Western Riverside County
Multiple Species Habitat Conservation Plan (MSHCP)
Biological Monitoring Program

Engelmann Oak (*Quercus engelmannii*)
Recruitment Survey Report 2007

7 March 2008

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NOTE TO READER:

This report is an account of survey activities undertaken by the Biological Monitoring Program for the Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP). The MSHCP was permitted in June 2004. The Biological Monitoring Program monitors the distribution and status of the 146 Covered Species within the Conservation Area to provide information to Permittees, land managers, the public, and the Wildlife Agencies (i.e., the California Department of Fish and Game and the U.S. Fish and Wildlife Service). Monitoring Program activities are guided by the MSHCP species objectives for each Covered Species, the information needs identified in MSHCP Section 5.3 or elsewhere in the document, and the information needs of the Permittees.

While we have made every effort to accurately represent our data and results, it should be recognized that our database is still under development. Any reader wishing to make further use of the information or data provided in this report should contact the Monitoring Program to ensure that they have access to the best available or most current data.

The primary preparer of this report was the 2007 Botany Program Lead, Diane Menuz. If there are any questions about the information provided in this report, please contact the Monitoring Program Administrator. If you have questions about the MSHCP, please contact the Executive Director of the Western Riverside County Regional Conservation Authority (RCA). For further information on the MSHCP and the RCA, go to www.wrc-rca.org.

Contact Info:

Executive Director
Western Riverside County
Regional Conservation Authority
4080 Lemon Street, 12th Floor
P.O. Box 1667
Riverside, CA 92502-1667
Ph: (951) 955-9700

Western Riverside County MSHCP
Monitoring Program Administrator
c/o Karin Cleary-Rose
4500 Glenwood Drive, Bldg. C
Riverside, CA 92501
Ph: (951) 782-4238

INTRODUCTION

The Engelmann oak (*Quercus engelmannii*; "QUEN") occurs from eastern Los Angeles County to northwestern Baja California (Roberts 1995) and has the smallest distribution of all of the oak species found in California (Scott 1990). Riverside County accounts for approximately 6 percent of the remaining QUEN populations (Scott 1991). In western Riverside County, the largest occurrence of QUEN occurs at the Santa Rosa Plateau Ecological Reserve and stretches along undeveloped areas in a narrow band west to San Mateo Canyon in the Cleveland National Forest. There are additional smaller occurrences at the Santa Margarita Ecological Reserve, the Southwestern Riverside County Multi-Species Reserve, and the Potrero Unit of the San Jacinto Wildlife Area.

In order to ensure the persistence of Engelmann oak in the Conservation Area, species-specific objective 3 for QUEN states that:

> *Within the MSHCP Conservation Area, maintain recruitment at a minimum of 80 percent of the conserved populations as measured by the presence/absence of seedlings and/or saplings across any consecutive five years* (Dudek & Associates 2003).

Tyler et al. (2006) define recruitment as "the establishment of new individuals into an age or size class of a population". In order to determine if recruitment is occurring, we must measure not just if seedlings and saplings are present, but also whether they are surviving long enough to join the next age class. Several studies have addressed the recruitment ability of Engelmann oak in the vicinity of the Santa Rosa Plateau, either by examining size class distribution of saplings and adults (Lathrop et al. 1991) or by monitoring survivorship of seedlings and saplings over the course of several years (Lathrop and Osborne 1991, Principe 2002). Some of these papers have also looked at fire as a factor affecting survivorship. Most of these studies found that establishment of seedlings is highly episodic and mortality rates often appears high on an annual basis, though seedlings that appear dead can resprout in future years when conditions improve. Because of the high variability shown in previous studies and the extreme variation in weather patterns in southern California, long-term data are needed to show whether Engelmann oak populations are successfully recruiting (i.e., effectively replacing aging adult trees).

In western Riverside County, QUEN hybridizes with California scrub oak (*Quercus berberidifolia*) in areas where the 2 species co-occur, including at the Santa Rosa Plateau. (Roberts et al. 2004). While scrub oak generally occupy drier sites and are more common in chaparral than QUEN, both species are found co-occurring in chaparral and oak woodland sites. Research has not been done on the impact of hybrid individuals on QUEN populations, nor on the extent to which such hybridization is occurring. For the purposes of this study, the Biological Monitoring Program is only interested in recruitment of oak individuals that appear to be pure QUEN.

The Biological Monitoring Program conducted a pilot Engelmann oak recruitment study at the Santa Rosa Plateau in fall and winter of 2005-2006 (henceforth: "2005"). The intention of this study was to follow seedlings and saplings over the course of at least 5 years to determine survivorship of individuals. We found that only 29.8% of all transects at the Santa Rosa Plateau contained seedlings or saplings. Based on the pilot study, we reached the conclusion that we needed to increase sampling intensity in order to better detect whether recruitment was occurring. We also measured additional environmental factors to test hypotheses about the effects of environmental factors on germination and recruitment rates across sites. In the fall and winter of 2006-2007 (henceforth: "2006") we resurveyed all transects established in 2005, established additional transects across the Conservation Area, and collected environmental data on all transects.

Survey Goals:

A) Increase the number of QUEN recruitment transects at the Santa Rosa Plateau and expand the study area to include more areas with QUEN occurrences.
B) Measure the presence/absence of QUEN seedlings, saplings, and adults on transects set up in areas with known QUEN populations.
C) Determine survivorship of seedlings, saplings, and adults from 2005 to 2006 on transects measured over two years.
D) Collect site environmental data such as vegetation community and grass cover to determine if these variables affect establishment and survivorship of seedlings and saplings.
E) Continue to test and refine study design to ensure success at collecting long-term data to show QUEN recruitment ability.

METHODS

Protocol Development

The protocol used for surveys in 2006 was modified from the protocol developed in 2005, the first year of the oak recruitment study. In 2006, we collected more environmental data at each site, including the percent of each transect covered by grass, rocks, and QUEN canopy. We also had observers record which Engelmann oak vegetation association the transect fell into, as defined by the 2005 vegetation map of western Riverside County (CDFG et al. 2005), to see if field observations matched information found in the map. In 2006, observers assigned each QUEN seedling, sapling, and adult an identification letter and measured the basal diameter and height of all seedlings and saplings in an effort to make cross-year comparison easier. Last, observers drew maps of each site, showing major landmarks and the distance and direction from each stake to semi-permanent objects such as adult trees or fences.

Personnel and Training

All individuals contributing to this study demonstrated familiarity with QUEN, and studied the distinguishing characteristics of the co-occurring oak species: coast live oak (*Quercus agrifolia*) and California scrub oak (*Q. berberidifolia*). All observers participated in field training at the Santa Rosa Plateau, and studied collections of adult oak specimens that are stored at the Biological Monitoring Program office and at the University of California Riverside Herbarium. Personnel conducting Engelmann oak surveys in 2006-2007 included:

- Diane Menuz, Botany Program Lead, (Regional Conservation Authority)
- Theresa Johnson, (Regional Conservation Authority)
- Adam Malisch (Regional Conservation Authority)
- Andrea Salzman (Regional Conservation Authority)
- Angela Coates (Regional Conservation Authority)

- Christina Greutink (Regional Conservation Authority)
- Esperanza Sandoval (Regional Conservation Authority)
- Lesley Hansen (Regional Conservation Authority)
- Rosina Gallego (Regional Conservation Authority)
- Ryann Loomis (Regional Conservation Authority)
- Valerie Morgan (Regional Conservation Authority)
- Ricardo Escobar (California Department of Fish and Game)
- Annie Bustamante (California Department of Fish and Game)

Study Site Selection

We chose the initial study site, the Santa Rosa Plateau, for the pilot study because it houses the largest stand of Engelmann oak in the Plan Area. We surveyed for additional occurrences of Engelmann oak in fall of 2006 as part of the Inventory-Phase Rare Plant Surveys. We directed these surveys at areas historically known to have Engelmann oak based on herbarium records, the California Natural Diversity Database, and other historic sources. We identified 5 additional areas in 2006 containing Engelmann oak: Santa Margarita Ecological Reserve ("Santa Margarita"), San Mateo Canyon, the Southwestern Riverside County Multi-Species Reserve ("Lake Skinner"), the area between Santa Rosa Plateau and San Mateo Canyon ("Tenaja Corridor"), and the Potrero Unit of the San Jacinto Wildlife Area ("Potrero"). We excluded Potrero from the QUEN recruitment study because only 1 Engelmann oak individual was found that was not a hybrid between Engelmann oak and California scrub oak, and we excluded San Mateo Canyon because we were denied permission to place stakes in this area. In 2006, we included Santa Margarita, the Tenaja Corridor, and Lake Skinner in the study area.

