**Western Riverside County MSHCP
Biological Monitoring Program
Engelmann Oak Recruitment 2018 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 (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 (CNF). Additional populations occur at the Santa Margarita Ecological Reserve (SMER), the Southwestern Riverside County Multi-Species Reserve (MSR), Bautista, Wilson Valley and a few remnant occurrences (ranging between 1 and 15 individuals) elsewhere within the Plan Area.

The MSHCP species-specific Conservation Objective 3 for Engelmann oak states that we are to "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). 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 (Muick and Bartolome 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.

We will survey randomly distributed plots within mapped Engelmann Oak vegetation at five study sites: the SRP and vicinity, MSR, SMER, Bautista, and Wilson Valley. Small remnant populations occurring at other locations will be surveyed separately in conjunction with Rare Plant Monitoring surveys. We will count individual oaks by age class at each of the randomly distributed plots. Age classes will be determined by measuring basal diameters of seedlings and saplings. Recruitment and replacement will be determined by following the growth of saplings and progression through age classes. We will analyze data collected for growth and replacement rates independently for each study site. Implementation of Objective 3 for this species will provide new data to guide, management and monitoring efforts. Our specific goals and objectives are as follows:

Goals and Objectives
1. Quantify Engelmann oak abundance at study sites.
    a. Record abundance of Engelmann oaks within sample plots in three age classes: seedlings, saplings and adult trees.
    b. Compare abundance across survey seasons.

2. Assess the health of the adult Engelmann oak population.
   a. Estimate percent leaf loss for individual adult trees within plots (where 0% indicates a fully foliated tree).
   b. Record branch loss.
   c. Record acorn abundance.
   d. Look for a correlation between amount of branch loss and acorn abundance.
   e. Record adult trees that appear to be dead.
   f. Compare health across survey seasons.

3. Determine whether true recruitment is occurring and senescing individuals are being replaced.
   a. Record basal diameter and height category (tall or short, where tall is >1.37 m) of previously tagged saplings to determine growth rates.
   b. Tag and record basal diameter of new saplings.
   c. Record saplings that have grown into adult trees.
   d. Record saplings that have died or cannot be relocated.
   e. Determine rate of replacement (new adults to dead trees).

4. Improve accuracy of plot relocation in future survey seasons.
   a. Revise and create new plot maps as needed.

METHODS

Survey Design

For our sampling design (i.e., population sub-sampling) we will use circular plots randomly distributed within Engelmann oak habitat. To identify suitable plot locations we used a Geographic Information System (GIS) vegetation map of Western Riverside County (CDFG et al. 2005) to delineate a survey area of Engelmann oak habitat within the SRP Ecological Reserve, the Tenaja Corridor, and a portion of the Cleveland National Forest. Based on the Sawyer and Keeler-Wolf (1995) definition of a vegetation association, we selected vegetation polygons where Engelmann oak is dominant or co-dominant with coast live oak (*Quercus agrifolia*), scrub oak (*Q. berberidifolia*), and/or western sycamore (*Platanus racemosa*). Using the "spsurvey" package (Kincaid 2017) of the R statistical program v. 3.4 (R Development Core Team 2017), we distributed points within this vegetation map following a Generalized Random Tesselation 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 (Theobald et al. 2007) and allow changes to the sample size without adversely affecting spatial balance. This design improves statistical effectiveness from our previous survey design (see Biological Monitoring Program 2009) by increasing randomness where large Engelmann oak populations occur, while allowing an increased sample size due to a decreased survey time per sampling unit.

Because of the large geographic separation of the populations at SMER, MSR, Bautista, and Wilson Valley we distributed survey plots at these locations independently of the larger population at SRP, Tenaja, and Cleveland National Forest. We used the

same vegetation map (CDFG et al. 2005) to delineate the survey area at SMER, however, this vegetation map does not identify Engelmann oak vegetation associations at MSR, Bautista, and Wilson Valley. For MSR, we used location information from survey work conducted in 2004 (*Zachary Principe, The Nature Conservancy, unpublished data*) to delineate two distinct areas occurring within the mapped Coast Live Oak association where individual adult Engelmann oak trees have been observed. For Bautista and Wilson Valley we used personal Engelmann oak tree observations to delineate our survey area. We then distributed points throughout the resulting polygons using the GRTS sampling design described above.

