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

Engelmann Oak
(*Quercus engelmannii*)
Recruitment Survey Report

23 March 2011

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

LIST OF APPENDICES

NOTE TO READER:

This report is an account of survey activities conducted by the Biological Monitoring Program for the Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP). The MSHCP was permitted in June 2004. The 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.

MSHCP reserve assembly is ongoing and it is expected to take 20 or more years to assemble the final Conservation Area. The Conservation Area includes lands acquired for conservation under the terms of the MSHCP and other lands that have conservation value in the Plan Area (called public or quasi-public lands in the MSHCP). In this report, the term “Conservation Area” refers to the Conservation Area as understood by the Monitoring Program at the time the surveys were planned and conducted.

We would like to thank and acknowledge the land managers in the MSHCP Plan Area, who in the interest of conservation and stewardship facilitate Monitoring Program activities on the lands for which they are responsible. A list of the lands where data collection activities were conducted in 2010 is included in Section 7.0 of the Western Riverside County Regional Conservation Authority (RCA) Annual Report to the Wildlife Agencies. Partnering organizations and individuals contributing data to our projects are acknowledged in the text of appropriate reports.

While we have made every effort to accurately represent our data and results, it should be recognized that data management and analysis are ongoing activities. 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 2010 Botany Program Lead, Jeff Galvin. 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 RCA. Further information on the MSHCP and the RCA can be found at www.wrc-rca.org.

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INTRODUCTION

Engelmann oak (*Quercus engelmannii*) has the smallest distribution of all oak species found in California and occurs from eastern Los Angeles County to northwestern Baja California (Scott 1991, Roberts 1995). Riverside County accounts for approximately 6% of the remaining Engelmann oak populations in California (Scott 1991). The largest occurrence of Engelmann oak in western Riverside County occurs at the Santa Rosa Plateau Ecological Reserve (SRP), and stretches along undeveloped areas in a narrow band west through the Tenaja Corridor to the eastern boundary of the San Mateo Canyon Wilderness Area in the Cleveland National Forest. There are additional populations at the Santa Margarita Ecological Reserve (SMER) and the Southwestern Riverside County Multi-Species Reserve (MSR), with smaller occurrences at the Potrero Unit of the San Jacinto Wildlife Area (Potrero), Sage, the Palomar Mountains, San Mateo Canyon Wilderness, and Estelle Mountain.

Species-specific conservation objective 3 for Engelmann oak as listed in the Western Riverside County MSHCP states that recruitment, as measured by the continuous presence of seedlings or saplings over a 5-year period, should occur at 80% or more of the known populations within the Conservation Area (Dudek & Associates 2003). However, production of seedlings and saplings is often not a limiting factor in the regeneration of oak stands; rather, overgrazing, exotic grass presence, altered fire regimes, and resource competition hinder this process (Bartolome et al. 1987; Lathrop and Osborne 1990, 1991). Therefore, we can more informatively track whether or not successful regeneration of Engelmann oak populations is occurring by quantifying change in abundance of individual age classes through time, as opposed to using a presence/absence metric that cannot capture replacement of senescing individuals or contraction/expansion of local populations.

The Biological Monitoring Program has documented Engelmann oak recruitment on 94 of 224 plots (42%), using 30 m x 5 m belt transects, over the past 3 years (see *Western Riverside County MSHCP Biological Monitoring Program Engelmann Oak Recruitment Survey Reports 2007 – 2009* available at http://www.wrc-rca.org/library.asp). While the previous survey method provided useful information about factors affecting oak recruitment, time investment per sampling unit (60 to 120 minutes) prohibited the sample size required to capture natural variation in oak abundance across the landscape. We describe here an alternative sampling design, population sub-sampling, that uses circular plots to substantially increase our sample size where large Engelmann oak populations occur (i.e., SRP and MSR), while greatly decreasing the time requirement per sampling unit (<20 minutes). We also describe a systematic survey method for monitoring abundance of seedlings and saplings where oak populations are small enough to survey the entire population (i.e., the Estelle Mountain Reserve, Potrero, and Sage).

Currently, many pathogens and insects, including the Golden Spotted Oak Borer (GSOB), are adversely affecting oak populations throughout Southern California. While current research indicates that GSOB are not causing damage to Engelmann oaks, coast live oaks (*Quercus agrifolia),* a common and co-occurring species, are a primary target for infestation (Coleman 2009). Pathogens, such as *Diplodia corticola,* are also contributing to coast live oak mortality throughout the Plan Area, including at the Santa Rosa Plateau (Eskalen 2010). Documenting evidence of pathogen and insect infestation across the

Conservation Area may aid in future management decisions as early detection of threats such as these are key to minimizing damage.

We began implementing a major revision of the study design in the fall and winter of 2010 – 2011 at 2 sites within the Plan Area, SRP and MSR. Our initial efforts focused on determining an appropriate sample size to capture natural variation in seedling, sapling, and mature oak abundance across the landscape. This two-part effort will continue in the fall and winter of 2011-2012. Our specific goals and objectives in winter of 2010 – 2011 were as follows:

Goals and Objectives

1) Quantify Engelmann oak recruitment at SRP and MSR.
   a) Use a Generalized Random Tessellation Stratified (GRTS) design to distribute circular plots throughout the survey sites.
   b) Record seedling and sapling abundance within each sampling station.
2) Quantify Engelmann oak recruitment at outlying populations.
   a) Systematically survey populations and record seedling and sapling abundance.
3) Quantify the health of adult oaks throughout survey sites.
   a) Record adult oak abundance within each sampling station.
   b) Estimate percent leaf loss from fully foliated trees.
   c) Look for signs of disease or damage to adult trees.

METHODS

Protocol Development

Based on the results of the previous Engelmann Oak recruitment surveys we determined that an increase in overall sample size and in the spatial size of sampling stations was necessary to capture the highly variable distribution of oak recruitment across the landscape. In order to achieve this goal, we decreased the time commitment per plot by eliminating all environmental covariates (grass cover, ground cover, and canopy cover), size measurements (diameter at breast height, basal diameter, and height) and some health estimates (acorn abundance, branch loss, and health). In general, analysis of these data did not lead to a better understanding of the factors affecting Engelmann oak recruitment or efficiently help meet the stated species objective. In addition, we determined that permanently marking plots and individuals was prohibitively invasive. Instead, we decided to relocate plots only using handheld GPS units with enhanced position accuracy (typically 3 m or less). To decrease the possible variation in plot location across years and minimize edge effects, we sampled circular plots (30-m diameter) instead of belt transects (30 m x 5 m).