At the Santa Rosa Plateau and Tenaja Corridor, we defined the study area to be all areas showing Engelmann oak vegetation associations in the 2005 vegetation map of western Riverside County (CDFG et al. 2005). At Santa Margarita, we used the vegetation map created by San Diego State University in combination with the aforementioned map to delineate the study area, and some areas were eliminated before transect selection due to inaccessibility (San Diego State University Field Stations Program 2001). The 2005 vegetation map does not show any Engelmann oak vegetation associations at Lake Skinner. However, Zach Principe (2004) marked individual Engelmann oak adult tree locations at Lake Skinner. We created two polygons in ArcGIS from that information which we use to delineate the study area at Lake Skinner.

Transect Location

In 2005, we chose midpoints for 106 transects at the Santa Rosa Plateau by selecting random points in ArcGIS stratified across the 7 vegetation associations containing Engelmann oaks shown in the 2005 vegetation map of western Riverside County. Vegetation series are defined by the dominant or co-dominant species in the overstory of a stand of vegetation (Sawyer and Keeler-Wolf, 1995). Vegetation associations are refinements of the series, reflecting differences in understory components. The Engelmann oak vegetation associations in western Riverside County consist of stands where Engelmann oak is dominant or co-dominant with coast live oak, scrub oak and/or western sycamore (*Platanus racemosa*) with understories consisting of grass, poison oak (*Toxicodendron diversilobum*) and/or annual forb species. Points were specifically limited to the edge of oak assemblages and were buffered to be at least 30 m away from one another. Surveyors then navigated to each random point and looked for the closest adult Engelmann oak. They chose the transect midpoint to be the point at the edge of this tree's canopy nearest to the random point. They chose a random compass direction from a predetermined list of random numbers generated by the Microsoft Excel Random Number Generating Function. The belt transect was then extended 15 m to either side of the midpoint in the direction of the randomly chosen compass direction.

We resurveyed all but 4 of the 2005 transects in 2006. We excluded 4 transects because of accessibility issues or because an inappropriate adult tree (incorrect species or dead in 2005) was originally used to determine the transect midpoint. We added additional transects in the refined study areas at the Tenaja Corridor and Santa Margarita in 2006 using the 2005 method outlined above. At Lake Skinner, because there were no Engelmann oak assemblages shown on the 2005 vegetation map, we chose random initial points throughout the study area in ArcGIS, buffered from one another by 30 m. We established new transects at Santa Rosa Plateau in 2006, stratified by vegetation association and buffered 30 m from other transect mid-points, but not limited to the edge of oak assemblages. In total, there were 15 transects at Santa Margarita, 183 at the Santa Rosa Plateau, 15 at Lake Skinner, and 52 in the Tenaja Corridor, for a total of 265 transects (Figure 1).

In 2006, we modified our method of selecting the transect azimuth. Instead of completely random bearings, we chose randomly within a constrained range that fell beneath the canopy of the oak tree. This eliminated transects that would have been tangential to the canopy.

Survey Methods

Surveys were conducted beginning 27 October 2006 and continued until 12 February 2007. Each belt transect was 30 m long and 5 m wide. Surveyors either navigated to pre-established transects or set up new transects using the above guidelines. Along the belt transect, surveyors measured and mapped all QUEN seedlings, saplings, and adults. We defined seedlings as those individuals with a basal diameter of less than 1 cm, saplings as those with a basal diameter of 1 to 10 cm, and adult oaks as any individual with a basal diameter greater than 10 cm, similar to the size classes used in QUEN research by Principe (2002) and Lathrop and Osborne (1991). Researchers commonly use size rather than age for classifying oaks because of the ease of taking size measurements and because factors such as mortality risks and reproductive behavior are often size rather than age-related (Tyler et al. 2006). We measured the basal diameter and height of all seedlings and saplings and recorded their position as at the edge, under, or outside the canopy. We measured the diameter-at-breast-height on all adults. We then collected estimates of rock, grass, and QUEN canopy cover across the entire transect. We recorded an estimate of the level of senescence in the canopy trees. We then drew detailed site maps to facilitate transect relocation in future years. The *2007 Western Riverside County MSHCP Engelmann Oak Protocol* and datasheets (Appendices A and B, respectively) provide a more detailed description of survey methods.

Data Analysis

We modeled the effects of the habitat information on seedling and sapling abundance at each transect using generalized linear models (GLMs) in R 2.5.1. GLMs are extensions of linear models that allow for a variety of distributions in the dataset. We looked at seedlings and saplings separately because we assumed that different factors might control the initial establishment of seedlings and the longer-term survival of seedlings to sapling stage. We initially fit the models with a Poisson distribution because this distribution better describes count data.

We considered models to be over-dispersed when the residual deviance exceeded twice the residual degrees of freedom (Lindsey 1999). Over-dispersion indicates an observed variance greater than that predicted by the model, and can result in biased model estimates. We substituted the quasipoisson family for the Poisson in models that showed overdispersion.

Models initially included main effects for 11 predictors (Table 1). We simplified models by removing predictors that were not significant one at a time until all predictors were significant at the alpha = 0.05 level. Some data were missing for some sites because we did not begin collecting some variables, such as grass cover, until after the study had already begun and because sometimes surveyors failed to collect certain pieces of data. We excluded 48 of 265 transects from data analysis because they were missing data on environmental predictors. Percent grass cover, percent Engelmann oak cover, percent rock cover, percent senescence, slope of the site, and slope along the transect were all collected in the field and were used untransformed in the analysis. The four major study areas (Santa Rosa Plateau, Santa Margarita, Tenaja Corridor, and Lake Skinner) were included in a single categorical variable called “Site”. Days into the study was calculated with 1 being October 27, 2006, the first day of data collection. Northness was calculated from the site slope and aspect using the following equation:

$$N = \text{cosine (azimuth) x sine(slope).} \quad (1)$$

This index provides a scale from -1.0 to 1.0 in which low numbers represent xeric south-facing slopes and higher values represent mesic north-facing slopes. We extracted elevation at the midpoint of each transect in ArcGIS using a USGS Digital Elevation Model with 30 m resolution.

Table 1. Predictors included in model of seedling and sapling abundance.

