

Oaks Through Time: Reconstructing Historical Change in Oak Landscapes¹

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Abstract

The San Francisco Bay Area was home to some of the most celebrated valley oak lands in California, their grandeur much chronicled by early visitors and residents. Despite extensive loss, there remains substantial local interest in their preservation and restoration, necessitating an understanding of historical distribution and subsequent change. Assembling and interpreting historical and current oak data for highly modified Bay Area landscapes, such as Sonoma Valley in this study, has involved the development of a range of new techniques. The use of historical data involves many uncertainties, but through careful, site-specific integration of written accounts from the 19th century, early maps and surveys, historical landscape and aerial photographs, and modern field data, it is possible to develop a likely scenario of historical oak distribution in Sonoma Valley. This and similar studies in the Napa and Santa Clara Valleys are contributing to a detailed picture of the changes undergone by oak savannah and woodland over the last two centuries. Preliminary results indicate a highly patchy distribution within areas considered to have had relatively homogenous or continuous cover. The distribution of valley oak savannah appears to have been largely determined by microtopography, soil type, and groundwater. We have also collected age data from recently cut trees, indicating age/size relationships and suggesting that major disturbance event(s) may have occurred several decades before the arrival of Spanish and Mexican settlers. GPS-based fieldwork to identify residual heritage trees has found many more trees surviving within these modified landscapes than expected. This study has been used to assess baseline erosion rates, determine site suitability for an oak woodland mitigation project, and to assist other efforts to maintain these trees as significant components of regional landscapes into the future.

Keywords: Historical distribution, historical vegetation patterns, valley oaks.

Introduction

The earliest written description of Sonoma Valley was recorded in the journal of Father Jose Altimira during his expedition to found the Sonoma Mission in 1823 (Altimira 1823). Altimira spent several days in Sonoma Valley taking an inventory of the resources that would aid the establishment of the mission; his observations provide a substantial amount of detail about vegetation patterns at the beginning of settlement. He described a *roblar*, or white oak grove (Brown 2001), on the valley floor, with trees “very tall and robust . . . 3 leagues from east to west, and one and a half leagues from north to south, though in some parts narrower.” These dimensions translate into an area approximately 7.8 miles long by 3.9 miles wide, about 30 square miles. His descriptions also include grasslands, riparian areas, uplands, and wetlands.

¹ An abbreviated version of this paper was presented at the Sixth California Oak Symposium: Today’s Challenges, Tomorrow’s Opportunities, October 9-12, 2006, Rohnert Park, California.

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In this study, I used a range of methods and sources to reconstruct the likely distribution of oaks on the floor of the Sonoma Valley at the beginning of the 19th century. By its nature, historical data contains many uncertainties and varying levels of accuracy and detail. Some sources for Sonoma Valley are quite detailed and can be easily tied to discrete points on the ground, others contain data that is less specific and more difficult to assign to definite locations. The difficulty of assessing the reliability of individual sources was addressed in several ways. Historical documents were reviewed and evaluated for content, accuracy, and location, and a field survey was carried out to map the distribution of remaining heritage oak trees. Recently collected oral histories from local elders were also consulted.

A key component of this study was the integration of this wide variety of sources, which in most cases allowed several pieces of data to be brought to bear on any particular location. This revealed converging lines of evidence among written accounts from the 19th century, early maps and surveys, historical landscape and aerial photographs, the current heritage oak survey, oral histories, soil maps, and infrastructure patterns. A similar technique was used by Cooper (1926) in reconstructing the pre-settlement characteristics of a large oak woodland near Palo Alto. The scenario of oak distribution developed in this current study should be considered a preliminary one that will be refined through further fieldwork and research.

A number of factors affect the distribution of oaks, including soil type, groundwater, micro-topography, and land use before and after European-style settlement. Of these, the effects of land use on heritage oak distribution is the most difficult to assess, and will require further study to better understand its impact. However, the results of this study suggest that a highly degraded, but discernable historical pattern can be still seen in the current distribution of heritage oaks.

Developing a picture of historical vegetation in Sonoma Valley requires taking into account the effects of land management practiced by indigenous peoples for centuries or millennia before Mexican settlement began, and was a primary consideration in the design of the study and analysis of the results (Parkman 2004). A variety of sources consistently indicate relatively open conditions at the time of settlement (Altimira 1823; General Land Office 1851-1887; O'Farrell 1848; Peabody 1851; Watkins 1888). Altimira reports Indians in the hills between Sonoma and Napa Valleys getting ready to "burn the long grass" during his visit in the summer of 1823. Other forms of native management in Sonoma Valley may have included pruning, scattering of seed, harrowing, and tilling of the soil to encourage the growth of certain plants (Anderson 2005). Details about native land management practices are outside the scope of this study, but were considered with respect to historical vegetation mapping.

Physical and historical evidence suggests that a map of pre-disturbance vegetation cover for Sonoma Valley should aim for a target date in the middle or late 18th century. However, because the earliest written records of vegetation in Sonoma Valley were not made until 1823 (Altimira 1823), reconstructing pre-disturbance conditions requires extrapolating back in time from a number of early historical sources. Building a picture of 18th-century conditions from data collected many decades or a century later would have a large potential for error. Likewise, characterizing the early to mid 19th-century landscape recorded by Altimira, Mexican land grant maps, and General Land Office (GLO) surveys as representing true pre-settlement conditions would also be inaccurate. Thus, 1800 was chosen as the middle

ground between the extremes of “too early” and “too late.” The year 1800 is a date for which conditions can be reconstructed with reasonable confidence, based on historical maps, observations, and surveys collected a few decades later, as well as modern field evidence.