Personnel and Training

Prior to the start of oak surveys, all field personnel participated in an office-based training. During this training, surveyors received an overview of the Engelmann oak recruitment project to date. Surveyors also participated in a field-based training session during which they were shown examples of all locally common adult oaks and, if possible, their seedlings and saplings. Once everyone was comfortable identifying oaks and understood the field procedure, surveyors divided into teams of 2 to set up and sample oak plots. At least 2 different teams sampled each plot. After synchronizing Personal Digital Assistants (PDAs) which we used to collect data, we queried the database to determine if any major inconsistencies existed between teams that sampled the same plots.

After completing the oak training, observers were able to differentiate between the seedlings of Engelmann oaks, Engelmann oak/scrub oak hybrids, scrub oaks (*Quercus berberidifolia*), and coast live oaks (*Quercus agrifolia*). Additionally, observers were able to estimate percent leaf loss for adult Engelmann oaks. The California Department of Fish and Game or the Regional Conservation Authority funded Biological Monitoring Program personnel. Biologists conducting Engelmann oak surveys in 2010 included:

- Jeff Galvin (Project Lead, Biological Monitoring Program)
- Karyn Drennen (Biological Monitoring Program)
- Ashley Ragsdale (Biological Monitoring Program)
- Betsy Dionne (Biological Monitoring Program)
- Masanori Abe (Biological Monitoring Program)
- Lynn Miller (Biological Monitoring Program)
- Rose Cook (Biological Monitoring Program)
- Jonathan Reinig (Biological Monitoring Program)
- Ashley Ragsdale (Biological Monitoring Program)
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- Lauren Ross (Biological Monitoring Program)
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- Julie Golla (Biological Monitoring Program)
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- Laura Magee (Biological Monitoring Program)
- Michael Robinson (Biological Monitoring Program)
- Sloane Seferyn (Biological Monitoring Program)
- Samantha Treu (Biological Monitoring Program)
- Tara Graham (Biological Monitoring Program)
- Elise Hinger (Biological Monitoring Program)

Study Site Selection

Population Sub-sampling

We defined the survey area at the SRP to be all areas showing Engelmann oak vegetation associations in the 2005 Geographic Information System (GIS) vegetation map of western Riverside County, from the eastern boundary of the Santa Rosa Plateau Ecological Reserve (SRPER) to the eastern boundary of the San Mateo Canyon Wilderness Area (CDFG et al. 2005) (Table 1). This area includes portions of Tenaja and the Cleveland National Forest (CNF). Sawyer and Keeler-Wolf (1995) define vegetation series by the dominant or co-dominant species in the overstory of vegetation stands, and 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 grasses, poison oak (*Toxicodendron diversilobum*) and/or annual forb species.

Table 1. Vegetation associations containing Engelmann oak populations at Santa Rosa Plateau, with number of sampling stations (n), area (ha), and percent total area of each Engelmann oak association.

Vegetation Association	*n*	Area	Percent of Total Area
Q. engelmanii/ Q. agrifolia/ Artemisia californica	2	1	0.15
Q. engelmanii/ Q. berberidifolia	89	81	12.20
Q. engelmannii/ Chaparral	47	50	7.53
Q. engelmannii/ Grass	188	155	23.34
Q. engelmannii/ Q. agrifolia	65	70	10.54
Q. engelmannii/ Q. agrifolia/ *Toxicodendron diversilobum*/ Grass	313	274	41.27
Q. engelmannii/ *T. diversilobum* / Grass	6	7	1.05
Q.engelmanii/ Q. agrifolia/ Platanus racemosa	31	28	4.23
Total	741	664	100.00

We used Arc GIS v.9.3 (ESRI 2009) to buffer the targeted vegetation associations at SRP by 15-m to prevent any sampling stations from extending beyond the boundary of the Conservation Area or onto paved roads. We also removed all areas that required more than 100-m of hiking through chaparral to access. At the SRP these areas accounted for 89 ha (< 12%) of the potential survey area. We used the "spsurvey" package (Kincaid 2009) of the R statistical program v. 2.5.1 (R Development Core Team 2007) to distribute points following a Generalized Random Tessellated Stratified (GRTS) sampling design. GRTS designs create a spatially balanced distribution of samples that lead to more uniform coverage of patchy landscapes than a truly random sample, while addressing bias resulting in autocorrelation among errors associated with regular sample distributions (Theobald et al. 2007). The GRTS design also allows addition and subtraction from the sample size without adversely affecting the spatial balance.

Because of the large geographic separation of the populations at MSR, we distributed sampling stations independent of the larger population at the SRP. The CDFG et al. (2005) vegetation map does not show Engelmann oak vegetation associations at MSR, but other researchers (Principe 2004) have marked locations of individual adult trees. We used data from Principe (2004) to delineate 2 distinct areas with Engelmann oak at MSR covering 3-ha. We distributed transects so they were at least 15-m from a paved road and the boundary of the Conservation Area.

Systematic Surveys

We based the survey areas for Sage, Potrero and Estelle Mountain on recently documented occurrences queried from the MSHCP Rare Plant Database. Each site contained 1 survey area. We did not include any occurrences in the immediate vicinity of the MSR and SRP survey sites or at the Santa Margarita Ecological Reserve (SMER). In addition, we excluded the known occurrences in San Mateo Canyon and the Palomar Mountains because they are prohibitively far from roads and maintained trails.

Plot/Survey Locations

Population Sub-sampling

We distributed 1000 initial sampling points at SRP and identified an additional 500 points to draw from in case we needed to replace inaccessible or overlapping points, or increase sample size. To create the sampling stations, we buffered each point 15-m to delineate a circular plot with a diameter of 30 m (area = 706 m^2). Of the original 1000 sampling stations, we replaced 43 because they overlapped with adjacent units. In addition, due to the larger-than-anticipated time commitment per sampling unit, we decreased the sample size to 741 after the first 2 weeks of surveys. At MSR, we distributed 10 initial sampling points and identified an additional 5 points to draw from in case we needed to increase the sample size or replace sampling stations. Of the original 10 sampling stations, we removed 1 because it overlapped an adjacent sampling unit. We replaced this sampling unit with the next one distributed within the additional 5 points.

Systematic Surveys

The 3 survey sites captured the canopy of all adult Engelmann oaks within the occurrence, as well as a 3-m buffer around the canopy. According to Osborne (1989), Engelmann oak seedlings are not commonly found more than 10 ft beyond the drip line of an adult tree.