Factor	Mean	S.D.	Range
Days Into Study	N/A	N/A	1-109
Elevation (m)	589.14	75.78	320-774
Grass Cover (%)	53.19	31.07	0-100
Northness[1]	0.04	0.13	-0.38- 0.48
QUEN cover (%)	26.48	19.47	0.5-90
Rock Cover (%)	7.41	12.82	0-80
Senescence (%)	15.75	16.22	0.5-96
Slope (%)	15.94	12.26	0-55
Transect Slope[2] (%)	10.92	9.5	0-50
Site[3]	N/A	N/A	N/A
Community[4]	N/A	N/A	N/A

[1]Calculated as N = cosine(azimuth) x sine(slope) where -1 is most south exposed and 1 is most north exposed

[2]Slope measured along the line of the transect

[3]Santa Rosa Plateau, Lake Skinner, Santa Margarita Ecological Reserve and Tenaja Corridor

[4]Chaparral or Oak Woodland/Grassland

We derived the factor "Community" from the vegetation association categories assigned by crew in the field. Surveyors either selected from the 7 vegetation associations on the datasheet or added new vegetation associations if none of the listed associations matched the survey site, resulting in a total of 22 vegetation associations listed for the 265 transects in this study. The vegetation associations derived from the western Riverside County vegetation map often did not correspond with the vegetation associations identified by crew in the field. We decided to use crew assessments rather than information found in the vegetation map because many points were on the border between two vegetation associations. In these situations, potential mapping error coupled with GPS error resulted in unacceptable uncertainty about the correct vegetation community. Furthermore, we decided to lump the vegetation associations selected by the crew into broader vegetation community categories. All transects that had vegetation associations that included chaparral were placed in the chaparral category while most of the remaining transects were placed in the oak woodland/grassland category. There were 14 transects that were not classifiable in those two categories; these transects were excluded from the analysis.

We used a GLM with quasipoisson errors to determine the effects of position under the canopy on the number of seedlings and saplings observed. In the field, surveyors assigned each seedling or sapling as being located either outside the QUEN canopy, on the edge of the QUEN canopy (from the edge of the canopy to about 1 m inside the canopy), or inside the QUEN canopy (anywhere fully under the canopy besides the edge). We included position as a categorical variable in a GLM model. We used Helmert contrasts to determine the effects of each individual canopy position on number of seedlings.

We originally hoped that specific QUEN individuals could be re-located each year and thus survival of individuals could be tracked through time. We made some effort to match individuals found in 2006 with those found in 2005. However, the comparison was often difficult, particularly on transects with clumped seedlings. While overall survivorship from 2005 to 2006 was not possible to analyze, we did perform Wilcoxon Signed Rank tests in R 2.5.1 to determine if there was a significant change in the number of seedlings and saplings from one year to the next. This test is a non-parametric alternative to the t-test that can be used with paired values. We performed the test separately on seedlings and on saplings. We only used those transects in the analysis that were given a high accuracy rating, indicating that at least 2 of the 3 transect stakes were relocated and that the transect in the 2006 field season was consistent with the map from the 2005 field season. We compared 80 transects using the Wilcoxon Signed Rank test to assess changes in seedling and sapling abundance between 2005 and 2006.

RESULTS

We conducted surveys on 265 transects in 2006. Overall, 29 percent of transects had seedlings, 24 percent had saplings, and 58 percent had adults (Table 2). The number of seedlings per transect ranged from 0 to 88, with a mean of 2.81 seedlings per transect (Figure 2, 4). Of the 76 transects occupied by seedlings, we found a mean of 9.80 and a median of 4.00 seedlings per transect. There were between 0 and 10 saplings per transect, with a mean of 0.44 saplings per transect (Figure 3, 4). Of the 63 transects with saplings, there was a mean of 1.84 and a median of 1.00 saplings per transect. We measured between 0 and 7 adults per transect, with a mean of 0.81 adults per transect. Of the 154 transects occupied by adults, we found a mean of 1.39 and a median of 1.00 adults per transect. We collected data on a total of 745 seedlings, 116 saplings, and 214 adults.

Table 2. Occupancy and abundance of seedings, saplings and adults on transects in 2006.

Site name	Number of transects	Percent with seedlings	Percent with saplings	Percent with adults	Number of seedlings	Mean of seedlings per transect (standard error)	Total saplings	Mean of saplings per transect (standard error)	Number of adults	Mean of adults per transect (standard error)
Lake Skinner	15	13.33%	20.00%	86.67%	37	2.47 (2.14)	5	0.33 (0.21)	19	1.27 (0.23)
Santa Margarita	15	0.07%	13.33%	93.33%	2	0.13 (.13)	5	0.33 (0.27)	26	1.73 (0.27)
Santa Rosa Plateau	183	31.69%	21.86%	49.18%	591	3.23 (0.69)	73	0.40 (0.09)	119	0.65 (0.07)
Tenaja Corridor	52	28.85%	34.62%	71.15%	115	2.21 (1.02)	33	0.63 (0.16)	50	.96 (0.12)
Totals	**265**	**28.68%**	**23.77%**	**58.11%**	**745**	**2.81 (0.53)**	**116**	**0.44 (0.07)**	**214**	**0.81 (.06)**

Three factors came out as significant in the GLM model looking at predictors of seedling abundance on transects (Table 3). Seedlings increased with increased elevation and decreased with increased grass cover. Seedlings were also negatively correlated with chaparral. The model for seedlings explained 11% of the variability in the data. Five factors were significant in the GLM model looking at sapling abundance on transects. Saplings increased with increased elevation and decreased with increased grass cover, more days into the study, more senescence, and a higher degree of northness. The sapling model explained 8% of the variability in the data. For both models, all parameter values were significant to $p < 0.05$.

For both saplings and seedlings, there were significantly more individuals in both the edge and inside positions of the canopy than outside (Figure 5). There was no difference between inside and edge for either age class.

Table 3. Predictors significant ($p < 0.05$) in GLM models of seedling and sapling abundance.

	Seedling Model Parameter Estimate (Standard Error)	Sapling Model Parameter Estimate (Standard Error)
Days Into Study	N/A	-0.00919 (0.00393)
Elevation (m)	0.00519 (0.00242)	0.00239 (0.00143)
Grass Cover (%)	-0.01533 (0.00620)	-0.00736 (0.00334)
Northness*	N/A	-1.87 (0.745)
Senescence (%)	N/A	-0.0172 (0.00782)
Community (Chaparral)*	-1.89 (0.802)	N/A

*northness defined as N = cosine(azimuth) x sine(slope)

**significance of chaparral community instead of oak woodland/grassland

For those transects with 2 years of data collected, there was no significant difference between the number of saplings from 2005 to 2006 ($p = 0.09$). We found a significant increase in seedlings numbers on transects from 2005 to 2006 ($p = 0.02$). On the transects compared in the Wilcoxon rank sum test, 2005 transects had an average of 2.7 seedlings per transect and 2006 transects had an average of 3.69 seedlings per transect (Figure 6).

DISCUSSION

We found variability in the level of recruitment at transects across the study area. Most transects had no seedlings or saplings, but transects with at least some seedlings present averaged almost 10 seedlings per transect. These results are consistent with other studies that have suggested that seedling recruitment takes place heterogeneously across the landscape at places where one year's substantial acorn production combines with favorable rainfall conditions to produce large numbers of seedlings (Principe 2002, Lathrop and Osborne 1991).

In this study, increased grass cover was correlated with decreased numbers of seedlings and saplings. Grass cover can reduce seedling establishment through competition for water resources. Studies have shown that competition with annual grasses and other annual species, which grow rapidly and have shallower roots than perennials, can decrease seedling establishment, growth and survival for several species of oak (Danielsen 1990, Gordon and Rice

2000). Our study did not distinguish between annual and perennial grass species and presumably many study sites contained some of each. Principe (2002) found that QUEN seedlings at mowed sites at the Santa Rosa Plateau generally had a greater chance of survival than those at sites that were not mowed. Abundance of saplings may have been affected by grass in two ways. First, sites with fewer seedlings (due to competition with grasses) have fewer seedlings to grow into saplings. Second, seedlings at sites with more grass cover may have reduced growth and survivorship and therefore fewer survive to become saplings.

