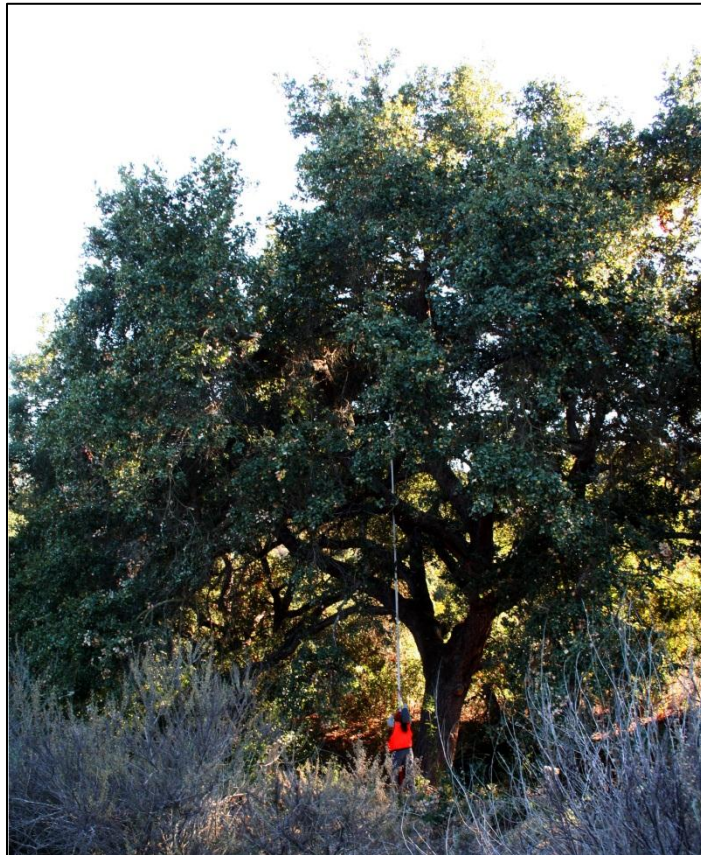


Oak Woodland Monitoring for the NROC Reserves in central Orange County

2010 FINAL REPORT
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Executive Summary

Monitoring to detect ecological change is an important component of many environmental and conservation programs. Developing a robust, accurate, and cost-effective monitoring program for a multiple-species conservation plan is scientifically and logistically challenging. The Nature Reserves of Orange County (NROC) manages 38,000 acres enrolled within the central/coastal Orange County HCP/NCCP. NROC is tasked with the responsibility to “facilitate implementation of an effective (adaptive) management program”. The NCCP includes CSS as well as significant amounts of chaparral, grasslands and oak woodlands. The NCCP allows priority to be placed on oak woodlands based on CEQA-required mitigation programs, recommendations prepared by The Nature Conservancy, and at the discretion of NROC. In addition, the NCCP covers a number of species which utilize oak woodlands during their life cycles, including: red-shouldered hawk, arboreal salamander, and black-bellied salamander.

Objectives: In consultation with NROC we focused on their key management objective “To maintain oak woodlands at their current extent and quality throughout the reserves.” As a result our key objectives were to (1) develop a robust and cost-effective monitoring protocol that would (2) provide information on oak populations relevant for adaptive management. To meet these broad goals we evaluated different methods to estimate woodland and tree structure and function. We evaluated sources of error and uncertainty in the methods. We characterized woodland and tree health including demography and recruitment, assessed risks to woodlands and trees including invasion by non-native plants and changes in fuel accumulation. In addition, we estimated pathogen prevalence and their potential impacts on oaks. This report details our methods and results after two years of field work.

Methods: The oak monitoring project was implemented in three stages: (1) mapping, (2) evaluation of protocols and field methods, and (3) initial monitoring. In stage 1 the extent of the woodlands were mapped from remotely-sensed imagery and field visits. In stage 2, preliminary data collection was conducted in order to test and modify methods, and establish a baseline understanding of the system. Both of these stages were completed in the 2009 field season. In 2010, we began stage 3, initial large-scale monitoring using a single, optimized method.