Survey Methods

Population Sub-sampling

Surveyors recorded all Engelmann oak and hybrid individuals (seedlings, saplings and adults) with at least 50% of their basal stem located within the sampling unit. Based on Muick and Bartolome (1987), we defined seedlings as individuals with a basal diameter of <1 cm, saplings as individuals with a basal diameter of 1 cm to <10 cm, and adults as individuals with a basal diameter ≥10 cm (see also Lathrop and Osborne 1991; Principe 2002). We used size rather than age for classifying oaks because of the ease of taking measurements. In addition, mortality risks and reproductive behavior are often size-dependent (Tyler et al. 2006). Surveyors recorded hybrids between adult Engelmann oak and scrub oak as 1 of 2 types based on morphological characteristics: either more closely related to Engelmann oak (H1), or more closely related to scrub oak (H2). We developed a guide with photographs of different leaf types to aid crews in tree identification while in the field. For seedlings and saplings, surveyors did not differentiate between hybrid types; instead, they determined if an individual was closer to a pure Engelmann (Pure) or a hybrid (Hybrid). If a surveyor was unable to classify an individual with confidence, the Botany Program Lead revisited the sampling station to make a final determination.

To assess the overall health of the Engelmann oak woodland within the survey area, surveyors estimated the crown density of all adult trees. Two surveyors estimated the percent defoliation from a fully foliated tree while standing 90º apart and between one-half to 1 tree length from the trunk of the tree (Zarnoch et al. 2004). A healthy individual received a rating near 0% while unhealthy trees received higher percentages. Surveyors used a photographic guide depicting varying degrees of defoliation to aid in arriving at an accurate percentage.

Surveyors averaged their estimates to reach a final value. Surveyors also used a photographic guide to check all Engelmann oak and coast live oak located within the sampling stations for signs of insect or pathogen infestation. Specifically, surveyors looked for GSOB exit holes, bleeding, cankers, branch loss, and scarring.

Systematic Surveys

Surveyors systematically surveyed the entire extent of each survey location. Surveyors followed the protocol for the population sub-sampling surveys.

Data Analysis

We examined plot data for each survey site separately, using R v.2.10.0 (R Development Core Team 2007) to perform all statistical analyses. We did not include H2 adults in any analysis because of the difficulty in separating them from scrub oak. In addition, we grouped H1 and pure adults, hybrid and pure seedlings, as well as hybrid and pure saplings. For all variables, we used the “total.est” function of the “spsurvey” package to calculate the mean, standard error, and 95% confidence intervals using a local variance estimator. In addition, we calculated estimates by geographic location and vegetation association for the 3 sites comprising SRP: SRPER, Tenaja, and CNF.

Because saplings represent a later stage of development and have a better chance of reaching the canopy, we believe sapling abundance is a better indicator of successful oak regeneration at a given site than seedling abundance. We calculated ratios of saplings to adult trees (S:T) across each survey site and vegetation community. Following Muick and Bartoleme (1987), we placed them into 1 of 4 broad categories: 1 = S:T ≥ 1:10; 2 = S:T between 1:10 and 1:2; 3 = S:T between 1:1 and 1:2; 4 = S:T ≤ 1:1.

We ran Shapiro-Wilk tests to determine normality for each variable, including and excluding plots with null data and, when appropriate, ran single-sample power analyses to quantify our ability to detect changes in measured parameters. In cases where we determined power analyses inappropriate, we plotted the mean and confidence intervals of each variable from a sample size of 2 to 741 to evaluate the efficiency of each sample size.

RESULTS

We surveyed from October 26th through December 15th 2010, taking a total 35 survey days (178 surveyor-days) to complete all 741 plots at SRP. The MSR survey site and each outlying population required 1 day to survey. On average, we completed 8.38 sampling stations per team per day, with a range from 1 to 18.

For the SRP site, we calculated mean abundances of adults, saplings, and seedlings per plot (Table 2; Figures 1 - 6). Across the whole site, we calculated a sapling to adult ratio of 1:1.86 that falls within the 3rd ratio class. Based on the results of the Shapiro-Wilk normality test, we determined that data for all variables were not normally distributed ($p <$ 0.001) and therefore inappropriate for power analyses. Plots depicting mean abundance of juveniles (seedling, sapling) across all sample sizes showed high variability within the first 200 plots, followed by a gradual tightening of confidence intervals and stabilizing of mean values (Figure 7, Figure 8). Values for adult abundance quickly stabilized within the first 200 plots and stayed relatively constant throughout the remaining 541 plots (Figure 9).

Table 2. Mean abundance (95% CI) for Engelmann oak, seedlings, saplings and adults stratified by ownership (site) and vegetation association.

Site	Vegetation Association	Adults	Seedlings	Saplings
SRP	ALL (*n* = 741)	1.65 (0.02)	6.95 (0.80)	0.89 (0.07)
SRPER	ALL (*n* = 609)	1.56 (0.06)	7.79 (0.97)	0.88 (0.08)
Tenaja	ALL (*n* = 51)	3.78 (0.54)	3.18 (0.80)	1.78 (0.27)
CNF	ALL (*n* = 81)	1.05 (0.15)	3.02 (0.70)	0.33 (0.07)
ALL	*Quercus Engelmanii*/ *Q. agrifolia*/ *Toxicodendron diversilobum*/ Grass (*n* = 319)	1.55 (0.08)	10.12 (1.66)	0.96 (0.12)
ALL	*Q. Engelmanii*/ Grass (*n* = 188)	2.41 (0.17)	7.05 (1.26)	1.32 (0.14)
ALL	*Q. Engelmanii/ Q. berberidifolia* (*n* = 89)	0.66 (0.14)	2.10 (1.53)	0.27 (0.10)
ALL	*Q. engelmannii*/ Chaparral (*n* = 47)	1.43 (0.24)	1.68 (0.78)	0.79 (0.23)
ALL	*Q. engelmannii*/ *Q. agrifolia*/ *Platanus racemosa* (*n* = 31)	1.84 (0.35)	3.35 (2.16)	0.48 (0.22)