Number of seedlings and saplings on transects were also both correlated with increased elevation. Higher-elevation sites may be cooler and retain more moisture. Scott (1991) found that more Engelmann oak woodlands are concentrated above 700 m elevation than expected by a random distribution.

Other important factors identified in the GLM model did not hold consistent for both age classes. The number of saplings was inversely correlated with the degree of senescence in adult trees. We measured senescence on adult trees as an aggregation of leaf and branch loss, averaged across all adult QUEN trees on the transect. One possibility is that trees showing less senescence are growing at sites with better conditions, so there is increased survivorship and recruitment of seedlings to the sapling stage at these sites.

Saplings were negatively correlated with northness, meaning that transects with more southern exposure had more saplings. One reason for this may be that some individuals called “saplings” could have actually been adult hybrids between QUEN and scrub oak. Surveyors in 2005 and 2006 were instructed to include in the survey all individuals that appeared to be QUEN based on leaf morphology and growth habit. Surveyors may have been overly inclusive of oak individuals that were not clearly Engelmann oak, but rather had leaf characteristics intermediate between scrub oak and QUEN. To complicate identification matters further, while scrub oak usually has a shrubby habit, sometimes it grows tree-like and thus is more easily confused with QUEN. Nine individuals marked as saplings on datasheets in 2006 had notes mentioning or questioning their hybrid status. Because surveyors were not explicitly asked to note hybrid status and there was no consistent difference in the data measurements between hybrid and non-hybrid individuals, all saplings, whether possibly of hybrid origin or not, were included in the analysis. It has been suggested that hybrids between QUEN and scrub oak are better at surviving drought than QUEN (Scott 1991). Also, chaparral sites, where hybrids are most likely to be found, are generally more xeric than oak woodland and grassland sites.

Previous work showed more QUEN saplings and large seedlings outside the canopy than under the outer and inner portions of the canopy and more small seedlings in the inner area of the canopy than on the outer area of the canopy and outside of the canopy (Principe 2002). We detected both more seedlings and more saplings on the edge and inside of the canopy than outside of the canopy. These discrepancies may be due to slight differences in our definitions of the three position categories and/or the fact that we did not separate out large and small seedlings for analysis

We found a significant increase in the number of seedlings on transects from 2005 to 2006. Because we collect data in the fall before most newly germinated acorns demonstrate above-ground growth, the youngest seedlings we measure should have initially recruited the previous winter. Interestingly, though winter of 2004-2005 had record rainfall, data show less seedlings in fall 2005 than in fall 2006. This may reflect the fact that recruitment is a factor of both rainfall and acorn production. It is possible that abundant rainfall in winter 2004-2005 caused more acorn production in fall 2005 and thus more seedling production in 2006. When we have more long-term data, we can model seedling and sapling abundance versus rainfall from previous years to examine this relationship. While the number of saplings on transects increased from 33 in 2005 to 46 in 2006 (n = 80), this increase was not statistically significant, and therefore we can not conclude that overall, at the Santa Rosa Plateau, there were more saplings in 2006 than in 2005. Furthermore, because we fear that some recorded "saplings" may actually be adult hybrid shrubs, we are concerned that the number of saplings on transects may be artificially inflated.

Recommendations for Future Surveys

If the identification system implemented in 2006 allows us to relocate individuals from one year to the next, we will be able to make survivorship estimates for each class of individuals. This is important so we can compare the rate of QUEN sapling recruitment to the adult class to the rate of QUEN adult mortality. If such a comparison is not feasible, then at least the survivorship of larger seedlings, saplings, and adults should be analyzed; or, as a last resort, individuals can also be analyzed as size classes.

Based on results of the 2006 effort, we plan to make several changes to the Engelmann oak protocol. We will collect grass cover information separately for annual and perennial grasses to see if annual grasses are more correlated with fewer seedlings than perennial grasses, as has been shown in previous studies. Also, we want to make sure that estimates of grass cover are consistent between observers. We will have observers group transects into more broadly defined vegetation communities rather than vegetation associations because the vegetation associations are too difficult for observers to differentiate between and because the broad-scale differences between coastal sage scrub, grassland, and chaparral may be more important for recruitment than smaller-scale vegetation changes. In order to eliminate days into study as a significant factor, we will randomize the order in which study sites are visited and compress the length of time over which the study is conducted. In order to better understand the reason why transects with highly senesced adult trees had fewer saplings, we will to divide the measure of senescence into separate estimates of branch death and leaf loss. This may show us whether lower numbers of saplings near highly senesced adult trees are related to parent tree health, as indicated by branch death, or by site conditions, as indicated by leaf loss.

One important issue to address is the possible presence of hybrid oak individuals on transects. Surveyors need to be thoroughly trained in all of the traits that separate scrub oak and pure QUEN individuals, including growth habit, leaf coloration, leaf size, hair type and coloration, and leaf margin and acorn cup characteristics (Roberts 1995). Furthermore, surveyors should be asked to record whether each individual fits all of the traits that define QUEN or if it has intermediate traits between QUEN and scrub oak. It should be possible to distinguish between hybrid and pure individuals even when they are young seedlings. This will allow us to determine how extensively, if at all, hybrid individuals have been included in survey data. This will also give us a better idea of where hybridization may be occurring and allow us to investigate these areas further. While the primary focus of this project is to determine the level of recruitment occurring with pure QUEN, there is value to collecting data about hybrid individuals. One long-term question we can evaluate is whether occurrences of hybrid individuals are contained, spreading to areas without pure QUEN stands and/or spreading to areas with pure QUEN.

While we found that several predictors are correlated with seedling and sapling abundance, these predictors accounted for 11% or less of the total variability in each of the GLM models. In order to better establish the factors that lead to seedling establishment and sapling recruitment, we recommend collecting data on acorn production on adult trees surrounding the transect. Acorn data can be collected in late October and early November just before acorn drop (Principe 2002). With a condensed period of data collection, we can collect the acorn data simultaneously with other transect data.

Figure 1. Engelmann oak (QUEN) transects in winter 2006- 2007.

