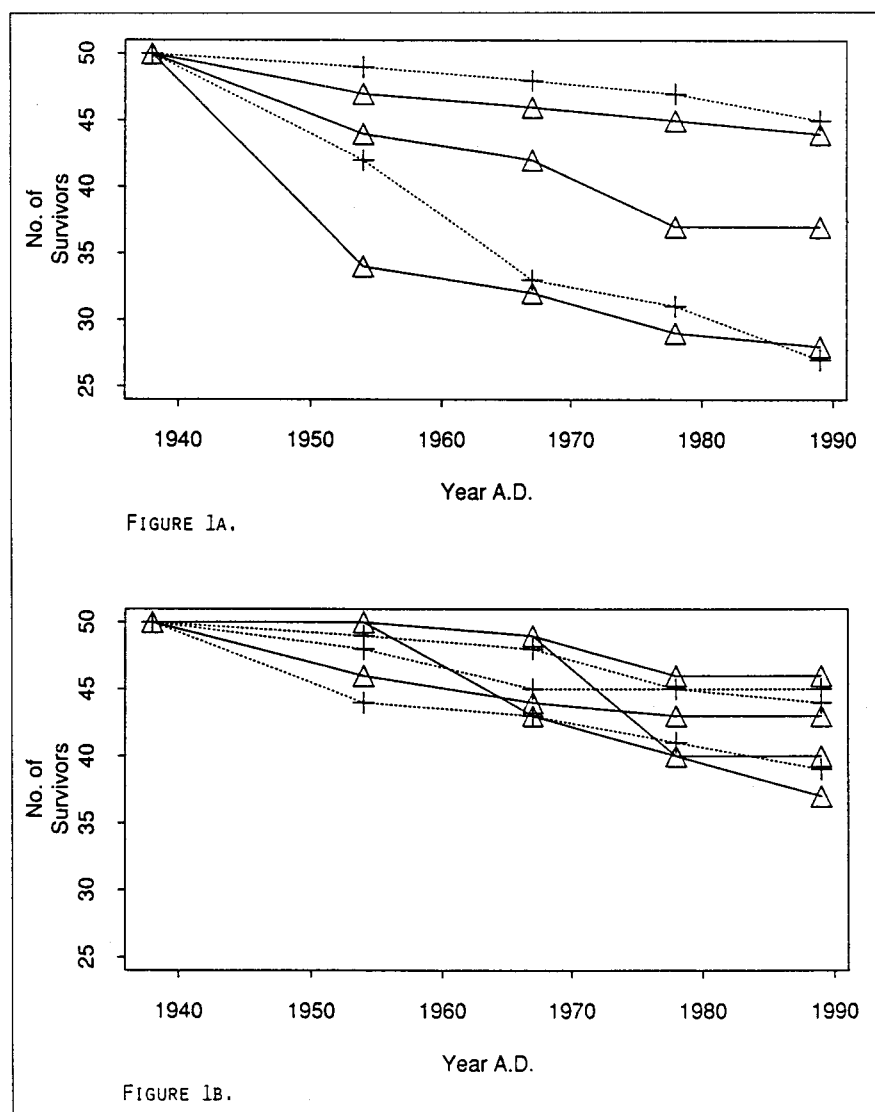
## RESULTS

During the 51 year time span of this study, 125 of the 600 sampled individuals disappeared, for an overall mortality rate of 0.45 +/- 0.22 deaths/100 trees/year (table 1). By habitat type, individuals in valley floor alluvium fared the worst, with a mean mortality rate of 0.54 +/- 0.33 trees/100/year. Mortality rates were extremely variable among stands in this habitat type (fig. 1a) and did not differ systematically between cropland and pasture land use. Individuals within the lower hillslopes and swales and rolling uplands habitats showed similar and less variable mortality rates of 0.33 +/- 0.15 and 0.29 +/- 0.13 trees/100/year respectively (fig. 1b). Differences in mortality rates among habitat types were not significant based on rank statistics.