We have selected a tree-based sampling protocol to monitor oak woodlands, instead of a plot-based approach. This avoids the difficulty of placing plots of a uniform size and shape, randomly, across an irregular, but narrow landscape feature. We developed a suite of response variables that help put a metric to each monitoring goal discussed above. Variables included standard forestry metrics like DBH, height, crown size and structure. We also recorded recruitment (oak seedling and sapling abundance), understory vegetation, presence and extent of several pathogens and their impacts on the oaks.

Results: We sampled trees in nine woodlands, five in the coastal preserves, and four in the central preserves. The typical adult tree was large with a 60cm diameter trunk and a height of 10m. There was little difference in the size of trees in coastal versus inland areas, though individual woodlands varied. Most trees had large and healthy crowns as assessed by uncompact crown ratio and canopy thinning. The density of adult trees in each woodland varied with coastal preserves tending toward higher densities. Seedlings and saplings were documented in most woodlands. Coastal preserves had higher numbers of seedlings and saplings than inland preserves. Moreover, coastal preserves had lower numbers of dead adult trees. These difference are most likely attributable to moisture, though fire and grazing history may also be important drivers. Across all woodlands, *Bromus spp.* was the most abundant

member of the understory. Inland woodlands had higher cover of non-native forbs and grasses in the understory.

Signs and symptoms of pathogens were present on nearly every tree sampled. Most trees showed some evidence of dieback. The most common causes documented were Oak anthracnose and wasp galls. Branch cankers were not particularly common, but occurred in several woodlands. More than half of all trees had boring damage from beetles. In our samples, Ambrosia beetles preferred coastal sites over inland sites, but other beetles were more evenly distributed. Fungus and rot were more common in coastal sites which also reflects the more mesic conditions.

Conclusion: We documented a complex web of relationships between oak trees, their environment, pathogens and recruitment. Many of the variables we measured are interrelated and differ between the coastal preserves and inland preserves. Most woodlands have more saplings per capita than dead trees. This is one indication that recruitment seems to be adequate throughout much of the county, although a more formal population model is needed to formalize this. Inland woodlands tend to have many fewer saplings per tree than coastal woodlands. This relationship is largely driven by position relative to coast, and is probably the result of a complex interaction between moisture, temperature, canopy cover and shade. Most of the trees throughout Orange County appear to be “healthy”. Although some symptoms, such as dieback and boring damage are widespread, we encountered relatively few trees with the most problematic diseases. Although symptoms like dieback can be unsightly and widespread, they pose little threat to the health of the population. Overall, we have developed a methodology that is accurate, relevant to management, and cost effective. Continued sampling will be needed to assess inter-annual changes in recruitment and disease as well as refine our understanding of recruitment and rates of population change.

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Introduction

Oaks are an important part of the California floristic province and contribute to its status as a biological hotspot (Grunzweig et al., 2008; Mahall et al., 2009; Seabloom et al., 2009; Tyler et al., 2008; Zavaleta et al., 2007). Oaks are a foundation species (Ellison et al. 2005) in the sense that their presence defines and supports an entire ecological community. In addition to being their own important habitat type and supporting woodland obligate species, oaks also provide critical resources to plants and animals from surrounding habitats. Oak woodlands provide crucial shelter and foraging opportunities not available in California's semi-arid scrub and grasslands. In addition, oak woodlands provide watershed protection, habitat for wildlife, recreational opportunities and enhance the aesthetic value of the region (Mahall et al., 2009; Seabloom et al., 2009; Tyler et al., 2008; Zavaleta et al., 2007).

Oak woodlands are considered at-risk due to direct habitat loss. Habitat conversion by humans may have reduced oak woodlands overall to 50% of their historical range or less (Zavaleta et al., 2007). In addition, Oak woodlands are at-risk from many human-mediated threats that may reduce the number and health of oak trees. Numerous sources report that the natural recruitment of oaks in California is too low to replace dying adults (Callaway and Davis, 1998; Dunning et al., 2003; Grunzweig et al., 2008; Mahall et al., 2009; Seabloom et al., 2009; Tyler et al., 2008; Zavaleta et al., 2007). However, because oaks are long lived, oak populations may be able withstand multiple threats. Once mature, woodlands may be able to persist with only a few (or one) successful recruitment events during the lifespan of an adult tree (Mahall et al., 2009; Zavaleta et al., 2007). Therefore it is difficult to evaluate whether oak recruitment is inadequate (Seabloom et al., 2009; Zavaleta et al., 2007). Further study of oak demography as well as major threats and stressors on oak woodlands is needed to determine if current recruitment is strong enough to maintain the current extent of oak woodlands and populations (Zavaleta et al., 2007).