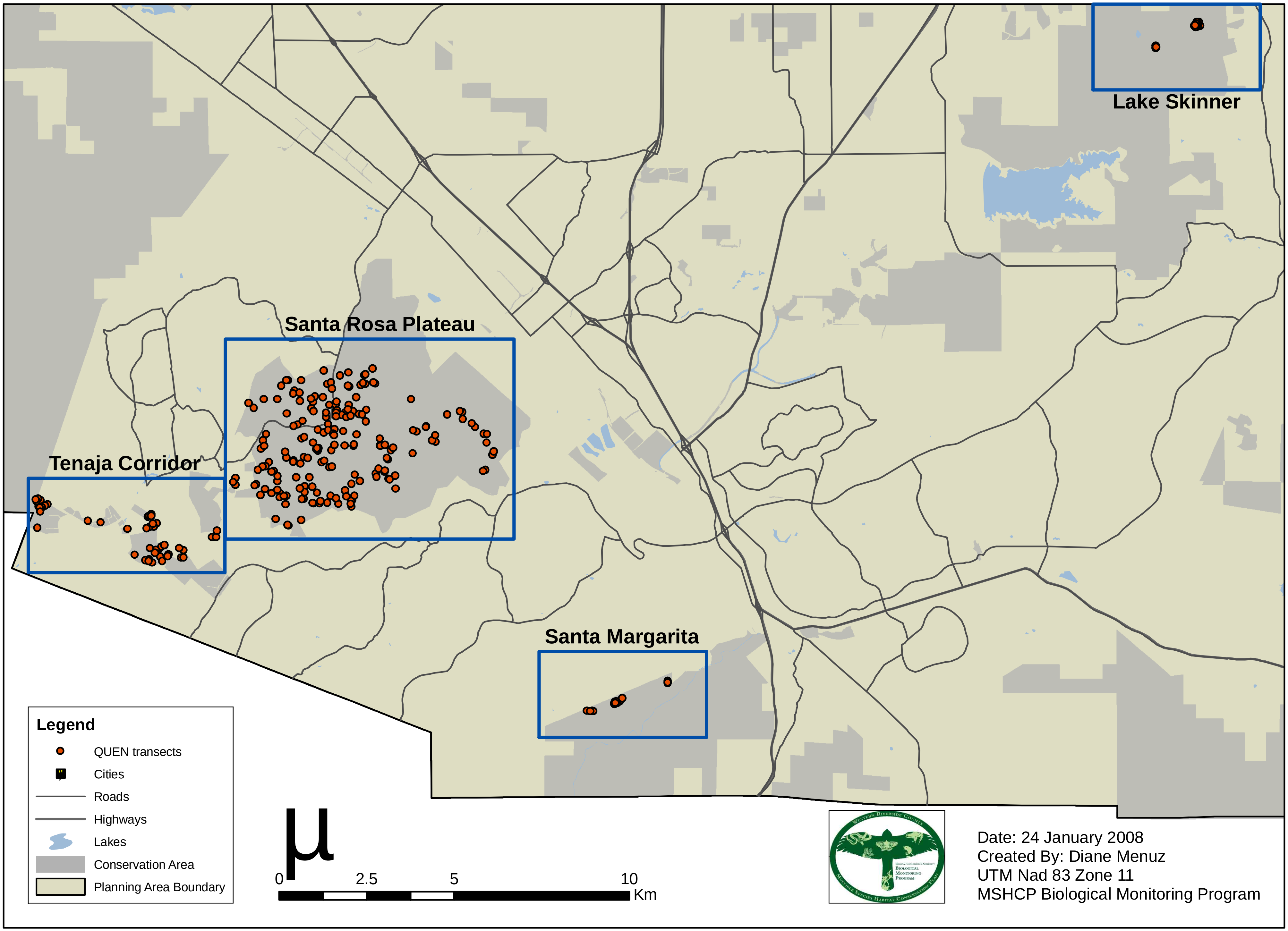


Figure 2. Seedling occupancy and abundance at Santa Rosa Plateau, Tenaja Corridor and Santa Margarita Ecological Reserve.

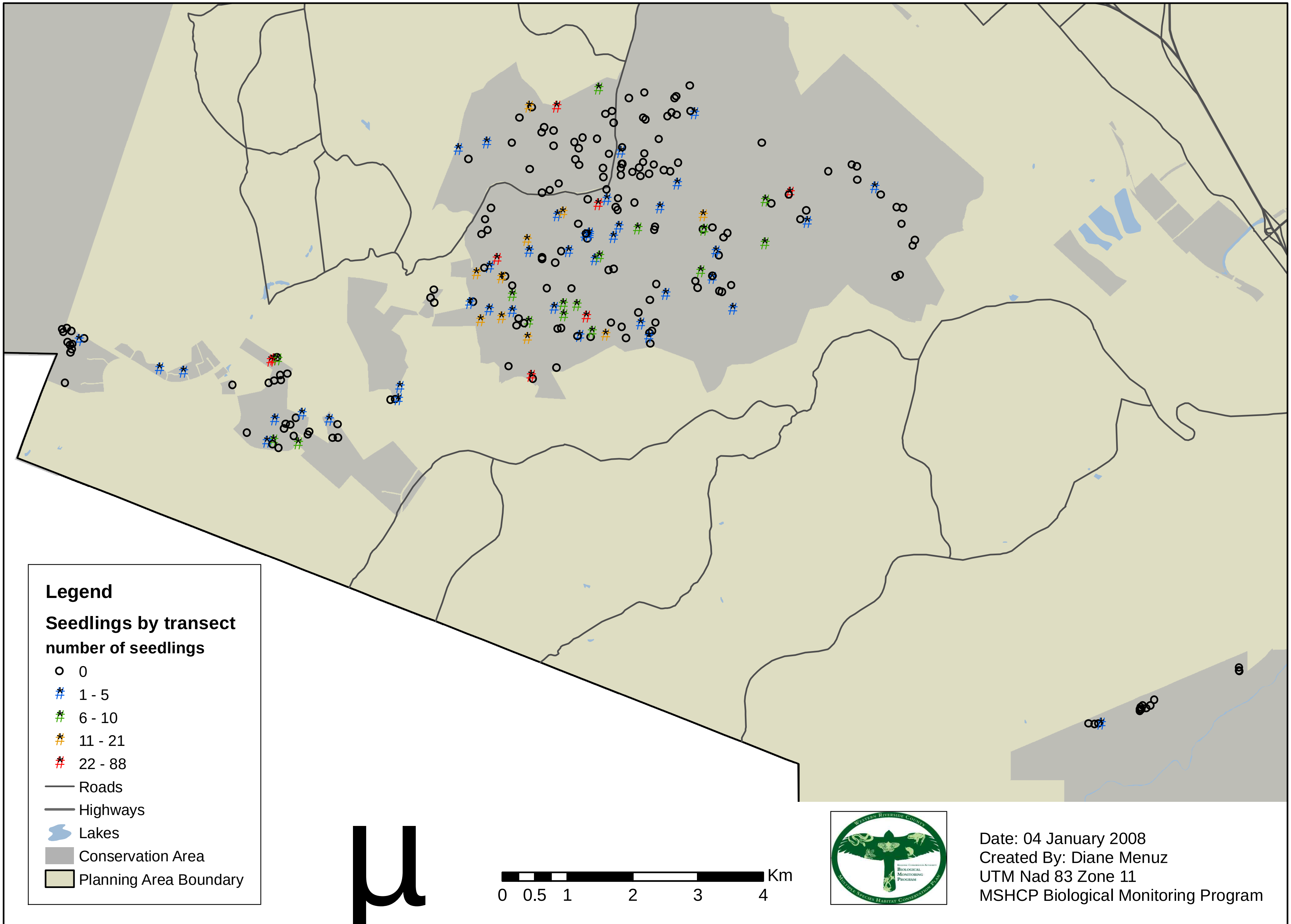
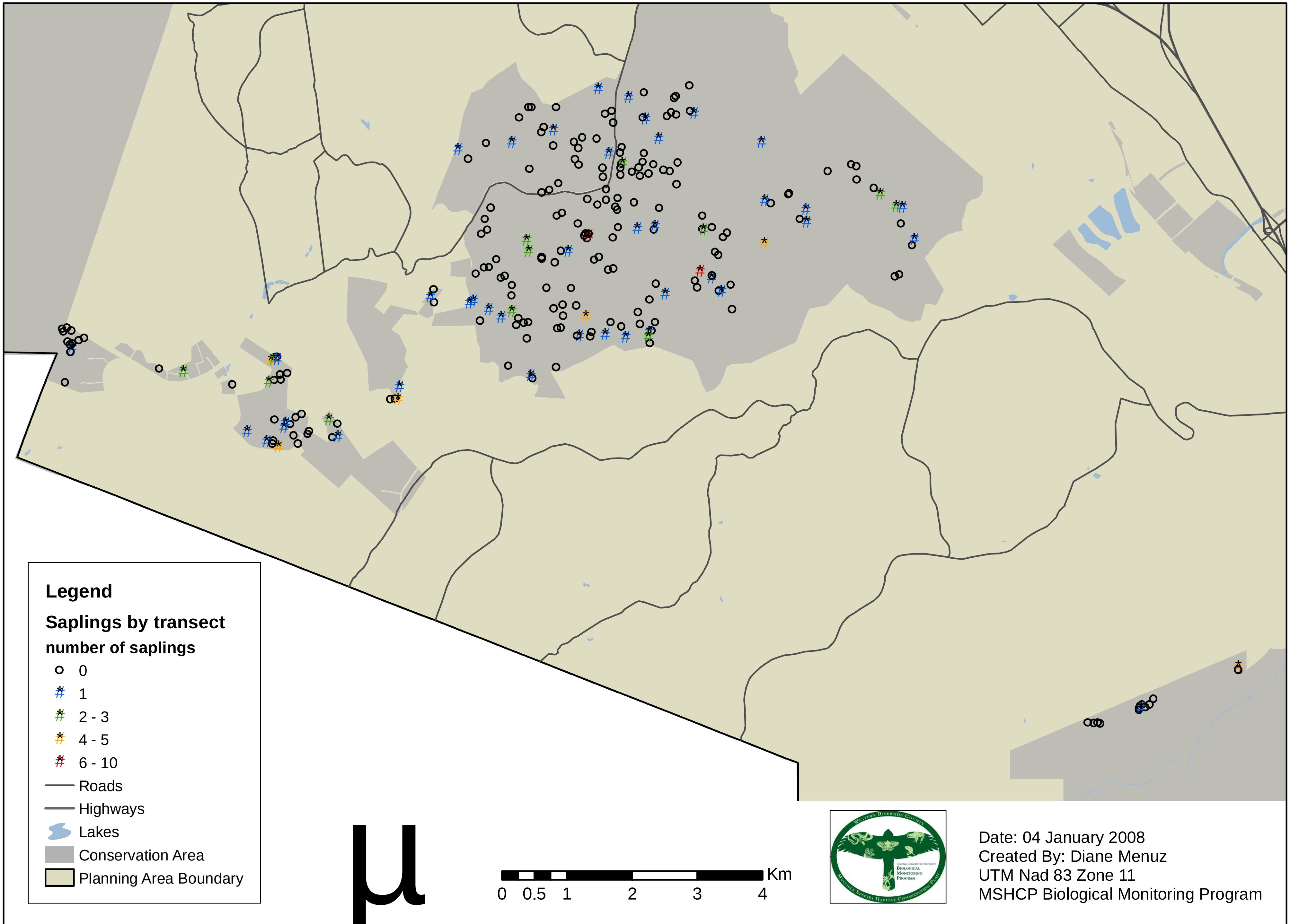