Methods

Age/Circumference Relationship

As a preliminary step to making a survey of heritage oaks, I tested the correlation between the age and size of valley oaks and valley oak hybrids. Ring counts and circumference measurements were taken from 18 oak stumps. Most were recently downed trees in the process of being cut up. Whenever possible, circumference measurements were made 48 inches above the base of the tree, approximately chest level when the tree was standing. Identification of species was made from remaining leaves and/or bark. In two cases for which identification was less certain, oak trees in the immediate vicinity were used as indicators.

Heritage Oak Survey

Because of their longevity, oaks provide a living record of earlier conditions. I was interested in surveying oak trees that were here at the time of the first recorded settlement of non-native people in Sonoma Valley in 1823 (Smilie 1976). When measurements from 18 valley oak stumps demonstrated a strong correlation between age and diameter (see Results), a minimum circumference of 132 inches was chosen for the heritage oak survey, corresponding to an age of about 180 years. The survey was done over the course of two weeks on foot and by car. Public roads provided physical or visual access to most parts of the valley. Where trees were visible but not accessible, conservative estimates of circumference were made. Locations of heritage trees were recorded either with a GPS unit (accuracy=30 feet), or by hand on topographical maps (accuracy = 125 feet) and transferred into a Geographic Information System (GIS) program.

Using the established age/circumference relationship (see above) valley oaks measured during the heritage oak survey were grouped into 20-year age/size classes and assigned estimated germination dates. For comparison, oaks measured during 19th-century GLO surveys (see below) were also grouped into 20-year age/size classes and assigned estimated germination dates.

Assessment and Interpretation of Historical Sources

The first step in the historical research component of this study was to assess and interpret the various data sources. Each source type required a specific approach to interpretation, taking into account how and why the data was collected, its level of detail and accuracy, vegetation changes that had already occurred, and how accurately the data could be assigned to specific points on the ground:

1. **Jose Altimira’s Journal.** With the exception of very brief mention in mission records, this document (Altimira 1823) represents the earliest written record of Sonoma Valley. Altimira traveled through the area in the summer of 1823, surveying possible sites for a new mission. His inventory of available resources, particularly vegetation, wildlife, and water, is an invaluable source of ecological data from the early 19th century. Interpreting this document presents several

challenges: it is written in archaic Spanish and thus difficult to translate (published translations are poor and contain errors); Altimira's cardinal directions are based on the position of the sun just after summer solstice and thus skewed by 30 degrees; distances are in leagues (approximately 2.6 miles) and varas (approximately 2.75 feet); and a number of landscape changes had already occurred, the most significant being the depopulation of Sonoma Valley through removal of native people to other Bay Area missions (Milliken 1995) and probably disease. My familiarity with a photocopy of the original manuscript, developed over the last six years, helped minimize these difficulties. My draft translation was checked and corrected by an expert in early California Spanish.³ Where cross-checking is possible, Altimira's distances and other observations appear to be fairly accurate. Journal entries can be located to points within a 100-yard to 1-mile radius.

2. **Land Grant records from the U.S. Land Court.** These records primarily cover the floor of Sonoma Valley and include maps and court transcripts. Careful reading of these documents allowed comments, observations, and map features to be attributed to specific points on the ground and entered into GIS coverages (Anonymous 1837; Anonymous 1840; Anonymous 1844; Boggs 1861; O'Farrell 1848; Peabody 1851). Accuracy and detail of individual records varies considerably. Data can be located to points within a 100-yard to 1-mile radius.
3. **General Land Office (GLO) surveys.** These records primarily cover the uplands outside the boundaries of the land grants. In a few places, these surveys crossed the valley floor, allowing cross-checking of other sources. Diameters and species of bearing trees (trees marked at the intersections of township and range lines) were recorded, allowing integration with, and cross-checking of, modern field data from the heritage oak survey to develop a survivorship graph for valley oaks extending back to the late 17th century (General Land Office: 1851, 1853, 1855, 1858, 1859, 1865, 1866, 1867, 1871, 1880, 1887). These records are quite detailed and represent the most specific and accurate records from the mid-19th century. Most data can be located to points within a 100-yard radius.
4. **Historical photographs** from the late 19th century were consulted as an aid to denying or confirming vegetation types in some parts of the valley. Aerial photos from 1942 were also consulted for particular areas. Historical photos were carefully analyzed to identify the points from which they were taken and the features within each photograph (U.S. Department of War 1942; Watkins, 1888). Aerial photos have been used by other researchers for mapping the former distribution of oaks⁴ (Brown 2001). The greatest challenge in interpreting these photos is accounting for landscape changes that had already occurred in the 65 years or more since the beginning of settlement. Data can be located to points within a 10-yard to 100-yard radius.
5. **Oral Histories:** Information recorded from local elders whose memories covered most of the 20th century were attributed to specific points and proved particularly helpful in identifying former wetlands (Dawson 2002). Accuracy is good to

³ Calhoun, Daniel. Personal communication. Referred by the staff at Bancroft Library, Berkeley.