Adaptive management (AM) is an efficient way to prioritize management and monitoring of natural resources in a complex and variable world (Schreiber et al. 2004, Lyons et al. 2008, Rout et al. 2009). In its most basic form, adaptive management is a strategy in which the ecosystem is monitored and management techniques are continuously tested and refined (Williams 1997, Pollak 2001, Lyons et al. 2008). An adaptive management approach is called for explicitly in the NCCP Planning guidelines for Orange County (USFWS and CDFG 1997a,1997b). As defined in the 1997 NCCP habitat management program, adaptive management is "a flexible, iterative approach to long term management of biotic resources that is directed over time by the results of ongoing monitoring activities and other information". This practice relies on flexible and self-correcting feedback loops of implementation, experimentation and adjustment fueled by data collection and analysis (Pollak 2001, Olsson et al 2004, Lyons et al. 2008, Carpenter et al. 2009).

As the "non-profit management corporation" called for in the Orange County NCCP, the Nature Reserves of Orange County (NROC) is tasked with the responsibility to "facilitate implementation of an effective (adaptive) management program (USFWS and CDFG 1997b).

Although the Orange County NCCP plan focuses on the coastal sage scrub (CSS) community, it acknowledges the importance of other communities as part of a stable landscape that helps support CSS. The 38,000 acres of NCCP includes CSS as well as significant amounts of chaparral, grasslands and oak woodlands. The NCCP allows priority to be placed on oak woodlands based on CEQA-required mitigation programs, recommendations prepared by The Nature Conservancy, and at the discretion of NROC (USFWS and CDFG 1997b). In addition, the NCCP covers a number of species which utilize oak woodlands during their life cycles, including: red-shouldered hawk, arboreal salamander, and black-bellied salamander.

The Nature Conservancy holds an additional 11,500 acres in conservation easements adjacent to the NCCP lands. Like the NCCP, these conservation easements are designed to preserve and protect the conservation values of the area in perpetuity. The Nature Conservancy is also obligated to monitor as part of their adaptive management program and has prioritized oak woodlands caps? along with CSS and grasslands. Since their conservation areas are directly adjacent to one another, and because NROC and TNC share common goals, including implementing a long term vegetation monitoring program, NROC and TNC are collaborating on this project by allowing sampling from NCCP lands and easement lands to be combined for the analysis.

Why Monitoring is Hard?

Monitoring failures can arise when data do not speak directly to monitoring objectives (Ferretti 2009). This often occurs when conservation documents use ambiguous terms such as “habitat value” which are not tied to simple and easily quantifiable metrics. When a monitoring program does not have a sound design and analysis plan before it is implemented, the data are often of poor quality (Schmeller, Gruber et al. 2008; Ferretti 2009). For example, failure to detect trends can occur when the magnitude of natural and accidental variation relative to temporal variation is poorly understood (Kull, Sammull et al. 2008; Schmeller, Gruber et al. 2008; Ferretti 2009). Stochastic variability can arise in the sampling design (when and where you take data) and response design (how you take data) (Stevens and Urquhart 2000; Larsen, Kinkaid et al. 2001; Whitacre, Roper et al. 2007). Often monitoring programs seek statistical advice after having been implemented when the data yield unexpected or inconclusive results (Marsh and Trenham 2008). At that point if the sampling or response design was particularly ill suited for the study objective, even the most skillful analysis can fail to salvage useful information from the data. As a result, analysis is often boiled down to basic statistical summaries, and yields an overly simplistic characterization of the process of interest (Kull, Sammull et al. 2008).

Having a statistically sound monitoring design and analysis plan is more cost effective (Lengyel, Deri et al. 2008), and optimizes the amount of meaningful information gleaned from a program. Optimizing monitoring results is key because time, funding and expertise often comes out of a small pool (Marsh and Trenham 2008; Fancy, Gross et al. 2009; Ferretti 2009). In addition, data analysis is the crucial link between monitoring and providing information useful for managers, politicians and other end users (Lengyel, Deri et al. 2008).