We clipped all survey areas so that no points were distributed within 15 m of the conservation area boundary or paved roads. Each of the random points was buffered 15 meters to create circular survey plots with an area of 707 m^2. Overlapping plots were excluded. When the protocol for Engelmann oak sampling was first developed (2010-2011 survey season) we identified 1000 sample plots for the SRP study site alone; however, after completing over 700 of these plots we determined that a sample size of 400 plots was sufficient to obtain stable means of oak abundances (see Biological Monitoring Program 2010 and 2011 for a complete description of the methods used). The sample sizes for SMER, MSR, Bautista and Wilson Valley are 25 plots, 10 plots, 8 plots, and 3 plots, respectively. Following initial plot establishment, we created maps of each plot to increase the accuracy of plot relocation, thus reducing data error due to slight differences in plot relocation over time. Surveys will be conducted between the months of October to January, or until all plots have been sampled.

Field Methods

We will re-survey plots using the same methodology as initial surveys in 2011-2012. Surveyors will be paired for each plot survey to aid in data collection and enable increased accuracy of visual estimates for some data. Surveyors will use the distance and bearings to the landmarks provided on plot maps to aid in relocating the plot center points (Figure 1).

Once a plot's center point has been relocated, the circular plot boundaries will be delineated by extending four 15-m long ropes from the center of the plot in the four cardinal directions. A fifth, unsecured 15-m long rope will be used to confirm whether any oaks near the edge of the plot boundary are in the plot. Surveyors will record all Engelmann oak and hybrid individuals (seedlings, saplings, and adults) within the plot (Figure 1).

All saplings on plots will be tracked across survey seasons. We believe that tracking the intermediate sapling stage of oak growth will provide us with the most reliable indicator of successful recruitment from seedling to adulthood. Based on Muick and Bartolome (1987), we define seedlings as individuals with a basal diameter of <1 cm, saplings as individuals with a basal diameter of 1–10 cm, and adults as individuals with a basal diameter ≥10 cm (see also Lathrop and Osborne 1991; Principe 2002). We use size as a surrogate for age because mortality risks and reproductive behavior are often size-dependent (Tyler et al. 2006) and because size can be more accurately recorded than other methods of capturing age. Saplings initially recorded during the 2011-2012 season

will be relocated and measured. Large seedlings will be measured and tagged if they are determined to have grown into saplings.
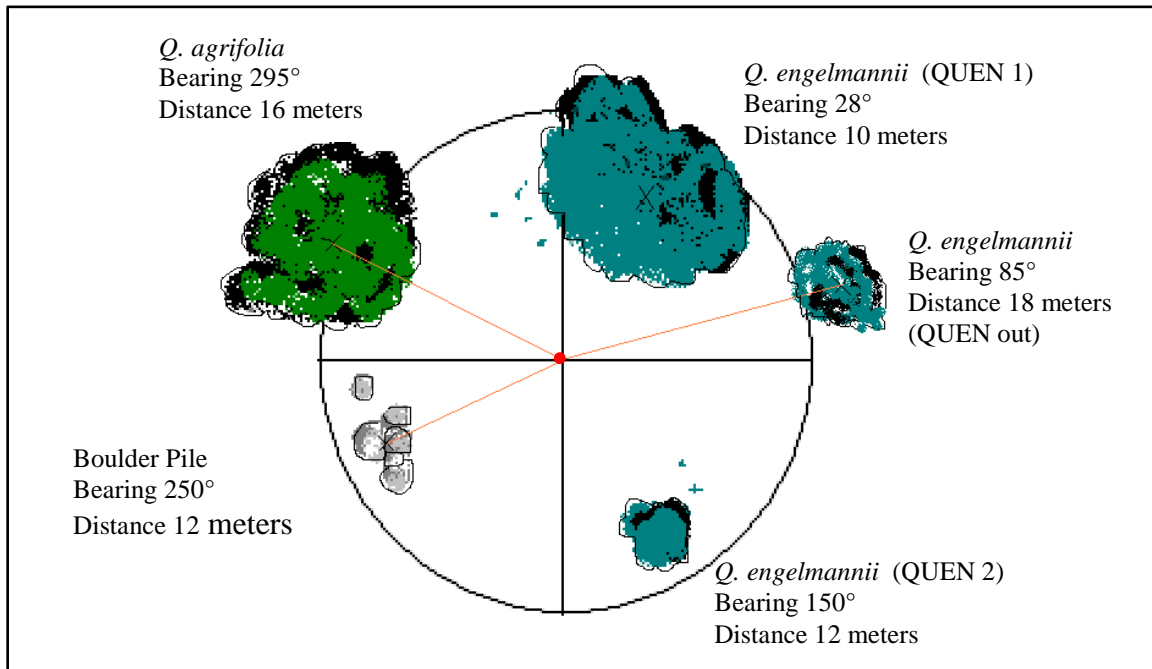
Figure 1. Locating circular plots, trees and landmarks.