There was considerable variation in mortality rates both within and between sampling periods (fig. 2). Differences among periods were not significant based on rank statistics. A larger

| Sample    | Habitat          |          | 1938-1954   | 1954-1967   | 1967-1978   | 1978-1989   | Mean | SD     |
|-----------|------------------|----------|-------------|-------------|-------------|-------------|------|--------|
| 1         | Valley alluvium  | Cropland | 2.00        | 0.45        | 0.85        | 0.31        |      |        |
| 2         | Valley alluvium  | Cropland | 0.75        | 0.35        | 1.08        | 0.00        |      |        |
| 3         | Valley alluvium  | Cropland | 0.38        | 0.16        | 0.20        | 0.20        |      |        |
| 4         | Valley alluvium  | Pasture  | 1.00        | 1.65        | 0.55        | 1.17        |      |        |
| 5         | Valley alluvium  | Pasture  | 0.13        | 0.16        | 0.19        | 0.39        | 0.54 | 0.33   |
| 6         | Lower Hillslopes |          | 0.00        | 1.08        | 0.63        | 0.68        |      |        |
| 7         | Lower Hillslopes |          | 0.00        | 0.15        | 1.67        | 0.00        |      |        |
| 8         | Lower Hillslopes |          | 0.00        | 0.15        | 0.56        | 0.00        |      |        |
| 9         | Lower Hillslopes |          | 0.50        | 0.33        | 0.21        | 0.00        | 0.33 | 0.15   |
| 10        | Rolling Uplands  |          | 0.25        | 0.48        | 0.00        | 0.00        |      |        |
| 11        | Rolling Uplands  |          | 0.75        | 0.17        | 0.42        | 0.44        |      |        |
| 12        | Rolling Uplands  |          | 0.13        | 0.16        | 0.57        | 0.20        | 0.29 | 0.13   |
| Mean (SD) |                  |          | 0.49 (0.58) | 0.44 (0.46) | 0.58 (0.46) | 0.28 (0.36) | 0.45 | (0.22) |

**Table 1—Summary mortality statistics for 12 valley oak stands in the Santa Ynez Valley between 1938 and 1989, organized by habitat type and time period. Rates are expressed as mean deaths/100 individuals/year (SD-standard deviation).**



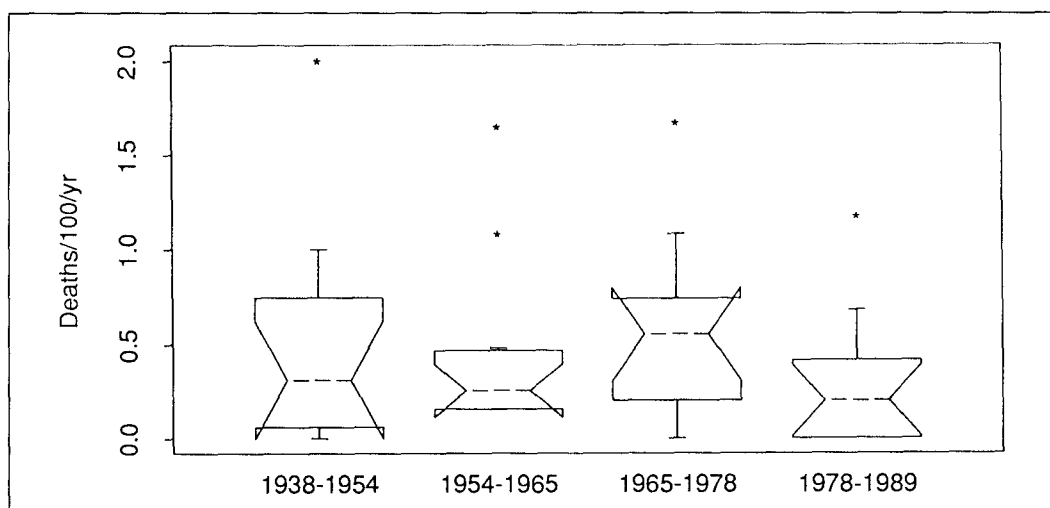
**Figure 1**—Survivorship curves for valley oak stands (50 trees per stand) in the upper Santa Ynez valley between 1938 and 1989. Habitat types include valley floor alluvium (Figure 1a; cropland (triangles) and pasture (crosses)), lower hillslopes and swales (Figure 1b (triangles)) and rolling uplands (Figure 1b (crosses)).

sample size would be necessary to isolate any apparent interaction between habitat type and time period. Average annual and seasonal precipitation did not vary significantly among the sampling periods (mean annual precipitation = 39.3 cm). Ground water data collected within the study area between 1941 and 1990 did show fluctuations, though these fluctuations varied considerably depending on the location of the test well (fig. 3). Both wells closest to the sampled stands gradually declined to minimum elevations in the mid to late 1960's. The historically low ground water levels of this period (94 feet and 111 feet below the surface) may have contributed to the high valley oak mortality rate between 1967 and 1978. The distances to ground water at the minimum well elevations greatly exceeded the