Ideally, monitoring data should be both precise and accurate. Although these terms are synonymous in common usage, they are not identical. The accuracy of a sample is very difficult to assess since we rarely know the true value of the variable of interest. However precision is

easy to quantify (Kercher et al. 2003, Milberg et al. 2008). Although accuracy is highly desirable, trend detection -- the key to understanding if an easement is working-- relies on precision which allows relative change to be measured (Milberg et al. 2008).

Maximizing precision requires minimizing sampling error introduced by how and who collected the data (Ferretti 2009). Inter-observer variability has been examined by numerous studies, and there is general agreement that it is an important source of error (Kercher et al. 2003, Vittoz and Guisan 2007, Whitacre et al. 2007). This effect can be compounded by the response design, particularly by methods that use subjective estimates, such as visual cover estimation in vegetation sampling (Milberg et al. 2008). This is particularly true if the observers are different each year (as is common with many monitoring programs) and if qualified and experienced data collectors are a rarity (Kercher et al. 2003, Schmeller et al. 2008). Yet even the most skilled observer will fail to make some observations (Milberg et al. 2008). Although “Such errors cannot be eliminated... they can be controlled” (Ferretti 2009).

In order to control error a good deal of effort must be spent up front during the design phase (Ferretti 2009). Appropriate sampling and response designs must be selected to collect data with a defensible relationship to the process of interest. Then the data analysis procedure must be linked back to project objectives, and should include advanced techniques (Atkinson, Trenham et al. 2004; Kull, Sammul et al. 2008; Marsh and Trenham 2008; Schmeller, Gruber et al. 2008; Fancy, Gross et al. 2009; Ferretti 2009). The monitoring design must be robust across numerous observers, yet efficient while collecting the necessary data with acceptable precision (Kercher, Frieswyk et al. 2003; Fancy, Gross et al. 2009). Knowing the degree to which differences between plots and sites can be attributed to natural and temporal variation rather than methodological error is also important (Kercher, Frieswyk et al. 2003; Schmeller, Gruber et al. 2008). Data quality objectives can then be defined based on project goals (e.g. trend analysis) and power analysis (Milberg, Bergstedt et al. 2008; Ferretti 2009). With this information on hand a standard operating procedure detailing data collection, data processing and quality checking can be defined, further reducing error (Milberg, Bergstedt et al. 2008; Ferretti 2009). This planning phase can be costly and include a period of research, however having a clear, statistically sound monitoring design and analysis approach saves costs over the long term (Lengyel, Deri et al. 2008; Marsh and Trenham 2008; Fancy, Gross et al. 2009).

Challenges Specific to Monitoring Long-Lived Species

Numerous studies have sought to measure the importance and variation of biological, spatial and temporal factors limiting oak recruitment. The results from these studies is limited by the differences in methods and the short duration of the studies relative to the oak’s lifespan (Tyler et al., 2008 Seabloom et al., 2009). As a result, a complete dataset tracking trees from recruitment to death is not available, nor do we fully understand what constitutes adequate recruitment or elevated rates of mortality. In addition we do not have a clear picture of what constitutes optimal conditions for recruitment and what conditions are the most threatening to entire oak populations. This makes managing and monitoring oak woodlands and understanding the key threats an appropriate application of adaptive management.

The initial monitoring program is based on the best available information from peer-reviewed literature and employs the standard methods used in forestry throughout the United States. We

will collect baseline data for numerous factors thought to be important to oak woodlands, with an eye on long-term demographic studies. We will use variance components analysis to identify factors with the most explanatory power and data collection protocols with the highest accuracy and precision. We will tailor the project in the next year to reflect those results and the most efficient and repeatable monitoring procedure.

Goals and Objectives

In consultation with NROC and TNC staff we focused on their key management objective:

To maintain oak woodlands at their current extent and quality throughout the reserves.

Our key monitoring objectives were therefore:

1. Develop a scientifically robust and biologically meaningful monitoring program
2. Provide information on oak populations and habitat relevant for management decision making.

These objectives were very broad but contained little specific information to guide its development. In the following section, we present specific objectives that address the broader goals and objectives.