  To understand the potential impacts on juvenile oak survival, surveyors will also record the type or types of substrate (e.g., rock, leaf litter, thatch) that dominate the area within a 1 meter radius of individual saplings; health categories (e.g. good, resprout, stressed, disease, dormant/dead); canopy cover; and presence of fire. Canopy cover is noted if the sapling occurs 50% or greater under the canopy of any larger tree, regardless of species. Fire is recorded at this time if it occurs within 1 meter of the sapling, but may also be recorded in the survey notes if it occurs elsewhere on the plot. Surveyors will record height categories (e.g., short or tall, where tall is ≥1.37 m) of saplings. Short saplings are more likely to survive to adulthood than seedlings due to having a woody stem and well-developed root system. Tall saplings, with leader stems that reach above the deer-browse line, gain height and girth more rapidly than short saplings, thus progressing more rapidly to the adult stage (Griffin and Muick 1990).

  In previous survey seasons, surveyors recorded hybrids between adult Engelmann oak and scrub oak as one of two types based on morphological characteristics: either more closely related to Engelmann oak (H1), or more closely related to scrub oak (H2). Predominance of characteristics was considered, such as leaf shape and color, appearance of the bark, and acorns. Because we have observed that leaf type can be highly variable in hybrids, even on a single individual, we chose to simplify the classification of questionable individuals based on habit: a hybrid oak with a tall, single trunk will be classified as H1, and a hybrid oak with multiple trunks and a smaller, shrub-like habit will be classified H2. For seedlings and saplings, surveyors will not differentiate between

hybrid types; instead, they will determine if an individual appears to be a pure Engelmann (Pure) or a hybrid (Hybrid).

To assess the overall condition of the Engelmann oak woodland within the survey area, surveyors will estimate the crown density of all adult trees. Density is used to assess the amount of defoliation on existing branches, potentially caused by drought-stress. We will not assess the amount of canopy cover, which can be affected by gaps in branching. Surveyors will estimate the percent defoliation from a fully foliated tree while standing 90º apart and between 1/2 and 1 tree length from the trunk of the tree (Zarnoch et al. 2004). Fully foliated individuals will receive a rating near 0% while sparsely foliated trees receive higher leaf-loss ratings. Surveyors may also use a photographic guide developed by the Monitoring Program at the beginning of recruitment surveys in 2007, depicting varying percentages of defoliation, to aid in consistent estimates across surveyors and survey seasons. Surveyors will average their estimates to reach a final value, and record the result in the appropriate category (0%, 1-10%, 11-20%, 21-40%, 41-60%, 61-80% or 81-100%). Surveyors will examine all Engelmann oak and coast live oak located within the survey plots for signs of insect or pathogen infestation using a photographic guide adapted from materials distributed by the United States Department of Agriculture Forest Service. Specifically, surveyors will look for goldspotted oak borer (*Agrilus auroguttatus*; GSOB) exit holes, bleeding, cankers, branch loss, and scarring. We will record acorn production for each adult tree by assigning individuals to an acorn class (Table 1) and by doing timed acorn counts (Koenig et al. 1994). Lastly, we will record recently broken branches over 10 cm (approx. 4 inches) in diameter. Arborists advise that removing limbs greater than 4 inches may increase vulnerability to internal decay (Colorado State University Extension), thus loss of these branches may be a good indicator of individual oak health.

Field Procedure

Plots

1. Before going into the field, surveyors will gather all required equipment from the plant room and download assigned points onto their GPS units. Assignments and field equipment checklist will be posted on the white board.

2. Using a GPS unit, surveyors will navigate toward the center point of an assigned plot. To more accurately determine the center point, surveyors will use the landmarks, distances and bearings described on a plot map provided for each survey site. These measurements take precedence over GPS readings, which may or may not have accuracy of 3 meters or less. A small number of plots may have photographs of landmarks provided as well.