⁴ Grossinger, Robin; Ruygt, J. Unpublished data on file, San Francisco Estuary Institute, Oakland, CA.

excellent, and most observations can be located to points within a radius of 10 yards to 200 yards.

6. **Soil maps:** Soil maps were analyzed to determine if historical vegetation types correlated with soil type. Of particular interest were correlations between the presence of heritage oaks and soil types, and between historical wetlands and soil type. These maps were published by the Soil Conservation Service in 1972 and were based on a combination of field surveys and analysis of aerial photos from 1942. Designated soil types can be tied to points on the ground with an accuracy of 100 feet, though the “ground-truthed” accuracy of the soil boundaries themselves is unknown.

Additional Sources

Currently existing vernal pools were recorded on topographical maps and transferred to a GIS program. These pools were assumed to be relicts, indicative of former conditions in those areas. Accuracy of these locations is 125 feet.

A visual analysis using maps of existing and former infrastructure was made in certain areas to determine if there was a correlation between the presence or absence of roads and certain historical vegetation types, particularly perennial or seasonal wetlands.

A current land cover map, developed by the Sonoma Ecology Center from color aerial photos taken in 2003 as well as some fieldwork, was also consulted (Sonoma Ecology Center 2004). Land cover designations on this map include a variety of land uses, such as residential, commercial, agricultural, and park land. To test the effects of land-use on the distribution of heritage oaks, locations of trees recorded during the heritage oak survey were plotted on this map to test whether their current distribution was positively or negatively correlated with particular current land uses. The land cover map is accurate to within 100 feet.

Integration of Data Sources

Preliminary results from the heritage oak survey demonstrated that the distribution of heritage oaks was correlated with particular soil types (see Results), a phenomenon noted by Brown (2001), Griffin (1988), Cooper (1926), and Jepson (1910). Specific soil types were also found to correspond to known historical wetlands such as Tolay Lake (just outside Sonoma Valley) and the Kenwood Marsh (O’Farrell 1848; Peabody 1851; Soil Conservation Service 1972; Sonoma County Surveyors Office 1860). Given these findings, it was decided to use soil type as the starting point for developing the historical vegetation map for the floor of Sonoma Valley, and to refine it through consulting the other sources. The refinement process increased the number of polygons above those found on the soil map, resulting in a mean polygon size of about 75 acres, which can be considered a rough level of resolution for this study. The goal was to develop a map that represented likely approximations of “average” historical conditions within each polygon.

While there was significant overlap, slightly different collections of data were consulted and integrated to refine the likely extent and location of historical vegetation types. Thus, somewhat different approaches were developed for each one:

Freshwater wetlands: the former extent of seasonal and perennial freshwater wetlands was determined by an iterative refinement of the historical picture. Due to

the limitations of the data, seasonal and perennial wetlands were lumped into a single category. Soil types associated with the well-documented and mapped historical wetlands of Tolay Lake and the Kenwood Marsh were marked in GIS as wetland wherever they occurred in the watershed.

Soil polygons containing currently existing vernal pools were also marked as wetland in GIS. However, as these exist on a number of soil types, some of which also contain heritage oaks, only individual soil polygons were marked in this case. The same approach was taken with wetlands documented in Altimira's 1823 journal.

In a few cases, a polygon identified as "freshwater wetland" contained one or more heritage oaks. Depending on the number and location of these oaks, a determination was made whether to keep the "wetland" designation, change it to "oak woodland" or to divide the polygon into two or more pieces, some designated "freshwater wetland" and some "oak woodland," (scattered oaks are sometimes found at the edges of wetlands).

Further refinements were made to the "freshwater wetland" polygons using evidence such as historical photographs, oral histories, the absence of heritage oaks, and the absence of roads, which in several cases still define the extent of historical wetland.

Oak woodlands and savannah: the likely former extent of oak woodland and savannah was determined by an iterative refinement of the historical picture. As noted above, the distribution of heritage oaks mapped during the oak survey correlated well with a limited number of soil types. These soil types were marked in GIS to develop a preliminary picture of oak distribution. To check and further refine this oak extent, a number of other sources were consulted: mid 19th-century Mexican land grant maps, mid 19th-century American maps, GLO surveys, and late 19th-century photographs. Refinement involved adjusting polygon borders and re-designating some "oak woodland" polygons as "wetland," or "riparian forest," where there was existing or historical evidence for the change.

To develop a rough picture of historical oak density, each soil type containing heritage oaks was scored for modern presence (number of heritage trees). The two soil types containing about one-third of the heritage trees (31 percent) received scores of 3 (high) for modern presence; the 5 soil types containing the middle third (37 percent) received scores of 2 (medium); and the 16 soil types representing the final third (32 percent) received scores of 1 (low). To avoid weighting the scores in favor of soils covering large areas, a modern density score was also calculated by dividing the area covered by each soil type by the number of heritage trees on them. The one-third of soils with the lowest density ($\geq 7.1 \times 10^6 \text{ ft}^2/\text{heritage tree}$) received scores of 1 (low), the middle third (density $3.7 - 5.4 \times 10^6 \text{ ft}^2/\text{heritage tree}$) were given scores of 2 (medium), and the soil types with the highest modern densities ($0.2 - 2.8 \times 10^6 \text{ ft}^2/\text{heritage tree}$) scored 3 (high). Finally, the modern presence and modern density scores were added to create a combined score. This combined score was applied to each polygon and used to map a possible scenario of historical oak density. As a final check, the oak distribution map was compared with the dimensions of the *roblar* described by Altimira in 1823.