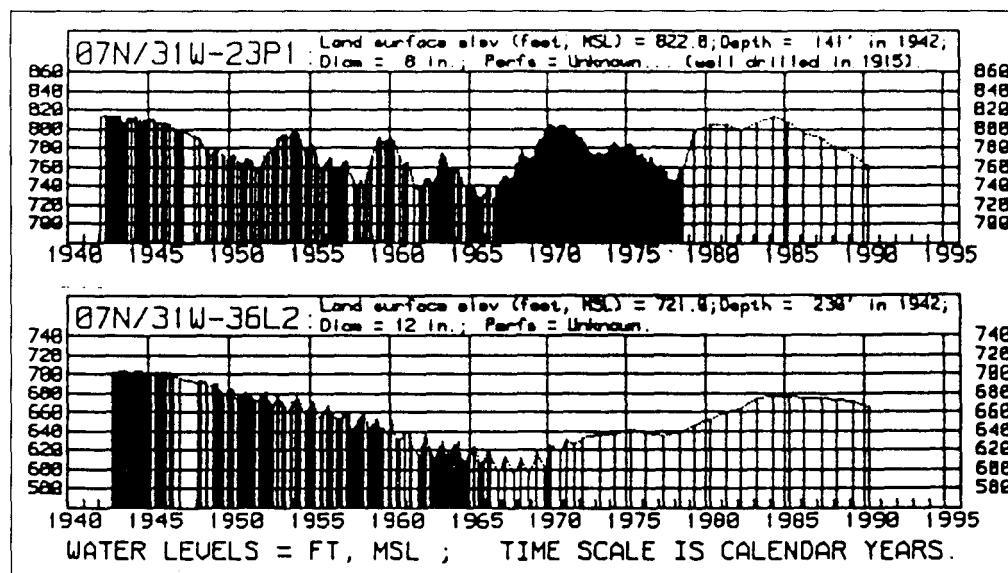
estimated maximum depth of valley oak tap roots of 66 feet (Griffin 1973).

It is interesting to examine human population growth in the upper Santa Ynez Valley during this century (fig. 4). This region has shown remarkable growth in population especially since 1950. However, this population growth is not associated with the mortality rates in valley oak stands that have remained under the same land use.

Variable mortality rates among stands make it impossible to determine with certainty whether valley oak mortality during the period 1938-1989 was density-dependent or density-independent. However, the best fit to all of the survivorship data (12 stands, 4 census periods per stand) was obtained using the simple,



**Figure 2**—Box plots showing the distribution of valley oak mortality among 12 stands during four time periods. Boxes show the median (dashed line) and quartiles (upper and lower horizontal lines) of the data, the ranges (vertical lines) and outliers (asterisks). Overlap between notched portions of the boxes indicates no significant difference among the means for each period at the 95% level.



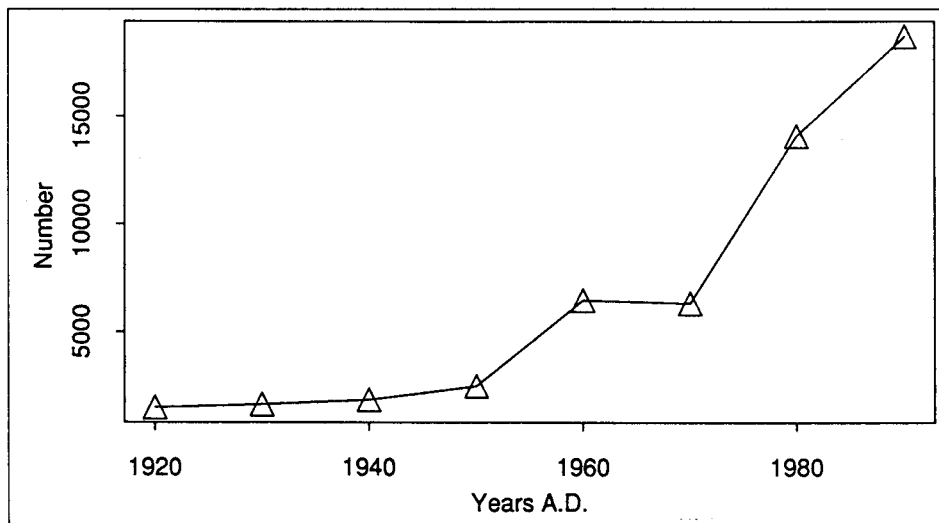
**Figure 3**—Ground water elevations (feet above mean sea level) in two wells near Los Olivos in the upper Santa Ynez valley between 1940 and 1990 (data courtesy of the Santa Barbara County Water Agency).