3. Surveyors will anchor the sampling ropes with a chain pin ("candy cane" stake) at the center point and extend four of the attached ropes in each of the cardinal directions, securing them with additional stakes. Surveyors will use the fifth rope to determine if individual oaks are in or out of the plot. More than 50% of the basal stem of an individual must be within the measured length of the rope for an individual to be considered inside the plot. Refer to the plot map and adjust the center point and ropes accordingly.

4. If center point relocation is difficult, surveyors will document additional information on the map form and indicate that the map has been updated in PDA.

5. Most plots will already have plot maps that were made during previous survey seasons. Plot maps will be made for any plot with an Engelmann oak occurring within 25 meters of the plot point (i.e., the oak may occur outside of the plot). To make a new plot map surveyors will create a map documenting the following information on the map form (Appendix A) as appropriate and indicate that the map has been created in the PDA.

    a. Surveyors will select one or more enduring landmarks, such as a large boulder or large tree, and record distance and bearing from the center point to the landmark. Photographs should be taken from the center point to the landmark if they will aid in relocating the plot.

    b. Surveyors will map the location and identifying information for individual Engelmann oak saplings and trees. Facing north from the center point and working in a clockwise direction, identify Engelmann oak adults and saplings as they are encountered in numerical order so that the first Engelmann oak adult tree encountered will be identified as "Adult 1" (sometimes also identified as "QUEN 1") on the map and in the PDA. Continuing in a clockwise direction the next Engelmann adult will be "Adult 2", etc. The same process will be done for saplings starting with "Sapling 1". Individuals that are on the edge of the plot will also be mapped, bearing and distance from the center recorded, and whether they are in or out of the plot. These individuals may be used as landmarks to aid in relocating the center of the plot.

    c. If there is more than one tree and they may be hard to tell apart on a plot map, please describe a distinguishing feature such as "QUEN 1 has a large hole in the base of the trunk" or include an easily recognized landmark, such as a uniquely shaped rock or fence.

6. Surveyors will record visible signs of recent disturbance such as fire. For fire, record percent of plot burned and burn intensity. Low intensity burn conditions are represented by fire-scarred vegetation and singed litter, but dry vegetation is not completely incinerated. High intensity burn conditions are represented by areas where only ash and/or basal stems of woody species remain.

7. Surveyors will count all seedlings (basal diameter < 1 cm) in the plot. Record the number of seedlings in each of two categories: "Pure" (Q. e*ngelmannii*) or "Hybrid" (Q. *engelmannii* x Q. *berberidifolia).*

Saplings

8. For all saplings (basal diameter = 1 to10 cm) surveyors will record the type ("Pure" or "Hybrid") for new saplings or select "recheck type" for previously recorded individuals if they disagree with the classification. Record basal diameter, whether the individual is tall ($\geq$ 1.37m) and health. Health categories are Good, Resprout, Stressed ($\geq$ 50% leaf loss), GSOB/disease, and Dormant/Dead (no live leaves or buds). For a Resprout in good condition, record

"Resprout". For a Resprout in stressed condition, record "Stressed". For multi-stemmed saplings record measurements for the main stem. For individuals with irregularly shaped stems (oblong in cross section) measure the basal diameter in two directions and record the average basal diameter. Record basal diameter at the ground level of the soil, after clearing away leaf litter, and then replace leaf litter after taking measurements. Create an ID tag etched with the plot ID, sapling number and "MSHCP" and attach it loosely to a stem that is likely to endure between survey years. Record the following habitat features:

a. Habitat substrate (bare ground, rock, leaf litter, thatch) that dominates the area within 1 m of the stem. "Leaf litter" is defined as broadleaf litter from trees and shrubs. "Thatch" is defined as a matted layer of mostly non-native grass lying at an angle of 45° or less. Surveyors should record all substrates that are likely to have an impact on the sapling.

b. Canopy cover. If ≥50% of the foliage of the sapling lies within the edge of the canopy, the sapling will be considered under the canopy even if rooted beyond the edge of the canopy.

c. The presence of recent fire affecting the sapling.

9. For saplings recently graduated to adults (basal diameter > 10cm) surveyors will record both sapling and adult data. The PDA will direct you to the appropriate data fields. Do not change the sapling ID or remove tags.