Goal: Describe the current status of adult oaks in woodlands:

Objectives:

- Characterize woodland and tree “health”
- Assess the likely longevity / robustness of current adult trees
- Assess risks to adult trees
- Estimating pathogen prevalence and likely consequences to adult trees

Goal: Understand if oak woodlands are likely to persist in the future

Objectives:

- Estimate the number of seedlings and saplings
- Evaluate probable future recruitment/replacement rates
- Assess other controls on recruitment including fuel accumulation, understory composition and invasion

Goal: Evaluate the power and robustness of the monitoring program

Objectives:

- Quantify the variability associated with different observers
- Quantify the variability associated with different methods
- Quantify spatial variability in adult oak trees as well as recruits, disease, and other members of the understory community
- Quantify temporal variability in recruitment, disease and understory metrics.
- Evaluate the cost effectiveness of alternative monitoring designs

Project Timeline

The monitoring program was designed to be implemented in three stages (Table 1). In stage 1 the extent of the woodlands on NROC and TNC land holdings are mapped. In stage 2, preliminary data collection is conducted in order to evaluate and refine field methods. Data collected during stage 2 also establish a baseline understanding of the oak woodland community. Finally, in stage 3 a long-term monitoring program is adopted and data collection continues using the optimized methods that resulted from stages 1 and 2. The entire process is expected to take three or four years.

Table 1: Oak monitoring work plan.

		Yr 1	Yr 2	Yr 3	Yr 4	...
Phase 1 Woodland Extent						
a	Mapping	8 or more woodlands	-	Finish Mapping Woodlands	-	
Phase 2 Preliminary Field						
a	Indicator Trees	192 Trees	300-500 Trees	Partial Revisits	Partial Revisits	Sample sizes and return visits based on previous years results
b	Sentinel Trees	32 Trees	50-100 Trees	Partial Revisits	Partial Revisits	
Phase 3 Comprehensive						
a	Indicator Trees	-	-	-	Sample Size TBD by Phase 2a	Implement long term rotating panel design
b	Sentinel Trees	-	-	-	Sample Size TBD by Phase 2b	

Stage 1: Field Mapping Woodlands

Stage 1 was planned based on the assumption that the extent of woodlands could be assessed from satellite images and aerial photos. We found that identifying the boundaries of woodlands was particularly difficult, especially in coastal areas with dense and tall shrubs. Scrub oak species, *Rhus integrifolia*, *Heteromeles arbutrifolia* and occasionally *Malosma laurina* were often large enough to give the impression of full oak canopies from above. As a result, in images without shadows (taken during low or diffuse light conditions or during mid-day), we were unable to determine the boundaries of the oak woodlands. In fact, it was often unclear which canyons were filled with dense maritime chaparral and which were filled with oak trees (or a combination thereof).

As a result stage 1 became an (almost) entirely field-based exercise. Field crew used large-scale maps, and hand drew polygons around oak woodlands while they made observations from a high vantage point. We then digitized those boundaries in GIS and were able to use them to guide our sampling design and distribution of sampling locations

This field mapping was nearly completed in year 1 (2009). To our knowledge, only one woodland remains unmapped in the coastal reserve, on Emerald Canyon Road, between El Moro Ridge and Bommer Ridge Roads. This canyon lays at the boundary of Crystal Cove State

Park and Laguna Coast Wilderness and was inaccessible to our field crews during the first round of sampling. In the central reserve only woodlands on TNC easements were mapped. Of those woodlands parts of Limestone Canyon (Hangman's Tree Road) and Whiting Ranch remain unmapped. If possible, these woodlands will be mapped during the late summer of 2011.

Stage 2: Preliminary Field Work

In stage 2, pilot data were collected in order to evaluate field protocols, accumulate a baseline dataset and to compare alternative sampling designs. In our first field season, we revised our field protocols four times as we grappled with some of the challenges working in these woodlands. As a result, we were able to arrive at an acceptable set of protocols but we were only able to sample a modest number of easily accessible trees.

In 2010 we revised our sampling design, and implemented a modified cluster-sampling approach in order to reduce the amount of time spent transiting between trees. We also made some additional revisions to our response design to reflect the new clustered approach, and were able to achieve our sample size goals.