density-independent model, which was obtained by least squares regression:  $N_t = -0.21 * t - 49.7$  ( $r^2 = 0.38$ ,  $p < 0.01$ ). The density-independent mortality for the 12 stands, with a starting stand size of 50 trees, ranged from 0.90 trees/year/stand to 0.16 trees/year/stand, averaging 0.41 trees/year/stand. At the higher loss rate, which applied to 2 of 12 stands, the 600 trees censused in 1938 would decline to 0 by the year 2026 (fig. 5a). At the average loss rate, the population would be reduced by 50% by the year 2060. Different results were obtained with the density-dependent model: the maximum mortality rate for a stand was 1.09 deaths/100 trees/year, and the average was 0.45 deaths/100 trees/year. Using this standard demographic model, the maximum rate yielded a

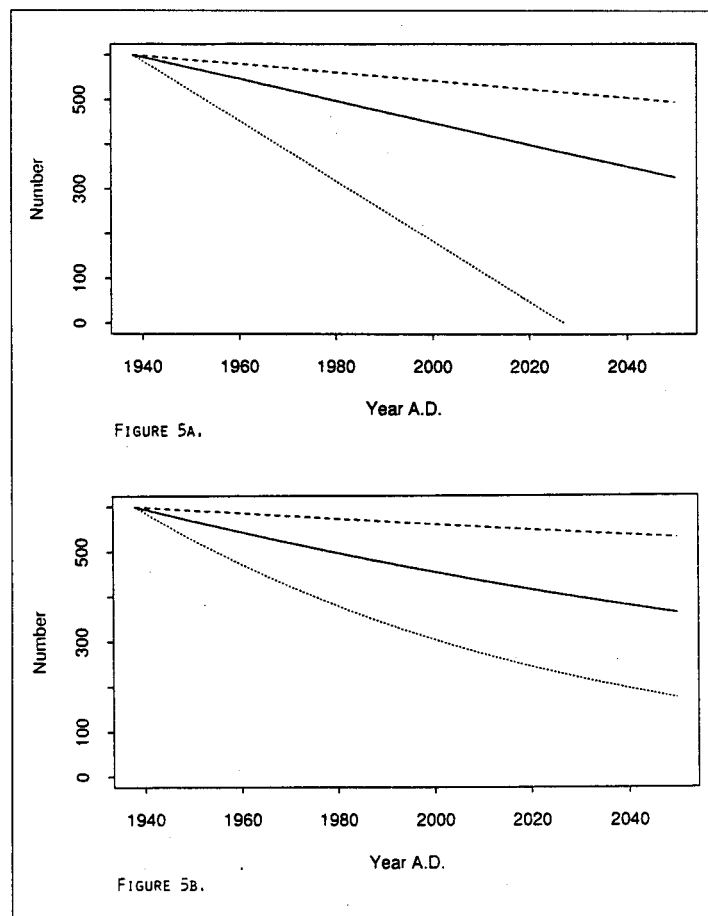
population decrease by a factor of two every 64 years (fig 5b), and the mean rate yielded a similar decrease every 156 years.

## DISCUSSION

Mortality rates reported here may underestimate actual rates for some periods due to the censusing of standing, recently dead individuals. Also, the analyses here presume no age depen-



**Figure 4**—Human population growth in the upper Santa Ynez valley between 1920 and 1990 (U.S. Bureau of the Census). 1990 population is projected by the Santa Barbara County Cities Area Planning Council.



**Figure 5**—Projected numbers of the sample of 600 valley oaks from 1938 to 2050 based on simple linear decrease of trees through time (Figure 5a), and constant mortality rate through time (Figure 5b). Solid line is based on the average mortality rate as measured in 12 stands, and dotted and broken lines are based on the maximum and minimum rates respectively.

dence in mortality. It would be useful to conduct actual age structure analyses of these stands. However, many of the large valley oaks in the upper Santa Ynez valley are hollow and therefore their age cannot be determined precisely. Finally, due to the wide variation of mortality rates among the stands, a much larger sample size may be necessary to detect significant environmental associations with mortality. There is a strong need for comparative studies in other valley oak habitat areas.

Presumably, the mortality rates for very young and very old individuals are considerably higher than those shown here. Given the best estimate of valley oak life span at 350 years (Elias 1980, Jepson 1910), density and age independent mortality in a sample of 600 valley oaks would be 1.71 trees/year, or 87 individuals over the 51 year period. The actual decline of 125 individuals of the sample population was 44 percent over this expected mortality.

This study shows a steady decline in the valley oak population with no obvious, consistent trend in mortality rates between 1938 and 1989. Given the relatively high mortality and lack of recruitment of canopy individuals over the past 50 years, it appears that an active program of sapling propagation is necessary to maintain or increase the size of the existing valley oak populations of the region.

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