Adults

10. Surveyors will collect information for each adult Engelmann oak within the plot.

a. For new adult Engelmann oaks, surveyors will classify them into one of three categories: Pure, H1 and H2. A hybrid with a large single stem will be classified as "H1" and a hybrid with multiple stems and a more shrub-like habit will be classified as "H2." If it is a previously recorded adult then it will already be designated into a class and if the surveyor disagrees with the classification they can check the "recheck type" button in the PDA. Additionally, indicate whether an individual is a resprouted adult.

b. Surveyors will estimate percent leaf loss from a fully foliated individual using a leaf loss photographic guide as a reference. To estimate leaf loss, surveyors will stand ½ to 1 tree length from the tree and about 90° to each other from the tree base. Each surveyor will estimate leaf loss and the average of the two estimates will be recorded in one of seven categories: 0%, 1-10, 11-20, 21-40, 41-60, 61-80, and 81-100% leaf loss. Leaf loss for dead trees will be recorded as "NA".

c. Surveyors will record recently broken branches > 10 cm (about 4 inches) in diameter. The wood should look fresh tan/red brown as oppose to gray and weathered.

d. The size of the acorn crop will be classified on a scale from 0 to 4, where 0 is no acorns and 4 is a "bumper crop" (Table 1).

Table 1. Acorn class sizes

0	no visible acorns
1	acorns visible after very close examination, very few acorns
2	acorns readily visible, but either not found throughout canopy or found throughout tree but only a few acorns per major branch, okay crop
3	acorns readily visible and found throughout tree and on most branches, but most minor branches have only a few acorns and acorns hang solo instead of in clusters, good crop.
4	acorns readily visible and covering entire tree, limbs appear to sag from weight of acorns, most minor branches have some acorns and most acorns are in clusters of 2, 3 or more, bumper crop!

    e. If the tree receives an acorn class greater then '0', observers will independently count all of the acorns they can see on the tree. Surveyors will stand ½ to 1 tree length from the tree and about 90 degrees to each other from the tree base and count all of the acorns that they can see in 15 seconds.

    f. With the aid of the photographic guide, surveyors will inspect all Engelmann oak and coast live oak (*Q. agrifolia*) and record and take pictures of any sign of insect or pathogen damage.

11. If surveyors are uncomfortable identifying individual hybrids within the plot, or if any other issues arise, they will select "Yes" from the "Revisit" field and record the reason in the "Notes" field.

12. Once surveyors have surveyed the plot, they will retrieve all field equipment, mark the plot as done on the assignment list, and navigate to the next assigned plot.

13. Upon returning from the field, surveyors will return all communal field equipment to the plant room and put PDAs in the "Need to Sync" box. Maps and updated transect lists in the tray labeled "Oaks".

Equipment List

- GPS unit with points uploaded
- PDA
- sampling rope
- pin flags
- chain pins (Candy Canes)
- measuring tape
- plot list and map
- identification aids
- blank diagrams
- calipers
- nail stakes
- camera
- ID tags
- pencil
- tally counter
- compass
- Ivy Block
- timer

TRAINING

Prior to the start of oak surveys, all field personnel will participate in an office-based training. During this training, surveyors will receive an overview of the Engelmann oak recruitment project to date and study samples of *Quercus engelmannii*, *Q. agrifolia*, *Q. berberidifolia*, and *Q. engelmannii* × *Q. berberidifolia* hybrids. Inexperienced surveyors will participate in field-based training with experienced staff and learn to identify mature Engelmann oaks, seedlings and saplings. They will be taught plot relocation and data collection procedures.

Training Results

After completing the oak training, observers will be able to differentiate between the Engelmann oaks, scrub oaks, Engelmann oak/scrub oak hybrids, and coast live oaks. Additionally, observers will be able to accurately relocate survey plots, estimate percent leaf loss of adult oaks, measure basal diameter of juvenile oaks, and record data using Personal Data Assistants (PDAs).

DATA ANALYSIS

We will map abundance for all Engelmann oaks observed using ArcGIS Desktop 10.5 (ESRI, Inc. 1999-2016). Count categories will be defined by ArcGIS, which uses Jenks Natural Breaks algorithm (ESRI 2017). We may make minor adjustments in count ranges of saplings and seedlings for clarity and comparison across multiple survey seasons. We will calculate basic descriptive statistics and examine changes in Engelmann oak abundance using Microsoft Excel 2013 and Mystat 12.02.00 (Systat Software, Inc. 2007). We will run chi-squared goodness-of-fit tests to test for significant changes in abundance, binning counts into the ranges represented on the abundance maps and testing them as categorical data. We will run chi-squared goodness-of-fit tests to test for significant changes in adult health categories.