Stage 3: Comprehensive Monitoring Program (planned)

Stage 3 will begin in 2011 and will be the result of the improvements that were made in stages 1 and 2. Although we are confident of our field methods, estimating spatial and temporal variation requires large sample sizes across the reserves over many years. The full extent of temporal variability in these metrics will not be clear for several more years. Despite the lack of definitive data on temporal variation, we plan on adopting a final design in year 3. This design will be tested during subsequent years.

Methods

Monitoring forests can be accomplished through point sampling (individual trees) or plot sampling (predefined blocks of habitat). In this study, we opted for point sampling. This approach is likely to be more flexible and efficient in these irregularly-shaped riparian woodlands. Tree-based sampling is also more interpretable when trying to understand discrete processes such as infection, death, or per capita recruitment.

In 2009, we piloted the project, collecting data on 72 trees, focusing on refining protocols, and ensuring their repeatability between teams. Having achieved an initial estimate of spatial variability in oak woodlands, we then expanded our sample size to 275 trees in 2010, focusing on improving our estimates of spatial variability, and the relationships of numerous metrics of health with disease, recruitment and understory condition.

Sampling Design

We based our sampling design on individual adult trees (measuring 10cm DBH or greater). In 2009 all trees were sited randomly throughout a single reach in each woodland we visited (Figure 1, left panel). Woodlands were located in coastal and inland regions. Of the 72 individuals sampled, 54 were sampled using a rapid assessment method (indicator trees). The

remaining 18 were sampled using the rapid assessment method and a more detailed method (sentinel trees). Our goal was to assess the tradeoffs between collecting time intensive, detailed information, and acquiring a larger sample size with less information. In addition, the 18 sentinel trees were sampled by two teams in order to assess inter-team variability.

After reviewing this data, and calculating sampling and traveling times, it was apparent that spatial variability was a key factor for assessing woodland and tree health. We found that traveling through woodlands to locate randomly selected trees was very slow. As a result we sought to reduce the time traveling between trees, by moving from a completely random sample of trees to a clustered sampling design in 2010 (Figure 1, right panel). For this design every sentinel tree is randomly located. We then assessed three additional trees clustered around the sentinel tree in three fixed directions.