Figure 3. Sapling occupancy and abundance at Santa Rosa Plateau, Tenaja Corridor and Santa Margarita Ecological Reserve.



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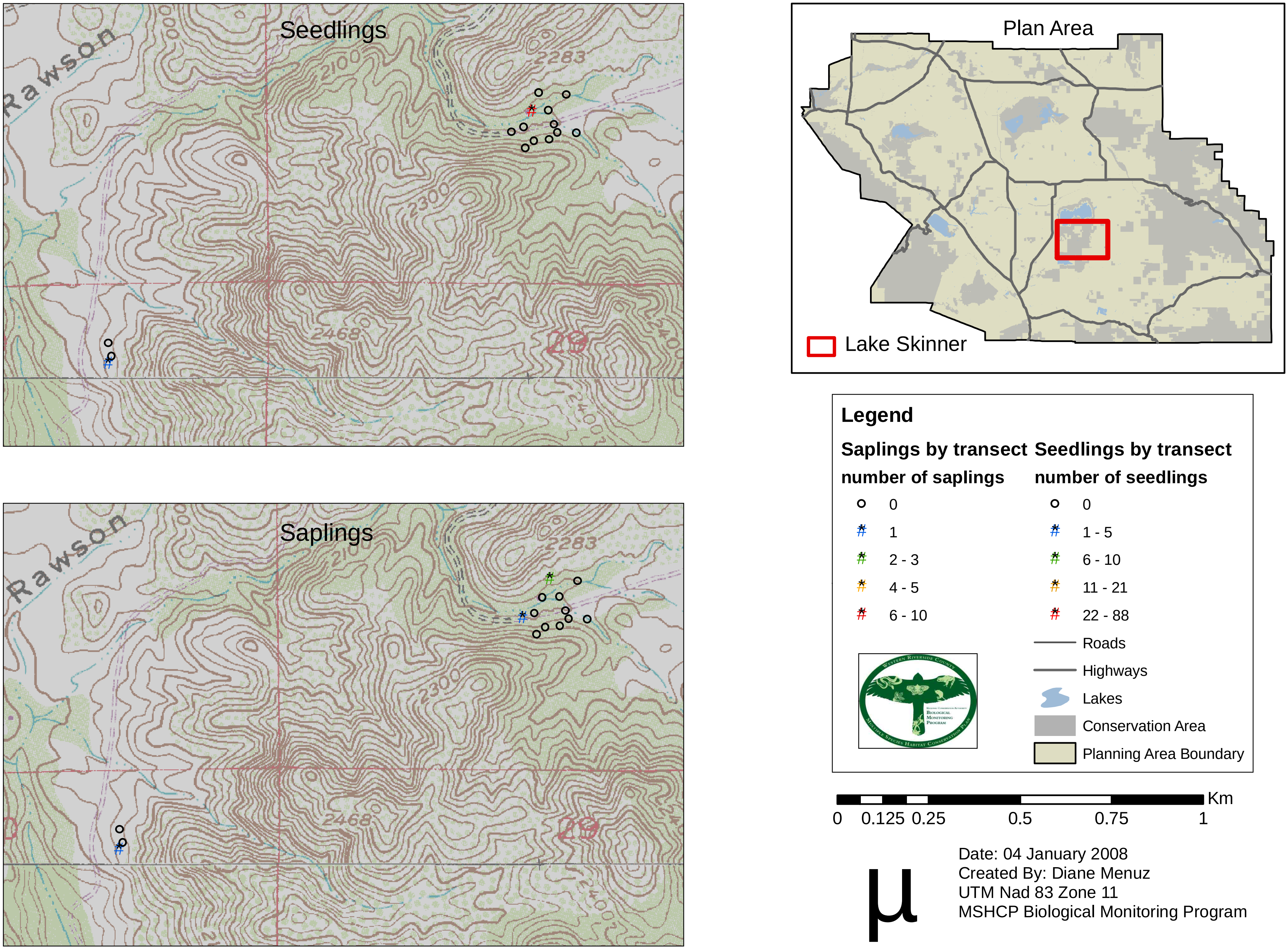
MSHCP Biological Monitoring Program

Figure 4. Seedling and sapling occupancy and abundance at Lake Skinner.