We will use Kolmogorov–Smirnov tests to test for significant associations between continuous and categorical data (i.e., sapling size and sapling survival) and we will use paired t-tests to test for significant growth in sapling basal diameter. Paired t-tests are appropriate for sapling growth data that is not normally distributed because we have a very large sample size ($n > 200$).

TIMELINE

- October: Pre-survey training for surveyors. Obtain access to survey areas.
- October: Surveys will be conducted. Data will be entered concurrently with surveys.
- Spring: Data analysis and report writing.

LITERATURE CITED

Biological Monitoring Program. 2009. Western Riverside County MSHCP Biological Monitoring Program Engelmann Oak Recruitment Survey Report. Prepared for the Western Riverside County Multiple Species Habitat Conservation Plan. Riverside, CA. Available online: http://wrc-rca.org/about-rca/monitoring/monitoring-surveys/.

Biological Monitoring Program. 2010. Western Riverside County MSHCP Biological Monitoring Program Engelmann Oak Recruitment Survey Report. Prepared for the Western Riverside County Multiple Species Habitat Conservation Plan. Riverside, CA. Available online: http://wrc-rca.org/about-rca/monitoring/monitoring-surveys/.

Biological Monitoring Program. 2011. Western Riverside County MSHCP Biological Monitoring Program Engelmann Oak Recruitment Survey Report. Prepared for the Western Riverside County Multiple Species Habitat Conservation Plan. Riverside, CA. Available online: http://wrc-rca.org/about-rca/monitoring/monitoring-surveys/.

[CDFG et al.] California Department of Fish and Game; Aerial Information Systems, Inc.; California Native Plant Society. 2005. Vegetation - Western Riverside Co. [ds170]. Publication Date: 2005-07-31. Online: http://bios.dfg.ca.gov/.

Colorado State University Extension. [Gardener Certificate Program]. CMG Garden Notes #616. Available online at: https://static.colostate.edu/client-files/csfs/pdfs/616.pdf. Accessed 12/5/2017.

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.

[ESRI] Environmental Systems Research Institute. 2017. ArcGIS Pro, Data Classification Methods. Available online at: http://pro.arcgis.com/en/pro-app/help/mapping/symbols-and-styles/data-classification-methods.htm.

Griffin JR, Muick PC. 1990. California Native Oaks: Past and Present. Fremontia 18:4-10.

Kincaid TM, Olsen AR. 2017. spsurvey: Spatial Survey Design and Analysis. R package version 2.3. Available online at: http://www.epa.gov/nheerl/arm/.

Koenig WD, Mumme RL, Carmen WJ, Stanback MT. 1994. Acorn Production by Oaks in Central Coastal California: Variation within and among Years. Ecology. 75(1):99-109.

Lathrop EW, Osborne CD. 1990. From acorn to tree: ecology of the Engelmann oak. Fremontia 18:30-35.

Lathrop EW, Osborne CD. 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.

Muick P, Bartoleme J. 1987. Factors associated with oak regeneration in California. USDA Forest Service General Technical Report, PSW-100:86-91.

Principe Z. 2002. Factors affecting Engelmann oak (*Quercus engelmannii*) regeneration [MS Thesis]. San Diego (CA): San Diego State University.

R Development Core Team. 2017. R: A language and environment for statistical computing [software]. R Foundation for Statistical Computing, Vienna, Austria. Available online at: http://www.R-project.org.

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. Encinitas (CA): F.W. Roberts Publications.

Sawyer JO, Keeler-Wolf T. 1995. A Manual of California Vegetation. Sacramento (CA): California Native Plant Society.

Scott TA. 1991. The distribution of Engelmann oak (*Quercus engelmannii*) in California. *In* Standiford RB, tech coord. Proceedings of the symposium on oak woodlands and hardwood rangeland management; October 31 - November 2, 1990; Davis, California. Berkeley, CA; USDA Forest Service Gen. Tech. Rep. PSW-GTR-126, pp. 351-359.