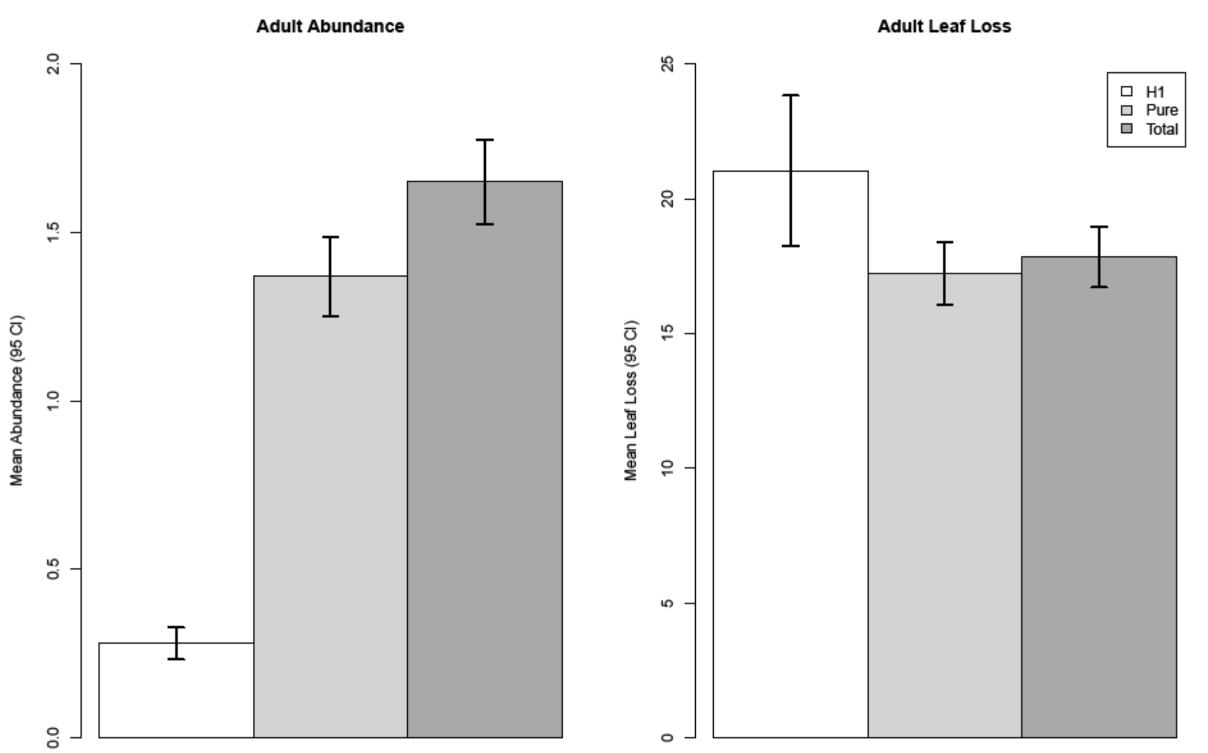

Figure 1. Left: Mean abundance (95% CI) of adult Engelmann oaks at SRP. Right: Mean percent leaf loss (95% CI) of adult Engelmann oaks at SRP.

Values for the 3 sites comprising the SRP (SRPER, Tenaja, and CNF) differed from those based on the pooled data set (Table 2). At Tenaja, we found higher sapling abundance, lower seedling abundance, higher adult abundance, and lower total recruitment. At the SRP, we found lower adult abundance as well as higher seedling abundance. Finally, at CNF, we found lower values for all variables. At CNF and Tenaja, we observed S:T ratios skewed more toward adult trees; however, at SRPER, we observed a ratio similar to that observed for the whole survey site.

When we evaluated the SRP data based on the 5 vegetation associations, values differed greatly from those based on the entire data set. In general, estimated mean values of seedling and sapling abundance were highest within the Q. *engelmannii*/*Q. agrifolia*/*Toxicodendron diversilobum/*Grass and *Q. engelmannii*/Grass communities and far exceeded values based on the entire dataset. Except for the largest value in *Q.* engelmannii/grass and the smallest in *Q.* engelmannii/*Q. berberidifolia*, calculated values for adult abundance were similar to the entire dataset (Table 2).

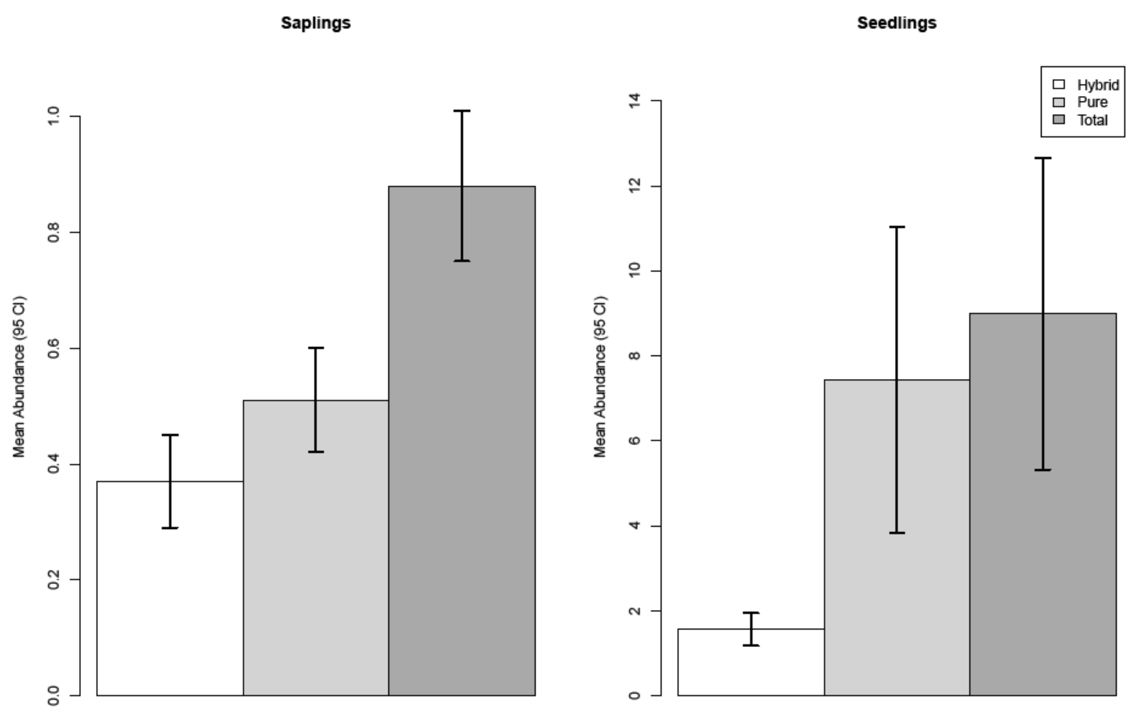

Figure 2. Left: Mean abundance (95% CI) of Engelmann oak saplings at the SRP survey site. Right: Mean abundance (95% CI) of Engelmann oaks seedlings at the SRP survey site.

For the SRP site, we calculated an average adult leaf loss of 17.84% (SE = 0.58) and documented 21 adult Engelmann oaks (2%) in 17 sampling stations (1%) with a high percentage of branch loss in the canopy, as well as 1 adult with cankers (Figure 1). Overall, leaf loss was less than 20% at 65% of sampling stations (*n* = 282), between 20 and 50% at 32% (*n* = 138), and greater than 50% at 3% (*n* = 14). We also documented 15 adult coast live oaks in 9 sampling stations with high branch loss and 1 with cankers.