Riparian forest: forested areas along creeks were considered "riparian forest." The extent of these areas was determined by a two-step process. Soil types designated as "riverwash" were mapped in GIS as "riparian forest." Further

refinements were made using historical photographs and maps to confirm the existence and adjust the position and extent of these areas.

No evidence for oaks. Some evidence for chaparral or grassland: This category covers soil types in which no heritage trees or other evidence for historical oak presence was found, but for which there is some physical or historical evidence for chaparral or grassland. Sources for this category included Altimira’s observations, GLO surveys, and modern observations.

Tidal marsh: Areas influenced by tidal flows and a mixture of salt and fresh water were identified as “tidal marsh.” A coverage for tidal marsh areas as defined by the San Francisco Estuary Institute was used for this project (San Francisco Estuary Institute 1999).

Results

Age/Circumference Relation

Ring counts and measurements of 18 recently cut valley oaks and valley oak hybrids revealed a good correlation between circumference and age (*fig. 1*) for trees from approximately 80 to 280 years old. The lack of data for trees younger than this means the trendline may be in error for valley oaks less than 80 years old.

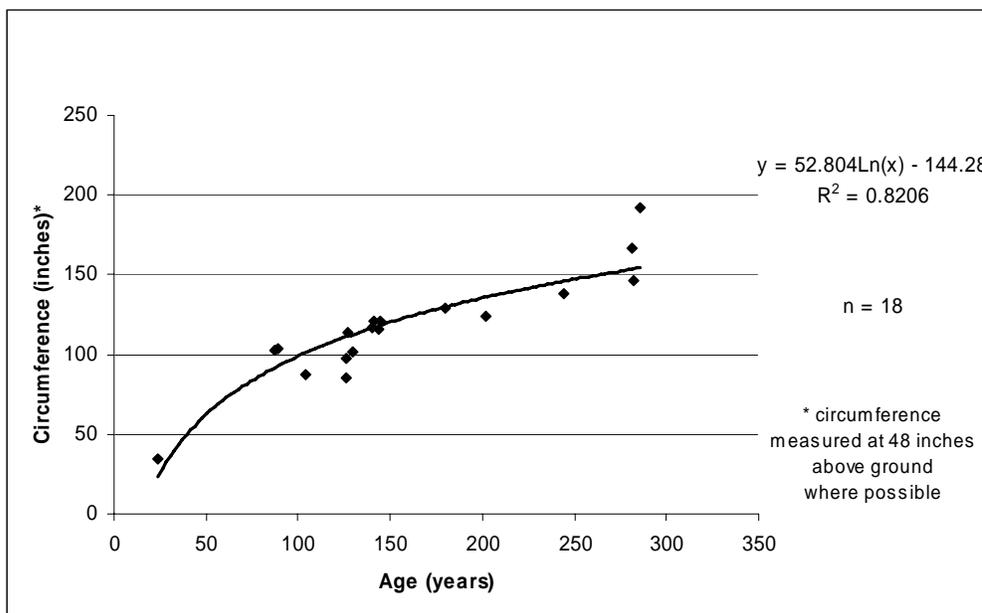


Figure 1—Valley oak age/circumference relation from ring counts of recently cut stumps, Sonoma Valley, California (includes hybrids)

Heritage Oak Survey

The heritage oak survey recorded 189 valley oak and valley oak hybrids (90 percent), 16 coastal live oaks (7.5 percent), 4 black oaks (2 percent), and 1 blue oak (0.5 percent) on the floor of Sonoma Valley with circumferences of 132 to 225 inches.

For valley oaks, this corresponds to a minimum age of 180 years, thus dating to the beginning of settlement or before. Figure 4 shows the locations of these trees.

A strong correlation was found between the presence of heritage oaks and soil type (*table 1*). Of 57 soil types found on the floor of Sonoma Valley, 23 (40 percent) had heritage oaks growing on them. Just two soil types, Tuscan cobbly clay loam and Los Robles gravelly clay loam supported approximately one-third (31 percent) of the heritage oaks, an additional five soils supported another third (37 percent), and 16 more soil types supported the remaining third (32 percent).

Heritage oaks were found growing in all land-use categories (*table 2*), with the greatest numbers in residential, commercial, and vineyard areas. Of the 23 soil types supporting heritage oaks, 21 also supported vineyards. Vineyards were found on a total of 49 soil types. Only two soil types with heritage oaks, Clough gravelly loam, and Red Hill clay loam did not have vineyards on them in 2004.