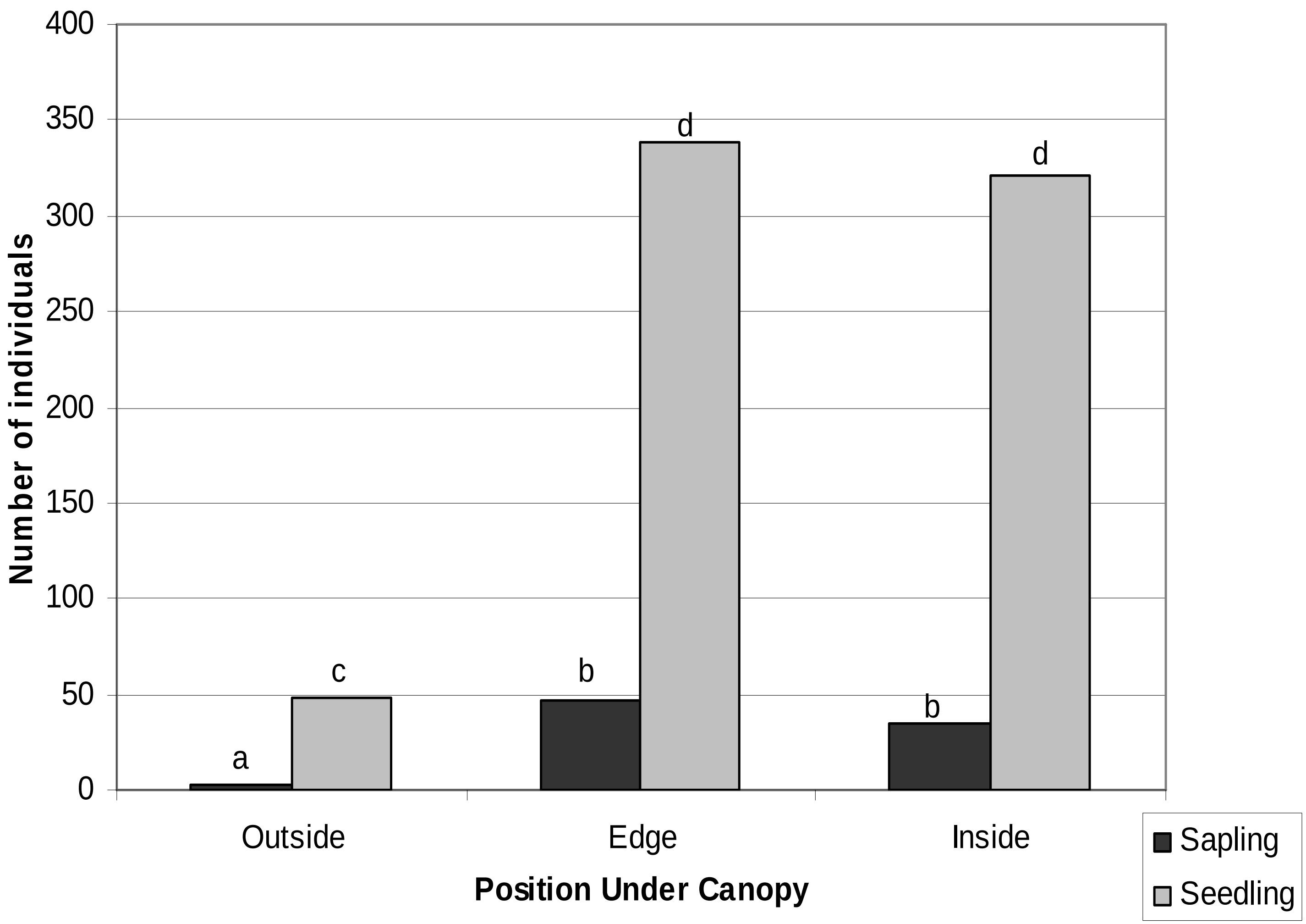


Figure 5. Number of Engelmann oak saplings and seedlings found outside, at the edge and inside adult canopy. Letters above bars indicate that saplings (a, b) and seedlings (c, d) are significantly different (p <.005).

Figure 6. Seedling and saplings found at the Santa Rosa Plateau in 2005 and 2006, at 80 transects that were able to be compared. Letters above bars indicate that seedlings (a, b) were statistically different between years, while saplings (c) were not ($p < 0.05$).

REFERENCES

California Native Plant Society. 2005. Vegetation Alliances of Western Riverside County, California. Final report prepared for the California Department of Fish and Game Habitat Conservation Division. Contract Number P0185404. August 2005 (Revised April 2006). Sacramento, CA

Danielsen, K.C. and W.L. Halvorson. 1991. Valley oak seedling growth associated with selected grass species. USDA Forest Service General Technical Report, PSW-126: 9-13.

Dudek & Associates. 2003. Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP). Final MSHCP, Volumes I and II. Prepared for County of Riverside Transportation and Lands Management Agency. Prepared by Dudek & Associates, Inc. Approved June 17, 2003.

Gordon, D.R. and K.J. Rice. 2000. Competitive effects of grassland annuals on soil water and blue oak (Quercus douglasii) (Fagaceae) seedling emergence and growth. American Journal of Botany, 87: 986-994.

Lathrop, E.W. and C.D. Osborne. 1991. Influence of fire on oak seedlings and saplings in southern oak woodland on the Santa Rosa Plateau Preserve, Riverside County, California. USDA Forest Service General Technical Report, PSW-126: 366-370.

Lathrop, E.W., C. Osborne, A. Rochester, K. Yeung, S. Soret, R. Hopper. 1991. Size class distribution of Quercus engelmannii (Engelmann oak) on the Santa Rosa Plateau, Riverside County, California. USDA Forest Service General Technical Report, PSW-126: 371-376.

Principe, Z. 2002. Factors affecting Engelmann oak (Quercus engelmannii) regeneration. Master’s thesis. San Diego State University.

Principe, Z. 2004. Research study at the Southwestern Riverside County Multi-Species Reserve, unpublished data.

R version 2.5.1. 2007. The R Foundation for Statistical Computing ISBN 3-900051-07-0

Roberts, F. 1995. Illustrated Guide to the Oaks of the Southern California Floristic Province: the Oaks of Coastal Southern California and Northwestern Baja California, Mexico. F.W. Roberts Publications, Encinitas, California.

Roberts, F., S. White, A. Sanders, D. Bramlet, S. Boyd. 2004. The Vascular Plants of Western Riverside County, California: An Annotated Checklist. F.W. Roberts Publications, San Luis Rey, California.

San Diego State University Field Stations Program. 2001. Santa Margarita Ecological Reserve vegetation survey, Online: http://fs.sdsu.edu/kf/maps/maps.php?r=1

Sawyer, J.O. and T. Keeler-Wolf. 1995. A Manual of California Vegetation. California Native Plant Society

Scott, T.A. 1991. The Distribution of Engelmann Oak (Quercus engelmannii) in California. USDA Forest Service General Technical Report, PSW-126: 351-359.

Tyler, C.M., B. Kuhn, F.W. Davis. 2006. Demography and recruitment limitations of three oak species in California. The Quarterly Review of Biology. 81(2): 127-15

Appendix A: Western Riverside County MSHCP Biological Monitoring Program Protocol for Installing New Engelmann oak transects 2006

1. Navigate to the given UTMs along the oak assemblage. If the UTMs are not at a suitable location (i.e. no QUEN around, tons of poison oak, dangerous area), find the nearest QUEN adult and place a green stake with yellow tip at the edge of the canopy. Record the correct UTMs on the datasheet.

2. Calculate a range of compass bearings, record the range on the data sheet (see below). You will be given a list of random compass bearings from which you will choose the first one that falls within the assigned range of bearings. Use a declinated (13°) compass and 50-meter tape to walk 15m out of the canopy and place a green stake with blue tip and then extend the tape 15m into the canopy and place a green stake with red tip for a total transect length of 30 meters. Make sure the stakes line up along the compass bearing. Record in the notes section the direction of the start and end stakes from the middle.

*Note: if the first random compass bearing is not possible (off a steep edge, through dense poison oak) please pick the next random bearing that falls within the assigned range of bearings that would make a safer route and record the corrected bearing on the data sheet.

3. If the UTMs make no sense at all and you can't find any nearby QUEN, do not install the point and report the problem back in the office so that a new random point can be chosen.

4. Now continue as usual with the rest of the survey =)

Calculating Oak angles:

For all new points, there will be an algorithm that will limit randomness to the area that bisects the edge of the tree canopy. No more tangential lines.