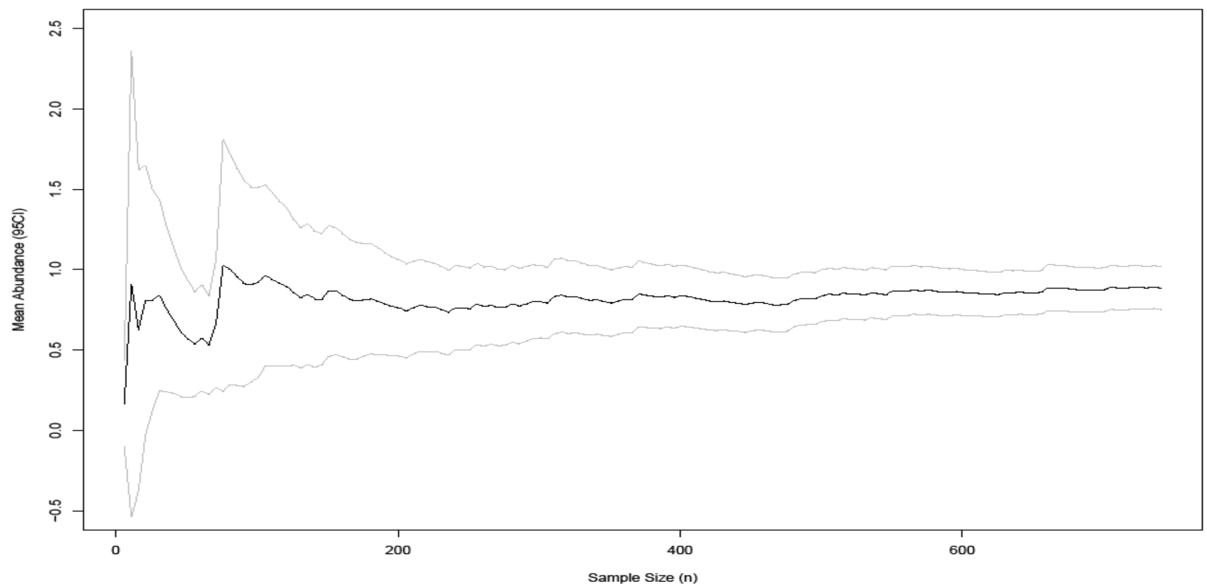

Figure 7. Estimated mean sapling abundance and 95% CI across all possible sample sizes (2 – 741) at SRP.

For the MSR site, we calculated a mean abundance per plot of 0.90 (SE = 0.28) adults, 0.70 (SE = 0.37) saplings, and 3.00 (SE = 1.92) seedlings (Figure 6). Across the whole site, we calculated an average adult leaf loss of 11.77% (SE = 14.93) and an S:T ratio of 1:1.29 that falls within the 3rd ratio class. Based on the results of the Shapiro-Wilk normality test, we determined that data for all variables were not normally distributed ($p < 0.001$) and, therefore, inappropriate for power analyses. We did not document any health issues at the MSR site.

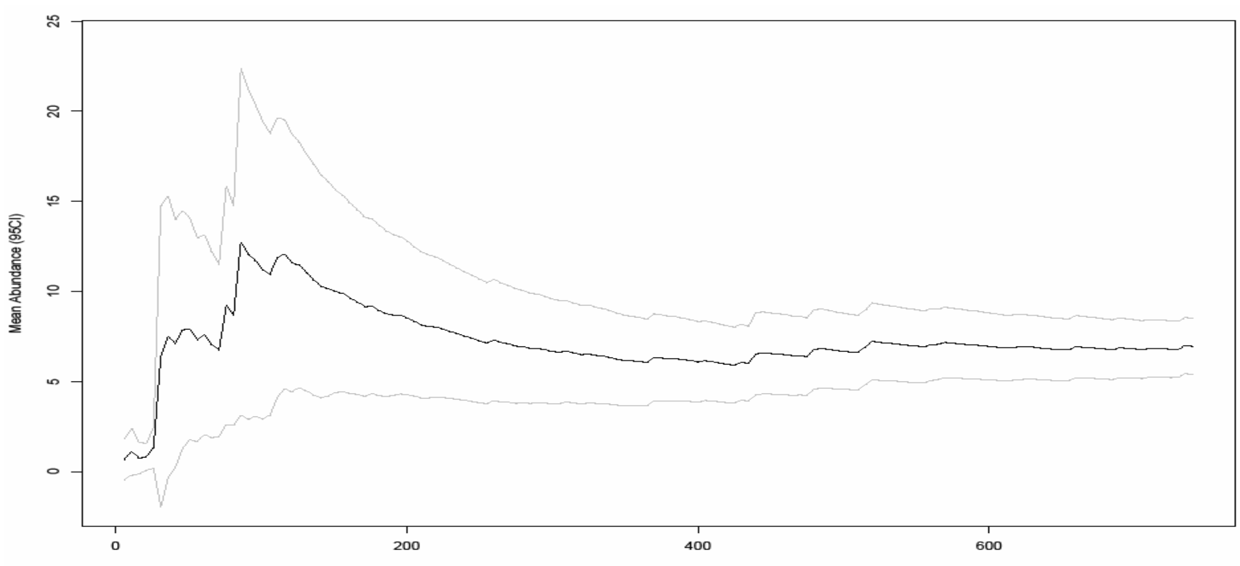

Figure 8. Estimated mean seedling abundance and 95% CI across all possible sample sizes (2 – 741) at SRP.

We observed recruitment at 2 of the 3 outlying sites, Estelle Mountain and Sage. At Estelle Mountain, we documented 1 adult with 20% leaf loss and 1 seedling growing in riparian woodland on the northwest side of the mountain. At Sage, we documented 1 adult with 5% leaf loss and 1 sapling. The population at Potrero contained 5 adults with an average of 13% leaf loss; we observed no recruitment.