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Table 1—Soil preferences for heritage oaks, Sonoma Valley, California (includes hybrids; heritage trees defined as 132 inches or more in circumference)

Soil type	Slope	Permeability	# of heritage oaks	Modern presence (score)	Soil type total area (10 ⁶ feet ²)*	Modern density Square feet per tree (10 ⁶ feet ²) (score)*	Combined score*	
Arbuckle Gravelly Loam	0-5	1.31	3	Low (1)	4	1.33 (3)	4	
AkB								
Clear Lake Clay	CeA	0-2	.13	6	Low (1)	51	8.5 (1)	2
	CeB	2-5	.13	2	Low (1)	53.6	26.8 (1)	2
Clear Lake Clay Loam	0-2	.13	6	Low (1)	75.3	12.6 (1)	2	
CcA								
Clough Gravelly Loam	2-9	1.31	3	Low (1)	33.9	11.3 (1)	2	
CgC								
	CgD	9-15	1.31	1	Low (1)	2.6	2.6 (3)	4
Goulding Clay Loam	GgD	5-15	1.31	8	Low (1)	25.4	8.5 (1)	2
Huichica Loam	HtA	0-2	1.31	21	Medium (2)	120.7	5.7 (2)	4
	HuB	0-5	1.31	1	Low(1)	2.8	2.8 (3)	**4
	ponded	ponded						
	HtC	2-9	1.31	19	Medium (2)	102.8	5.4 (2)	4
Lariger Loam	LaC	5-9	1.31	10	Medium (2)	2.1	0.2 (3)	5
Los Robles gravelly clay Loam	0-5	.42	31	High (3)	42	1.4 (3)	6	
LuA								
	LvB	0-2	.42	5	Low (1)	94.2	18.9 (1)	2
Red Hill Clay Loam	RhD	2-25	1.31	13	Medium (2)	64.5	5.0 (2)	4
	RhE	15-30	1.31	4	Low (1)	4.1	1.0 (3)	4
Riverwash	RnA			6	Low (1)	42.8	7.1 (1)	2
Spreckles Loam	SkC	2-9	.42	7	Low (1)	25.8	3.7 (2)	3
	SkE	15-30	.42	6	Low (1)	22.0	3.7 (2)	3
Tuscan cobbly clay loam	0-9	.42	34	High (3)	71.7	2.1 (3)	6	
TuC								
Wright Loam	WmB	0-5	1.31	1	Low(1)	31.6	31.6 (1)	2
	WgC	0-9	1.31	5	Low (1)	23.3	4.7 (2)	3
Yolo Loam	YnA	0-2	1.31	3	Low (1)	13.6	4.5 (2)	3
Zamora Silt Clay Loam	0-2	.42	15	Medium (2)	61.7	4.1 (2)	4	
ZaA								
Total Oaks			210					

*Modern presence score based on absolute number of oaks present, divided into low, medium and high categories (see fig. 2)

Square feet per tree score based on modern density, divided into low, medium and high categories

Total score = (modern presence score) + (square feet per tree score)

**single tree is on soil type boundary and slightly above level of former wetland

Table 2—Locations of heritage oaks in Sonoma Valley with respect to land-use designations.

Land-use	# Heritage oaks	% Heritage oaks
Transportation	5	2
Closed Woodland	20	9
Commercial	29	14
Vineyard	26	13
Other agriculture	13	6
Open woodland	23	11
Residential	75	36
Riparian	3	1
Urban Parks	7	3
Facilities	4	2
Grasslands	5	2
Total	210	99% (due to rounding)

The results of dividing size classes recorded during the heritage oak survey into approximate 20-year age groupings are shown in figure 3. The results of dividing size/age classes recorded in the mid 19th-century General Land Office surveys are shown in figure 4.

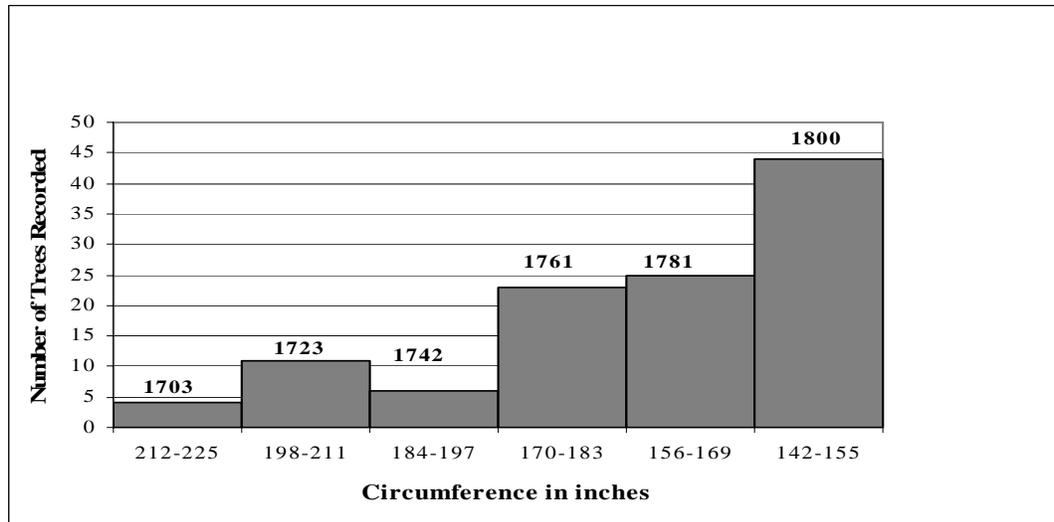


Figure 2—Valley oak size class abundance from heritage oak survey, Sonoma Valley, California (includes hybrids) (Dates are estimated germination year for middle of size class.)