Theobald DM, Stevens DL, White D, Urquhart NS, Olsen AR, Norman JB. 2007. Using GIS to generate spatially balanced random survey designs for natural resource applications. Environ Manage 40:134-146.

Tyler CM, Kuhn B, Davis FW. 2006. Demography and recruitment limitations of three oak species in California. Q Rev Biol 81(2):127.

Zarnoch SJ, Bechtold WA, Stoke KW. 2004. Using crown condition variables as indicators of forest health. Can J Forest Res 34:1057-1070.

APPENDIX A. Plot Map

Date_____

Plot ID_____

Surveyors_____
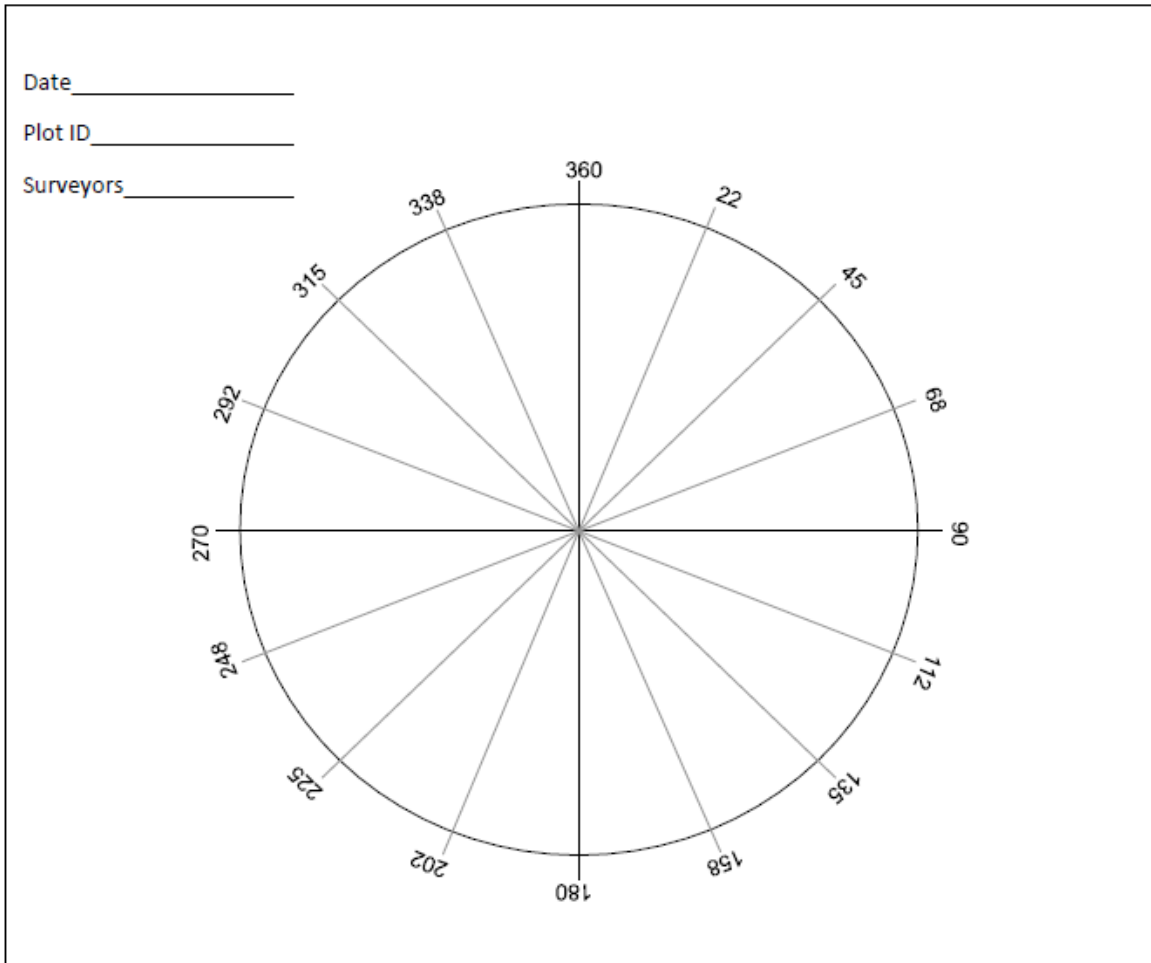
	Description	Bearing	Distance	Notes
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				