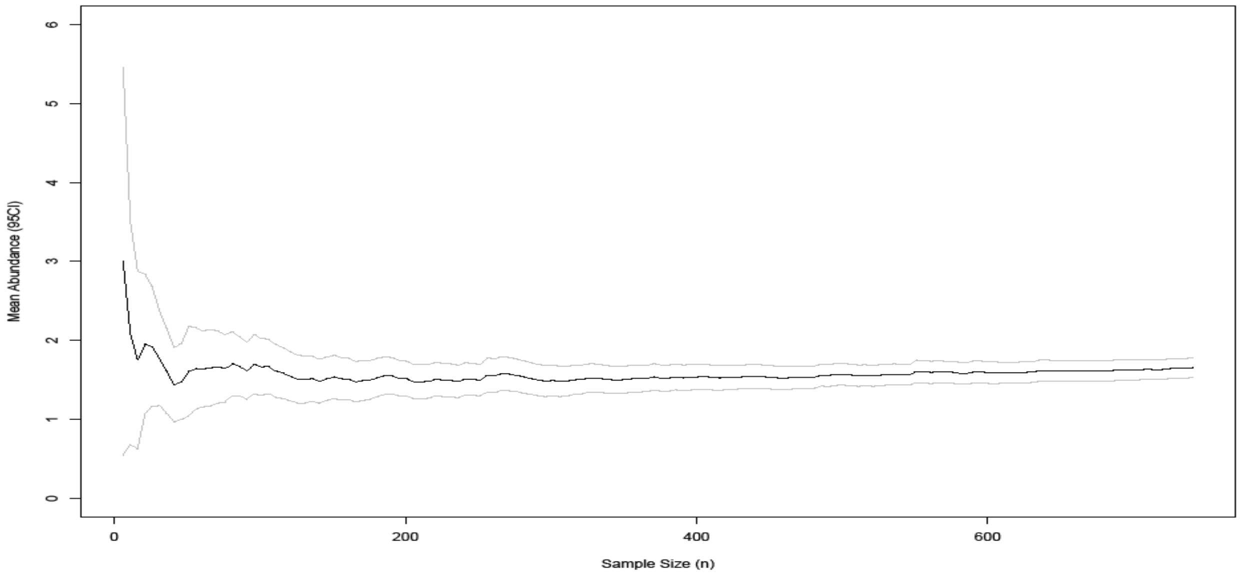

Figure 9. Estimated mean adult abundance and 95% CI across all possible sample sizes (2 – 741) at SRP.

DISCUSSION

The primary goal of this project was to quantify Engelmann oak recruitment across the conserved populations. This year we focused on characterizing recruitment at the core population that stretches from the Santa Rosa Plateau Ecological Reserve west to San Mateo Canyon Wilderness Area. We also sampled plots at the Southwestern Riverside Multi-Species Reserve and visited 3 outlying populations. Overall, seedling abundance was extremely variable across the SRP survey site, from a maximum of over 1500 seedlings to a minimum of 0 at 476 plots (64%). However, due to the large sample size, confidence intervals remained positive and relatively tight (± 22%) considering the range of included values. Differences in sapling abundance between plots varied less than seedlings, and as a result, calculated confidence intervals were tighter (± 15%). Values for adult abundance showed the least variation between plots, with over 434 (57%) containing the basal stem of at least 1 adult, resulting in the tightest confidence intervals of any recorded variables (± 7%).

Although the distribution of data was not appropriate for parametric analyses (e.g., power analyses), plots depicting change in mean abundance for various samples sizes (2 through 741) provided us with valuable information to evaluate the efficiency of our survey design (Figures 4 – 6). Based on these graphs, we believe that a sample size of 400 sampling stations adequately captures the natural variation in recorded variables across the survey area while decreasing the required time commitment by almost 50%. Despite the decrease in sample size, with 400 stations we will still be surveying a substantially larger area (28 ha) than with the previous survey design (4 ha).

At MSR, with the exception of total adult abundance and percentage leaf loss, confidence intervals for all variables overlapped 0, making interpretation difficult. A number of factors may have contributed to the highly variable nature of these values, including low adult abundance, a small survey site, and the method used to define the survey site; although, the most likely cause is the small sample size. As evidenced by the results for SRP, recruitment is highly sporadic across the landscape and a large sample size is necessary for confidence intervals to remain positive and close to the mean.

Recommendations for Future Surveys

For the 2nd year of surveys with the revised protocol, we recommend decreasing the sample size to 400 at the SRP survey site. This change will drastically decrease the time commitment for the project without significantly altering the results. In addition, we should expand the scope of the study to include the population at the Santa Margarita Ecological Reserve and other outlying populations in the Santa Ana and Palomar Mountains.

We should also consider recording more variables to better characterize the age structure of sampled populations. Variables could include basal diameter and height for saplings as well as diameter at breast height (DBH) for adults. These data would minimally increase the time commitment per sampling station while increasing our understanding of recruitment within conserved populations.

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Appendix A. Engelmann Oak Recruitment Survey Protocol

INTRODUCTION

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

Species-specific objective 3 in the MSHCP for Engelmann oak states that recruitment, as measured by the continuous presence of seedlings or saplings over a 5 year period, should occur at 80% or more of the known populations within the Conservation Area (Dudek & Associates 2003). However, production of seedlings and saplings is often not a limiting factor in the regeneration of oak stands; rather, over grazing, exotic grass presence, altered fire regimes, and resource competition hinder this process (Bartolome et al 1987; Lathrop and Osborne 1990, 1991). We then suggest that regeneration can more accurately be described by quantifying change in abundance of individual age classes through time, as opposed to a presence/absence metric that cannot capture replacement of senescing individuals or contraction/expansion of local populations.

The Biological Monitoring Program has measured Engelmann-oak recruitment over the past 3 years on 42% (*n* = 94) of two-hundred and twenty-four 30-m x 5-m belt transects (*Western Riverside County MSHCP Biological Monitoring Program Protocol for Engelmann Oak Recruitment 2005 - 2009*). While the method provided useful information about factors effecting oak recruitment, time investment per sampling unit (e.g., 60 to 120 minutes) prohibited the sample size required to capture natural variation in oak abundance across the landscape. We describe here an alternative sampling design that uses circular plots to substantially increase our sample size where large Engelmann oak populations occur (i.e., SRP, SMER, and MSR), while greatly decreasing the time requirement per sampling unit (e.g., 1 to 20 minutes). We also describe methods for monitoring abundance of seedlings and saplings where oak populations are small enough to systematically sample the entire population (i.e., San Mateo Canyon, the Estelle Mountain Reserve, Potrero, Sage, Bautista Canyon, and the Palomar Mountains).

Currently, many pathogens and insects, including the Golden Spotted Oak Borer (GSOB), are adversely affecting oak populations throughout Southern California. While current research indicates that GSOB are not causing damage to *Q. engelmannii*, Coast Live Oaks (*Quercus agrifolia),* a common and co-occurring species, are a primary target for infestation (Coleman 2009). Pathogens, such as *Diplodia corticola,* are also contributing to *Q. agrifolia* mortality throughout the plan area, including at the Santa Rosa Plateau (Eskalen

2010). Documenting evidence of pathogen and insect infestation across the conservation area may aid in future management decisions.