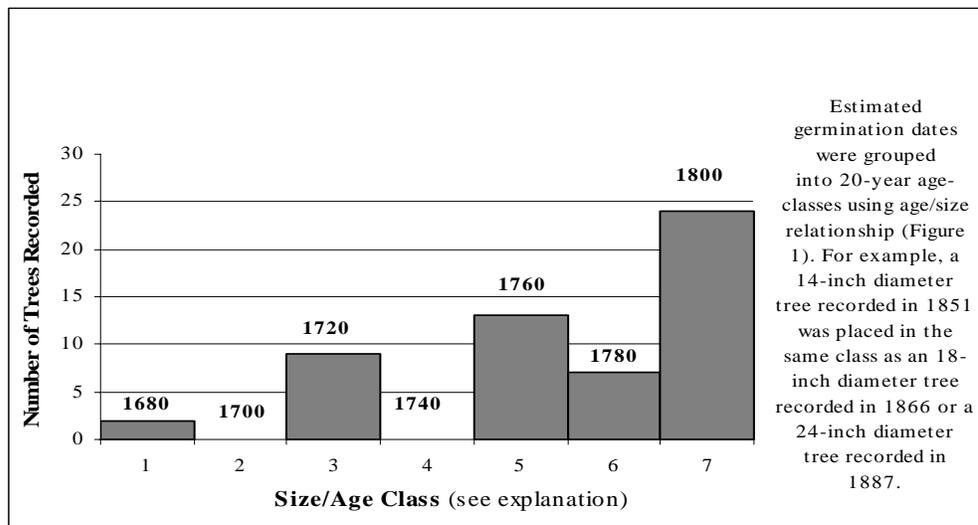


Figure 3—Valley oak* size/age class abundance, Sonoma Valley, California from General Land Office surveys, 1851 to 1887 (Dates are estimated germination year for middle of size/age class.)

*recorded as “white oak”

Integration of Data Sources

Integration of all data sources resulted in figure 4. As an example of how integration worked in practice, consider an area extending about two miles from the base of the hills near Carriger Creek across the valley floor to Sonoma Creek, and north and south about two miles, including parts of present-day El Verano (*see “example area” box, fig. 4*). The heritage oak survey recorded only a few large trees in this area. Abundance scores (*table 1*) developed from the survey suggest a variety of historical conditions here, including soil types supporting very low or low densities of oaks, as well as polygons in which there was no evidence for oaks, but some evidence for grassland or chaparral. Riverwash soils along Carriger Creek define a likely riparian corridor, and the bottomlands near Sonoma Creek match soil types associated with wetlands found at former Tolay Lake and the Kenwood marsh.

I tested these designations against a number of historical sources. An early map (O’Farrell 1848) shows a few oaks in this area, with what appears to be an abundance of willows in the possible wetland area near Sonoma Creek. A Carleton Watkins photograph (1888) of the same area shows a medium density of oaks on the alluvial fan of Carriger Creek, but very scattered oaks elsewhere. Oaks can be seen in this photograph growing within the polygons designated as “no evidence for oaks.” Close inspection reveals these to be relatively small trees (trunks less than 24 inches in diameter, or 72 inches in circumference) and thus most likely *not* present in 1800. The likely wetland area is too distant to be analyzed from this photo. Infrastructure analysis of the likely wetland area reveals few roads and larger parcels in this area. A street name in El Verano near Sonoma Creek is “Willow Street.”

In this case, integrated analysis revealed one anomaly: a heritage oak growing in the likely wetland area. In other parts of Sonoma Valley, heritage trees were recorded in areas that have maintained their wetland character; however, these trees are all found on small mounds or rises which put them slightly above the surrounding terrain. As the polygons developed in this study are meant to represent average

historical conditions, the presence of a single heritage oak in a wetland area was not deemed significant enough to change its designation, particularly given the multiple lines of evidence supporting a wetland designation.

One refinement was considered during the integration phase for this example area: raising the estimated historical oak density on the Carriger Creek alluvial fan from “low” to “medium.” As the alluvial fan does not coincide with the soil polygon for this area, it would require a substantial amount of further analysis to define this new polygon. As historical sources suggest, oak densities within this polygon ranging from “very low” to “medium” giving it an average overall value of “low.”