For each new point, once the edge has been located,

1. measure the direction of the line parallel to the edge in both directions.
2. On a piece of scrap paper, figure the difference between those two lines, in degrees.
3. Next Take 10% of that difference
4. Reduce both sides by that number of degrees.
5. Now that you have narrowed your approach, you can look down the list of random numbers and find the first unused number that falls within your range.

Appendix B: Western Riverside County MSHCP Biological Monitoring Program Protocol for Engelmann Oak Recruitment Data Collection 2006

1. Re-locate transect stakes (there should be 3) using the GPS coordinates. The center stake should be close to the UTMs and located along the canopy edge (yellow tip). There should also be a stake at either end of the transect (blue tip = start of transect, red tip = end of transect). If you can not locate last year's stakes, use the last year's oak transect map and compass direction to best align this years' transect. From the center point, the transect should extend 15m in either direction. This will be 15m into the oak assemblage, and 15m out. A 50m tape will be used. If the any of the stakes are missing, please replace with new stakes and record on datasheet the status of the stakes at the bottom of the datasheet. Also record the transect accuracy. 1 indicates perfect or nearly perfectly alignment. 2 indicates so-so alignment and a 3 indicates that last year's data should not be compared with this year's data because the alignment is off.

* Note: There was variability in the compass bearing used last year due to declinated and un-declinated compasses. We are using bearings declinated to 13º so please record the corrected bearing on the datasheet. Also record corrected UTMs if the GPS is greater than 5 meters off the middle stake's location.

2. From the center point, use a clinometer to measure the slope (%) of the transect. Use a compass to measure the aspect (degrees) of the oak assemblage. Then measure the slope of the aspect direction (%). Record these values on the data sheet.

3. Estimate the amount of senescence (%) of the canopy of the QUEN being surveyed and any other nearby QUEN that is significantly influencing the transect (covering >20% of transect). This estimate should be a percentage that reflects the area that has lost or is losing its leaves, including major dead branches and is a reflection of canopy health and vigor.

4. The surveyor will walk the transect from beginning (0) to end (30). The beginning of the transect starts outside of the oak assemblage and the end of the transect is inside the canopy.

*Note: Last years' field notes may indicate which direction was the start and end points, use these instead.

A search image should be developed to survey a belt 2.5m on either side of the transect. Within this belt, every Engelmann oak should be recorded and mapped.

5. For every oak encountered record:

A) I.D. (use A-Z and then AA, BB, CC, etc.)

B) Distance along the transect that it was encountered (m)

C) Whether it was a seedling (<1cm), sapling (1-10cm), or adult (>10cm)

D) Whether the oak was tall enough to join the canopy. A positive response is justified if any of the individual's branches/leaves are at or above the level of the lowest average canopy level for that area within the assemblage; negative, if the leaves are beneath the canopy level.

E) The relative position of the oak to the canopy edge (I = inside canopy, E= edge of canopy, O = outside of canopy). Edge encompasses an approximately 1 m swath from the extreme edge of the canopy to 1 m into the interior. Inside is anything else inside the canopy and outside is anything fully outside of the canopy.

6. For every seedling and sapling encountered, measure the basal diameter (mm) using digital calipers and the height (cm) using the meter stick. Basal diameter should be taken at the base of the stem and for larger saplings at the highest point of emergence for those trees emerging on uneven ground.

7. For every adult and sapling that is tall enough, measure the diameter at breast height (dbh, in cm). Breast height is defined as 4.5 feet (1.37m) above the forest floor on the uphill side of the tree. This measurement is measured off of the highest ground level at the base of the tree for those on uneven surfaces. Trees that fork at dbh, measure just below the fork.

* Note: For trees with multiple trunks: The dbh should be the sum of the dbh's of the many trunks. These should be entered as individual measurements in the notes column, separated by commas. In the "notes" column, make note that there are multiple stems.

8. As you record the measurements of each oak, simultaneously and as accurately as possible, map each oak along the 2 page transect diagram using its I.D., starting at 0 meters to 30 meters (datasheets 2 and 3).

9. As you map, tag any saplings (>1cm dbh) that you see that may help identify the transect for future years. Label them with the transect number and the ID number (i.e. 128-B). Also, record the distance from the metal tag to the transect line in the notes column for that individual.

10. Now that you're very familiar with the area, pick an Engelmann Vegetation Association / what are the dominant species associated with the QUEN assemblage.

11. Next, record the percent cover of grasses/annuals, rocks and QUEN. The percent cover reflects the area within the transect that is covered/shaded by either foliage or rocks. 1% cover = 1.5 m^2 or about 1.2 m x 1.2 m square of the transect area. It is very rare for a transect to be 100% of any one category, also the grasses/annuals cover plus the rock cover cannot exceed 100%.

12. When you are done collecting data for the transect, compare your results with last year's data. On the copy of last year's datasheet, create an ID column and fill in any ID information that you can figure out. For example, if you labeled an adult QUEN as "C", write next to their adult QUEN "C". If there were QUEN recorded last year that you do not see this year, take another look around. If there is another seedling in the same spot that could have been misidentified as QUEN, make a note of it on both datasheets by labeling it with a letter you have not yet used and writing "possible mis-I.D. from last year" in the notes section of this year's datasheet.

Appendix C: Engelmann Oak Recruitment Survey Form

Page 1 of 4

ENGELMANN OAK RECRUITMENT

Name	Date	Site # Bearing:
UTME ____ ____ ____ ____ ____ ____		UTMN ___ ___ ___ ___ ___ ___ ___
Corrected UTME ____ ____ ____ ____ ____ ____		Corrected UTMN ___ ___ ___ ___ ___ ___ ___
Estimate of Senescence:		Corrected Bearing:
TransectSlope:_____% Aspect:_____° Slope:_____%		Position: I = Inner E = Edge O = Outer

I.D.	Oak Location (m)	Seedling (<1 cm)	Sapling (1-10cm)	Adult	Joined Canopy?	Position (I, E, O)	Basal Diameter (mm)	Height (cm)	DBH (cm)	Notes / Dist. to Tag

Engelmann Vegetation Associations:	Check One	
QUEN / Toxicodendron diversilobum / Grass		Grass Cover : ____________%
QUEN - Q. agrifolia / Tox. diversilobum /Grass		
QUEN / Chapparral		Rock Cover : ____________%
QUEN / Annual grass-herb		
QUEN - Q. berberidifolia		
QUEN - Q. agrifolia		QUEN Cover : ____________%
QUEN - Q. agrifolia - Platanus racemosa		
Other (please specify):		

Were there stakes present? Where?

Engelmann Oak Recruitment Survey Form Page 2 of 4

ENGELMANN OAK RECRUITMENT

Name:	
Date:	Transect:

*Start at bottom of sheet

Non-oak
Tagged Item: Label w/ I.D.

30	
29	
28	
27	
26	
25	
24	
23	
22	
21	
20	
19	
18	
17	
16	

* Please Map Tagged items as well and record on the data sheet

Engelmann Oak Recruitment Survey Form Page 3 of 4

ENGELMANN OAK RECRUITMENT

Name:	
Date:	Transect:

*Start at bottom of sheet

Non-oak Tagged Item: Label w/ I.D.

15	
14	
13	
12	
11	
10	
9	
8	
7	
6	
5	
4	
3	
2	
1	

* Please Map Tagged items as well and record on the data sheet

Engelmann Oak Recruitment Survey Form Page 4 of 4

ENGELMANN OAK RECRUITMENT

Name:	Date:
Compass declinated: Yes No	Transect:

SITE MAP Include bearing and distance from at least two of the transect stakes to at least two different permanent/semi-permanent objects (ie tree, bench, signpost, fence)

Notes about access and identification of site