We will implement a pilot survey in the fall and winter of 2010 – 2011 and 2011 – 2012 at three sites throughout the plan area: SRP, MSR, and SMER. Our initial efforts will focus on determining an appropriate sample size to capture natural variation in seedling, sapling, and mature oak abundance across the landscape. Our specific goals and objectives in winter 2010 – 2011 are as follows:

Goals and Objectives

4) Quantify Engelmann oak recruitment at the SRP, SMER, and MSR
    a) Use a Generalized Random Tessellated Stratified (GRTS design to distribute circular plots throughout the survey sites.
    b) Record abundance within each plot for seedlings and saplings.
    c) Using 2 years of data, calculate the detectable change in abundance across years.
5) Quantify the health of adult oaks throughout the survey sites.
    a) Record abundance within each plot.
    b) Estimate percent leaf loss from a fully foliated tree.
    c) Look for signs of disease or damage to adult trees.

METHODS

Population Sub-sampling

Survey Design

We defined the survey area at the SRP to be all areas showing Engelmann oak vegetation associations in the 2005 Geographic Information System (GIS) vegetation map of western Riverside County from the eastern boundary of the Santa Rosa Plateau Ecological Reserve to the eastern boundary of the San Mateo Canyon Wilderness Area (CDFG et al. 2005) (Table. 1). Vegetation series are defined by the dominant or co-dominant species in the overstory of a stand of vegetation following 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 grasses, poison oak (*Toxicodendron diversilobum*) and/or annual forb species.

We used Arc GIS v.9.3 (ESRI 2009) to buffer the targeted vegetation associations at SRP by 15-m to prevent any sampling units from extending beyond the boundary of the conservation area or onto paved roads. We also removed all areas that would require more than 100-m of hiking through chaparral to access. At the SRP these areas account for 22-ha (< 3%) of the total survey area. We used the "spsurvey" package (Kincaid 2009) of the R statistical program v. 2.5.1 (R Development Core Team 2007) to distribute points following a Generalized Random Tessellated Stratified (GRTS) sampling design. Generalized Random Tessellated Stratified designs create a spatially balanced distribution of samples that lead to more uniform coverage of patchy landscapes than a truly random sample, while addressing bias resulting in autocorrelation among errors associated with regular sample distributions

(Theobald et al. 2007). The GRTS design also allows addition and subtraction from the sample size without adversely affecting the spatial balance. We distributed 1000 points at SRP within the first frame and an additional 500 points to draw from incase we need to increase the sample size or replace inaccessible or overlapping sampling units. To create the sampling units, we buffered each point 15-m to delineate a circular plot with a diameter of 30-m (A = 706-m^2). Of the original 1000 samplings unit, we removed 43 because they overlapped with adjacent units. We replaced these sampling units with the next 43 distributed within the additional 500 points.

Table 1. Vegetation associations containing Engelmann oak populations at Santa Rosa Plateau, with number of sampling units (n), area (ha), and percent total area of each Engelmann oak association.

Vegetation Association	*n*	Area	% of Total Area
Q. engelmanii/ Q. agrifolia/ Artemisia californica	2	1	0.14
Q. engelmanii/ Q. berberidifolia	108	81	11.33
Q. engelmannii/ Chaparral	76	60	8.39
Q. engelmannii/ Grass	251	168	23.49
Q. engelmannii/ Q. agrifolia	105	90	12.58
Q. engelmannii/ Q. agrifolia/ Chaparral/ Coastal Sage Scrub	0	0.2	0.03
Q. engelmannii/ Q. agrifolia/ Toxicodendron diversiloba/ Grass	406	274	38.31
Q. engelmannii/ *T. diversiloba* / Grass	0	7	0.98
Q.engelmanii/ Q. agrifolia/ Platanus racemosa	52	34	4.75
Total	1000	715.2	100.00

Because of the large geographic separation of the populations at SMER and MSR, we distributed sampling units independent of the larger population at the SRP. At SMER, we used a vegetation map created by San Diego State University (SDSU 2001) in combination with CDFG et al. (2005) to delineate the survey area. Due to the inaccessibility of a portion of the woodland, using ArcGIS 9.3 (ESRI 2009) we clipped the polygon so it only included areas accessible with less than 100-m of bushwhacking through chaparral. The resulting survey area covered approximately 17-ha of the 114-ha woodland (15 %). According to the CDFG vegetation layer, the entire survey area is classified as "*Quercus Engelmannii/ Quercus agrifolia/* Chaparral/ CSS". We clipped the SMER survey area so that no points were distributed within 15-m of the conservation area boundary or a paved road. Within the resulting polygon we distributed points (n = 27) at the same density, 1 point per .7 ha, as at the SRP. The CDFG et al (2005) vegetation map does not show Engelmann oak vegetation associations at MSR, but locations of individual adult trees have been marked by other researchers (Principe 2004). We used data from Principe (2004) to delineate 2 distinct areas with Engelmann oak at MSR covering a total of 3-ha, and distributed points (n = 5) at a density of 1 per .7 ha throughout the polygon so they were at least 15-m from a paved road and the boundary of the conservation area.

Field Methods

We will conduct surveys four days a week, Monday through Thursday, starting Monday, October 25th. Surveys will run from October to mid December or until all plots have been sampled (n =1032).

Surveyors will record all Engelmann oak and hybrid individuals (seedlings, saplings and adults) with at least 50% of their basal stem located within the sampling unit. Based on the definition used by Muick and Bartolome (1987), we define seedlings as individuals with a basal diameter of <1 cm; saplings as individuals with a basal diameter of ≥1 cm to <10 cm and a diameter a breast height (DBH) <10-cm; and adult as individuals with a DBH ≥10 cm (Lathrop and Osborne 1991, Principe 2002). We use size rather than age for classifying oaks because of the ease of taking measurements. In addition, mortality risks and reproductive behavior are often size-dependent (Tyler et al 2006). Surveyors will record hybrids between *Q. engelmannii* and *Q. berberidifolia* adult oaks as 1 of 2 types based on morphological characteristics, either more closely related to Engelmann oak (type 1), or more closely related to scrub oak (type 2). We constructed a guide with photographs of different leaf types to aid crews in tree identification while in the field (Appendix A). For seedlings and saplings, surveyors will not differentiate between hybrid types; instead, they will determine if an individual is closer to a pure Engelmann (Pure) or a Hybrid (Hybrid). If a surveyor is unable to determine an individual, the Botany Program Lead will revisit the sampling unit to make a final determination. In order to assess the overall health of the Engelmann Oak woodland within the survey area, surveyors will estimate the crown density of all adult trees. Two surveyors will estimate the percent defoliation from a fully foliated tree while standing 90º apart and between one half to one tree length from the trunk of the tree (Zarnoch et al 2004). A healthy individual will receive a percentage near 0 percent while an unhealthy tree will receive a much higher percentage. Surveyors will use a photographic guide depicting varying degrees of defoliation (Appendix B) to aid in arriving at an accurate percentage. Surveyors will average their estimates to reach a final value. Surveyors will also use a photographic guide (Appendix C) to check all *Q. engelmannii* and *Q. agrifolia* located within the plots for signs of insect or pathogen infestation. Specifically, surveyors will look for GSOB exit holes, bleeding, cankers, branch loss, and scarring.