Discussion

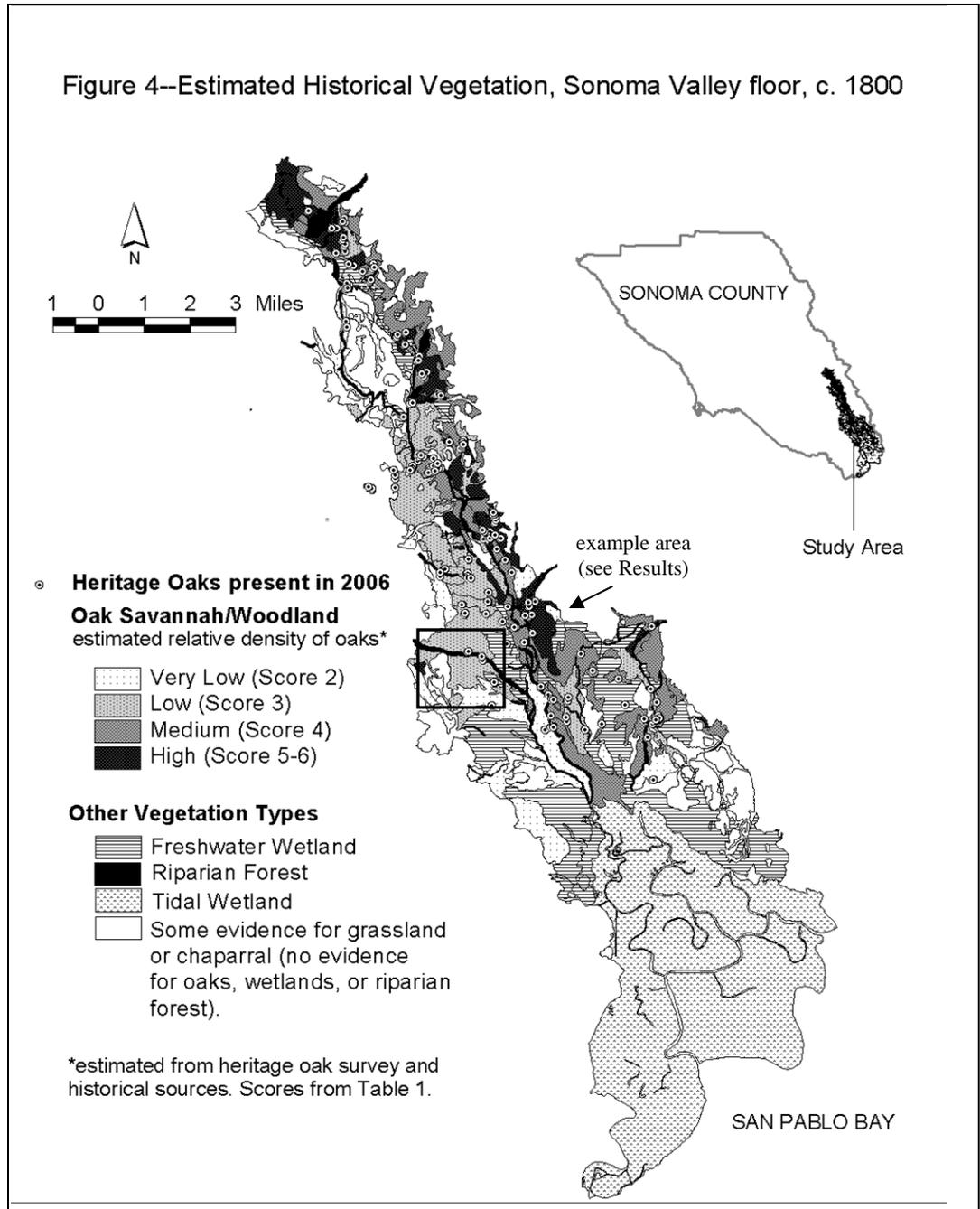
This study was able to make only a preliminary assessment of the effects of land use on heritage oak distribution. An initial analysis in table 2 shows heritage oaks growing on every land use type in Sonoma Valley. While fewer heritage oaks might be expected to survive under intensive land use designations of commercial, residential and agricultural, these were precisely where the most heritage oaks were found. Survival of heritage trees in residential areas may be due to people’s fondness for large trees, and the same may hold true, perhaps to a lesser degree, in commercial areas. Survival of heritage oaks on agricultural land is harder to explain. Perhaps agricultural lands supported a higher proportion of oaks in the past and the survivors represent a very small fraction of these original trees. If this is true, then agricultural lands are under-represented as former oak habitat. Alternately, some forms of agriculture, such as cattle raising and viticulture, may not necessarily have resulted in the clearing of large numbers of trees in the past, given the openness of the landscape depicted in early maps, accounts and photographs. Offered a choice, early settlers would likely have chosen open areas for fields and pastures. Present-day vineyards are found on 49 soil types, 21 of which also support heritage oaks. Twenty-eight soil types support vineyards but no heritage oaks; further research could determine whether some of these soils appear to offer good potential oak habitat. Another factor that was not addressed in the current study was the effect of woodcutting on the distribution of heritage oaks. While local elders report woodcutting on a commercial scale in the uplands (Dawson 2002), historical sources do not mention this activity on the valley floor.

Locations of trees recorded during the heritage oak survey suggest that small variations in microtopography played a significant role in valley oak distribution in Sonoma Valley in the past. For example, there are a number of heritage trees just east of Highway 12 in Kenwood, growing on a knoll rising about 20 feet above a former wetland. One large oak on this knoll is only 2 or 3 feet above the former wetland. Cooper (1926) mentions that groundwater at or near the surface seems to exclude valley oaks and that these trees achieve their “best development where the water table is 10 to 20 feet below the surface,” or where the roots can easily penetrate more deeply. Altimira (1823) called Sonoma Valley “a fountain of fountains” because of the abundance of surface water even in the summer. Many parts of Sonoma Valley were probably unsuitable for oaks in the past because of the high water table. Small variations in topography probably provided small areas of suitable oak habitat in places that were otherwise incompatible. For the most part, the resolution of this study was not fine enough to capture these areas.

Comparing the results of the age/size class analysis from the heritage oak survey with the age/size class analysis from the General Land Office (GLO) surveys (*figs. 2 and 3*) reveals a strikingly similar pattern, despite the fact that these data sets were collected well over 100 years apart (note: the trendline used to estimate the ages of the smaller trees recorded during the GLO surveys could be in error, as it was based on the size/age correlation demonstrated in older trees. Verification of the similarity between the heritage oak survey and the GLO surveys will require further research into the younger age classes). The most prominent aspect of both is the sudden rise in the number of surviving trees that germinated around 1800. The simplest explanation for this similarity is that both data sets reflect the same population of trees. The proportions of the various age classes did not change much over time, except that the oldest trees died off. Alternatively, an appearance of similarity could have been created by two independent factors, for example: a bias toward certain tree sizes by GLO surveyors and a greater harvesting of the 1760 and 1780 age/size class in the era immediately preceding the GLO surveys.