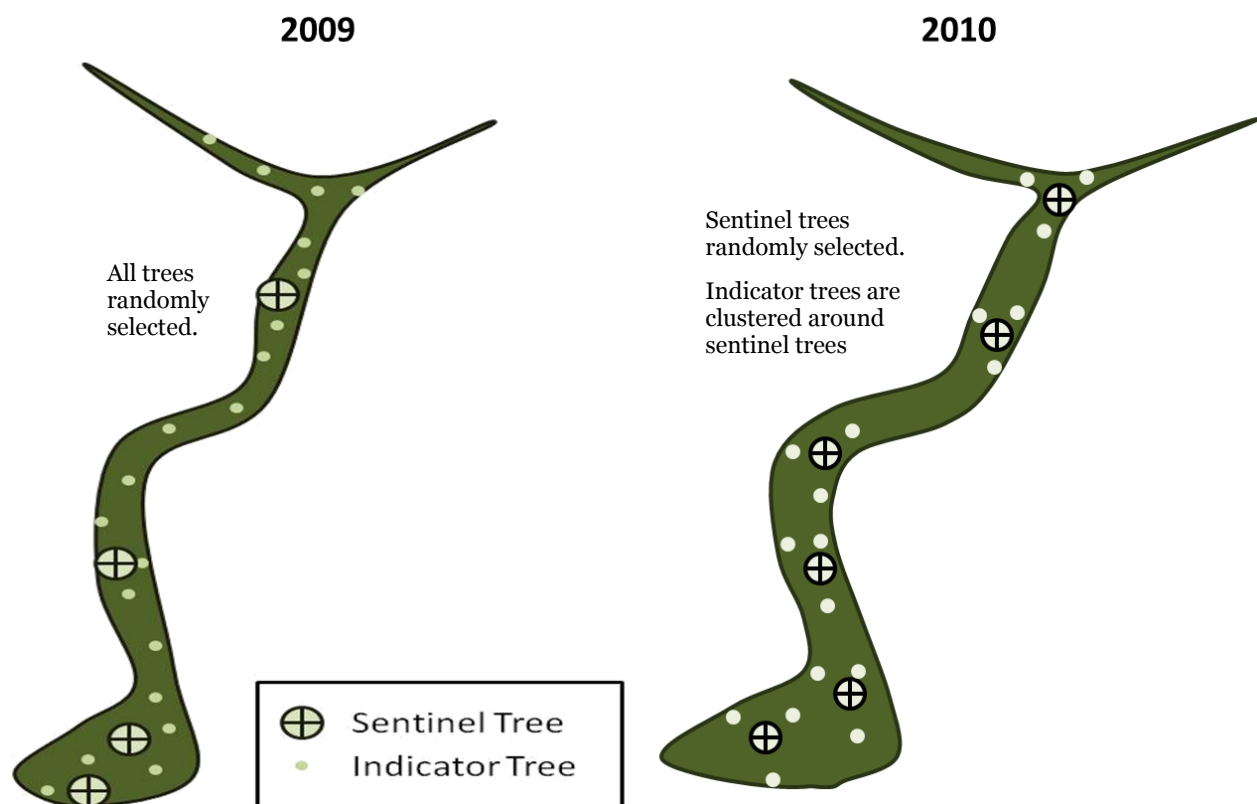


Figure 1: The sampling design in 2009 and 2010. In 2009 all trees were located randomly. In 2010 trees were clustered in groups of four (one sentinel and three cluster trees).

In 2010, we expanded our sample size to nine woodlands and 277 trees. We visited NROC/NCCP woodlands in the coast and woodlands on TNC easements inland (Table 2). Note that James Dilly Greenbelt Preserve was not sampled randomly, because oaks occurred in clusters of a few trees throughout a matrix of CSS and chaparral in the canyon bottom there.

Table 2:

Woodlands sampled in 2010 including name, ownership, and sample sizes.

*JDG was not sampled randomly due to the way oaks were aggregated in a CSS matrix.

Code	Coastal (NROC Lands)	Sentinel	Cluster	Total
AWC	Aliso-Wood Canyon	12	28	40
EMC	El Morro Canyon	8	20	28
JDG*	James Dilly Greenbelt	3	8	11
LCW-1	Laurel Canyon	12	23	35
LCW-3	NE of Toll Rd. x Laguna Canyon Rd.	8	23	31
Total		43	102	145

Code	Inland (TNC Easements)	Sentinel	Cluster	Total
BSC	East of Boy Scout Camp	11	26	37
FMC	Freemont Canyon	11	25	36
GYP	Gypsum Canyon	16	30	46
SSC	Shoestring Canyon	4	9	13
Total		42	90	132

Response Design

In both 2009 and 2010, we sampled trees using two protocols. A rapid protocol for many trees and a more detailed and time-consuming method for a smaller number of randomly selected trees (called sentinel trees). In 2009 trees assessed using both protocols were sampled independently and located randomly throughout the woodland. In 2010, we moved to a cluster sampling design in which rapid assessment trees were chosen around the randomly selected sentinel trees. The switch to a cluster design in 2010 necessitated a change in some protocols. Point intercept transects for understory and overstory condition were conducted between the main stems of the sentinel tree and each of three cluster trees in 2010, instead of under a sentinel tree as we did in 2009 (Figure 1). In 2009 transect length was determined by adding 50% of the canopy radius to either side of the drip line. In 2010 transect length was based on the distance between trees.

Cluster trees were selected based on their distance from the sentinel tree in three compass directions (northwest, northeast, and south). In order to ensure that transect lengths were reasonable distances we limited their length to 20m in closed, crowded woodlands and to 40m in open, sparse woodlands (Figure 2). If there was no tree on the exact compass bearing, we allowed teams to site cluster trees which were within our distance limitations and closest to the predetermined direction, within limits. In some cases there were fewer than three suitable cluster trees.