Field Procedure

1) Before going into the field, surveyors will gather all required equipment from the desks located in the plant hallway. Team, vehicle, and plot assignments will be posted on the white board located in the plant hallway.
2) Using a Garmin etrex Lengend HCx GPS unit, observers will navigate to the coordinates marking the midpoint of an assigned plot.
3) Surveyors will place a metal stake (Candy Cane) at the center point of the plot and attach the 15-m ropes. Next surveyors will pull 3 of the 4 ropes straight out from the center and secure them with a metal stake.
   a) Surveyors will use the 4th rope to determine if individuals are in or out of the plot.
   b) If the plot is mostly open, surveyors may pull one of the ropes in a circle to delineate the boundary of the plot.

4) Surveyors will record the abundance of all seedlings (Basal diameter < 1-cm), saplings (Basal diameter from 1-cm – <10-cm), and adults (Basal diameter > 10-cm) within the 2 categories of Engelmann Oaks: Pure *Engelmannii* or *Engelmannii* x *berberidifolia.* Surveyors will use calipers to determine which group to assign individuals. For all adult Engelmann's, surveyors will separate hybrids into two groups, H1 and H2. For all adult trees, surveyors will estimate the percent leaf loss from a fully foliated individual.
    a) Surveyors will record all individual whose basal stem is at least 50% in the plot.
    b) While estimating leaf loss, surveyors will stand 90º apart and approximately one half to one tree length from the base of the tree. Surveyors will average their estimates to reach a final value.
    c) With the aid of a photographic guide (Appendix C), surveyors will check all Engelmann Oak and Coast Live Oak for possible signs of insect or pathogen damage.
5) Once surveyors have searched the entire plot, they will gather all field equipment, update the quadrat sheet, and navigate to the next assigned plot.
    a) If uncomfortable identifying all the individuals with in the plot or other issues arise, surveyors will select "Yes" from the "revist" field and record the reason in the "Notes" field.
6) Upon returning from the field, observers will return all communal field equipment to the desk's in the plant hallway; plug in and place the PDA in the box labeled "PDA's to sync; and place the map and updated transect list in the box labeled "Oak Maps".

Equipment

- Garmin etrex Legend HCx GPS unit
- 4 Metal Stakes (Candy Cane)
- Rope Octopus
- Single Rope
- Plot list
- PDA
- Identification aids
- Map
- Calipers

Survey Design

While most populations of Engelmann Oaks in the conservation area are included in the 3 survey sites (SRP, SMER, and MSR), there are a number of small, outlying populations located at Potrero, the Northwest corner of the Palomar Mountains, West of Sage Road, Bautista Creek, the San Mateo Canyon Wilderness, and the Estelle Mountain Reserve. For these areas, we will map the extent of the population and consider the woodland to include the canopy of all Engelmann Oaks plus a 3-m buffer around the canopy. According to Osborne (1989) Engelmann Oak seedlings are rarely present more than 10 feet from the closed canopy.

Field Methods

We will conduct surveys opportunistically throughout the fall and early winter until we have sampled all sites (n = 6). Since many of the survey sites require a substantial hike to access, we will map and survey each area in 1 visit.

Because the population sizes at these outlying locations are so small (< 25), surveyors will survey the entire oak woodland and not sub-sample the population. Surveyors will systematically search the entire survey area and record abundance of seedlings, saplings, and adult Engelmann Oaks. For all adult *Q. engelmannii,* surveyors will estimate the percent leaf loss from a fully foliated individual and for all oaks (*Q. engelmannii* and *Q. agrifolia*) document evidence of insect and pathogen damage.

Field Procedure

1) Before going into the field, observers will gather all required equipment from the desks located in the plant hallway. Team, vehicle, and plot assignments will be posted on the white board located in the plant hallway.

2) First, surveyors will navigate to the outlying population.

3) Using a Garmin etrex Lengend HCx GPS unit, surveyors will map the extent of the Engelmann Oak canopy.

4) Next, surveyors will systematically search the under the canyon and within 3 meters of the canopy for seedlings, saplings, and adults. Surveyors will record leaf loss for all adult Engelmann Oaks.

   a) Surveyors will record all individual whose basal stem is at least 50% in the plot.

   b) While estimating leaf loss, surveyors will stand 90º apart and approximately one half to one tree length from the base of the tree. Surveyors will average their estimates to reach a final value.

   a) Surveyors will check all Engelmann Oak and Coast Live Oak for possible signs of insect or pathogen damage.

5) Upon returning from the field, observers will return all communal field equipment to the desk's in the plant hallway; plug in and place the PDA in the box labeled "PDA's to sync; and place the map and updated transect list in the box labeled "Oak Maps".

Equipment

- Garmin etrex Legend HCx GPS unit
- PDA
- Identification Aides
- Map

TRAINING

Prior to the start of oak surveys, all field personnel will participate in an office-based training. During this training, observers will receive an overview of the Engelmann Oak Recruitment Project from past and present. Observers will also participate in a field based training session. During this session, observers will be shown examples of all common adult oaks and if possible their seedlings and saplings. Once everyone is comfortable with their identifications and field procedures, observers will be broken into teams of two to set up and sample oak plots. Teams will be rotated so that each plot is sampled twice. The database will be queried and sampling units compared to determine if any major inconsistencies exist between observers.

Training Results

Observers that successfully complete training will be able to differentiate between the seedlings of Engelmann oaks, Engelmann oak/ Shrub oak hybrids, scrub oaks, and coast live oaks. Additionally, observers will be able to properly place adult oaks into 1 of 5 classes used to determine the overall health of an individual.

DATA MANAGEMENT

Observers will collect data using Pendragon 5.1 forms (Pendragon Software Corporation 2007) on Palm TX (Palm Inc., Sunnyvale, California) Personal Data Assistants (PDA). While the project is ongoing, we will store these data in a MySQL v.5.0.51 database (Sun Microsystems, Inc. 2005) and upon completion of the yearly survey, transfer them to an access database (Microsoft Corporation 2007). We created the Pendragon, MySQL, and Access forms with primary keys to maintain relational integrity and minimize the chance of user error.

TIMELINE

We will limit our survey effort to include seedlings that have survived at least one summer. Because Engelmann oak seedlings germinate in the fall and then do not show above-ground growth for several months, we can use the fall and winter to conduct recruitment surveys.

Training- Thursday, October 21st and Monday, October 25th

First day of surveys- Tuesday, October 26th

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