The distribution of oaks recorded during the heritage oak survey (*fig. 4*) matches well with the historical description of the *roblar*, taking into account the fact that Altimira did not explore beyond present-day Glen Ellen (Smilie 1975). Heritage oaks in this part of Sonoma Valley cover an area measuring 8.6 miles long by 3.9 miles at the widest, compared to Altimira's observation of 3 leagues by 1½ leagues, "though in some places narrower" (7.8 miles x 3.9 miles). Thus the distribution of heritage oaks appears to represent a highly degraded but still discernible historical pattern. Converging lines of evidence between modern field data and historical sources allowed a refinement of the historical picture to a fairly detailed level of resolution. The correlation of soil type with the presence of heritage oaks, as well as with current and former wetlands, suggests that soil type is useful as a preliminary indicator of historical vegetation. Correlation of oak presence and oak density with soil type has been noted by other researchers, including Brown (2001), Griffin (1988), Cooper (1926), and Jepson (1910). Two soil series mentioned in Brown's study, Yolo and Zamora, also occur in Sonoma Valley, with Zamora silt clay loam receiving a medium high score for heritage oak presence, and Yolo loam a medium score. Brown's historical sources for Santa Clara indicated "uneven distribution of oak woodland, oak savannah, and clearings" on these soil types. Just two soils support nearly one-third (31 percent) of the existing heritage oaks in Sonoma Valley—Tuscan cobbly clay loam and Los Robles gravelly clay loam. Brown found that a gravelly loam in the Garretson series may have supported the densest oak groves in Santa Clara. Gravelly loams cover a very small area of Sonoma Valley and support only a few heritage oaks, though the Arbuckle series has one of the highest densities of heritage oaks here.

Figure 4--Estimated Historical Vegetation, Sonoma Valley floor, c. 1800



Assume for the moment that the rise in the number of surviving oaks that germinated around 1800 is real—what would it say about the history of oaks here? The fact that this pattern shows up in both surveys suggests it is *not* just reflecting a mortality rate, with more younger oaks surviving than older ones, because the GLO surveys recorded their data from relatively young trees. In this case, the sudden rise in the oak population might be due to conditions that encouraged the survival of oak seedlings. Two possibilities are climate change, and/or a disruption in native land management such as periodic burning. California experienced a long-term drought

from 1755 to 1820 (Goodridge 1991), so climate change seems an unlikely trigger for such a rise. The possibility that a decrease in native burning caused the rise in oak survival is supported by several pieces of evidence. The accumulation of leaf litter is known to favor acorn germination (Merrick and others 1999). While the first known Spanish entry into Sonoma Valley occurred in 1810, and the first settlement was established in 1823, the San Francisco mission, just 30 miles to the southwest, was established in 1775. The passage of disease along trade routes during or preceding the period of contact is well documented (Calloway 2003; Milliken 1995). The combination of missionization and disease could have severely diminished or wiped out the local native population decades ahead of settlement, potentially reducing or eliminating traditional land management practices such as burning. There are no indications in Altimira's journal (Altimira 1823) that anyone was living in Sonoma Valley at the time of his visit; in Petaluma, Napa, and Suisun he records meeting local natives, but not here. His observation of small-trunked Douglas firs on Sonoma Mountain suggests a process that can be seen today—the invasion of open grasslands by this native tree species. “Small-trunked” implies relatively young trees not more than a few decades old. As cessation (or suppression) of fire is known to encourage the growth of Douglas firs (Mac and others 1998), the disruption of native land management practices could have already left visible evidence in 1823. Further research is needed to test this hypothesis.

Conclusions

This preliminary study suggests that integrating field data and a variety of historical sources is an effective approach to developing a detailed picture of historical vegetation patterns, one that minimizes uncertainties about the accuracy of individual historical sources. This approach seems most likely to succeed in areas like Sonoma Valley where a mosaic of land uses are found and where field data on heritage oaks can still be collected. This project could probably be duplicated in other parts of the north bay, parts of the Central Valley and probably elsewhere. While broadly described as a *roblar*, the floor of Sonoma Valley at the beginning of settlement appears to have supported a complex mosaic of oak woodland, oak savannah, seasonal and perennial wetlands, riparian forest, grassland, and chaparral. Some of these historical patterns are reflected in the local infrastructure. The extent of former wetlands can still be traced in the placement of streets and roads, probably because people developed the better-drained areas first. Integrated mapping such as used in this study should prove useful as a conservation and restoration tool, identifying areas in need of preservation and places where restoration of oak landscapes is most likely to succeed. To date, the results of this study have been used to assess baseline erosion rates (through cover factor values used in modeling with the Revised Universal Soil Loss Equation), to determine site suitability for an oak woodland mitigation project being considered by the California Department of Transportation (Caltrans), and are expected to assist other efforts to maintain and restore oak woodland and other historical vegetation patterns as significant components of regional landscapes into the future.

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