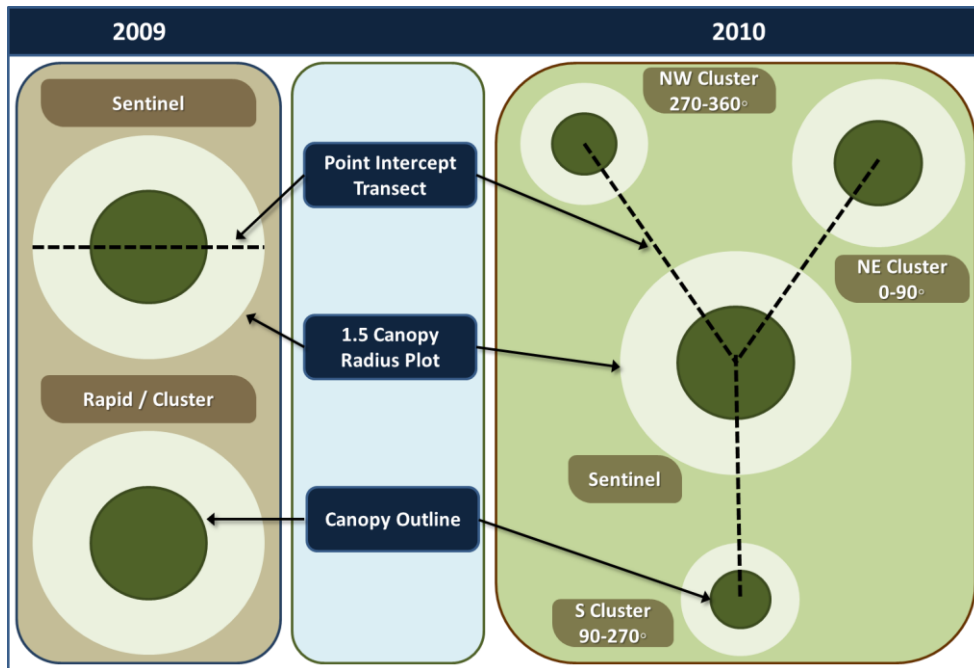


Figure 2: Response design conceptual diagram and comparison.

Tree Assessment

All trees (sentinel and indicator trees) were rapidly assessed for several health and structure metrics (Table 3). These include measures of tree size and vigor, levels of reproduction and recruitment, as well as signs and symptoms of disease. For the sentinel trees, teams began a more detailed inventory of recruitment and disease symptoms. First, teams drew a diagram of the sentinel tree plot marking locations of seedlings, saplings, and dead trees. As part of this effort, teams carefully counted the number of dead adult trees, seedlings (diameter at root crown <3cm) and saplings (between 3cm DRC and 10cm DBH) and other live adults. If a tree had several hundreds of seedlings, teams estimated the number using small $\frac{1}{2}$ m² quadrats. The canopy width was also measured, allowing us to estimate the seedling density per square meter of canopy. If there were acorns, team members took turns counting acorns for 30 seconds, and took the average of the result. Finally teams scrutinized each tree carefully for symptoms of diseases, and scored their presence or absence. Specific diseases were separated into several categories based on their primary symptom, and marked for their presence or absence (Table 4)

Table 3:
Metrics for rapid assessment of all trees.

Metric	Units or Levels	Description of Protocol
Single or Multi-Stemmed	Y/N	Visual assessment
Diameter at Breast Height	cm	Measured with DBH tape
Tree Height	m	Telescoping measuring pole
Height to Canopy	m	
Acorns	0-3 [none, 1-9, 10-99, 100+]	Visual assessment
Seedling	0-3 [none, 1-3, 4-6, 6+]	
Saplings	0-3 [none, 1-99, 100 999, 1000+]	
Canopy Thinning	0-4 [0, 1-10%, 11-49%, 50-75%, 75%+]	Visual assessment of canopy transparency
Dieback	Y/N	Visual assessment
Shelf Fungus		
Evidence of Boring		
Cankers and Rot		
Leaf Disturbance		

Table 4:
Evaluating oak diseases and pathogens at sentinel trees.

Metric	Potential Agent
Dieback	Oak anthracnose, branch cankers, gall wasps, lecanium scale, pit scales
Shelf Fungus	Sulfur fungus, hedgehog fungus, Hypoxylon, ganoderma root rot
Boring Damage	Ambrosia beetles, round-headed beetles, flat-headed beetles, carpenter worm
Cankers and Rot	Canker rot, wetwood, alcoholic flux
Leaf Disturbance	California oak worm, fruit tree leaf roller, woolly oak aphid, powdery mildew, oak mistletoe, oak ribbed casemaker