

# Monitoring Understory Composition of Blue Oak Woodlands on Conservation Easements<sup>1</sup>

Adena R. Rissman,<sup>2</sup> Sarah E. Reed,<sup>2</sup> Chuck Hughes,<sup>3</sup> and Richard Reiner<sup>4</sup>

## Abstract

Conservation easements are an increasingly popular strategy for conserving biological diversity on private land. Long-term vegetation monitoring on conservation easements can provide critical information on persistence of biological diversity and abundance of invasive species. We sampled understory plant composition on five of The Nature Conservancy's conservation easements in the Mt. Lassen foothills of Northern California. We established 73 plots of 10-meter radius, measured species composition with the point-intercept method, and compiled a full species list for each plot in 2005 and 2006. We found significant differences in the relative cover of native and non-native annual grasses and annual forbs among easement properties. Relative cover of native plants was significantly higher in herbaceous plots (50 percent) than in plots with blue oak (*Quercus douglasii*) canopy (21 percent). We found medusahead (*Taeniatherum caput-medusae*) in 64 percent of plots and yellow star thistle (*Centaurea solstitialis*) in 9 percent of plots. Overlap of species composition between years was correlated with difference in date sampled each year but not correlated with confidence in plot relocation. Our analysis of community diversity and relative abundance provides a baseline for future change. Finally, we make recommendations for the design of future monitoring efforts on conservation easements.

*Keywords:* Biological monitoring, conservation easements, Lassen foothills, plant diversity, point-intercept, *Quercus douglasii*.

## Introduction

Conservation easements are an increasingly popular tool for conserving private land in the United States (Merenlender and others 2004). Conservation easements are voluntary agreements between private landowners and a land trust or government agency to restrict land use in exchange for payment or tax reductions (Byers and Ponte 2005, Gustanski and Squires 2000). Conservation easements are also used as mitigation for development. California oak woodlands are more than 80 percent privately owned (Pavlik and others 1991), and conservation easements are an important tool for conserving biodiversity and working ranches on California oak woodlands (Sulak and others 2004). Recent scrutiny of conservation easement transactions (Reiterman 2005, Stephens and Ottaway 2003) has led to calls for

---

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

<sup>2</sup> Ph.D. Student, Department of Environmental Science, Policy, and Management, 137 Mulford Hall, University of California, Berkeley, CA 94720. e-mail: arissman@nature.berkeley.edu, sreed@nature.berkeley.edu

<sup>3</sup> Botanist, Sycamore Environmental Consultants Inc., 6355 Riverside Blvd Ste. C, Sacramento, CA 95831. e-mail: cchughes@pacific.net

<sup>4</sup> Ecologist, The Nature Conservancy, 500 Main St. Chico, CA 95928. e-mail: rreiner@tnc.org

additional monitoring on conservation easement properties (Kiesecker and others 2007, Rissman and others 2007a). Monitoring of easements can be divided into two general activities: compliance monitoring and ecological monitoring beyond compliance (Rissman and others 2007b). Compliance monitoring requires easement holders such as land trusts to periodically return to a property to assess whether the terms of the easement agreement are being upheld by the landowner. Ecological monitoring, the focus of this paper, differs from compliance monitoring in that it collects data on species and natural communities to provide assurance that easement agreements are effective in meeting conservation goals beyond the specific terms of the easement. Monitoring species composition alone cannot identify the drivers of vegetation change but can help assess whether diversity is retained on the easements over the long-term.

The Nature Conservancy acquired conservation easements on more than 71,000 acres in the Mt. Lassen foothills in Northern California to conserve blue oak woodlands and other conservation targets (The Nature Conservancy 2006). Because biodiversity protection is one of the primary goals of the Lassen foothills project, ecological monitoring is valuable for providing information on the status and trends of biodiversity elements in blue oak (*Quercus douglasii*) woodlands (Reiner and others 2001). We undertook an easement monitoring project to document the status of understory plant communities, avian communities, and oak woodland canopy structure, and to map the vegetation communities of the easements. In this paper, we focus on understory vegetation monitoring of blue oak woodlands and interspersed grasslands on the conservation easements. Two of the primary threats to the long-term persistence of blue oak woodlands are non-native plant invasion and poor oak recruitment (Pavlik and others 1991), and our focus on understory composition addresses both of these factors.

Understory vegetation is a common choice for monitoring because plants are generally sedentary and relatively easy to monitor, sensitive to site-specific variation (Spellerberg 2005) and because vegetation composition surveys can provide important information on common and rare native and invasive species. The vegetative understory of California oak woodlands is dominated by non-native annual grasses and forbs (Jimerson and Carothers 2002, Pavlik and others 1991). Unusual or poor soils and rock outcroppings can provide native species refuge from highly competitive invasive species (Anderson and others 1999). Portions of the Lassen foothills have thin, volcanic soils and exposed bedrock that supply habitat for native species with limited distributions.

Our primary objective was to characterize the understory vegetation of five conservation easements in the Lassen foothills region. Specifically, we compared indices of species diversity, native and non-native functional guilds, abundance of two invasive species medusahead (*Taeniatherum caput-medusae*) and yellow star thistle (*Centaurea solstitialis*), and presence of blue oak seedlings among easement properties. A comparison across easements can provide a greater understanding of the relative contribution of each property to protecting native plant diversity and help set priorities for land management including invasive species control. Next, we determined some of the site and landscape-scale factors that predict community composition. Finally, we assessed sampling error and used this information to provide recommendations for monitoring strategies for detecting patterns in species composition and change over time.

## Study Area and Methods

### Study Area

The study was conducted on five ranches in eastern Tehama and Shasta Counties, California. All of the ranches are within The Nature Conservancy's Lassen foothills project area, which was established in 1997 to protect the region's under-protected or rare species and natural communities. Among these conservation targets is a large and ecologically intact blue oak woodland landscape. Blue oak is endemic to California, occurs mostly on private lands, and is threatened by residential development and woodcutting in many parts of its range (Pavlik and others 1991). The Nature Conservancy's primary conservation strategy in the area is the purchase of conservation easements. These easements restrict development, woodcutting, and other extractive uses and allow the properties to be maintained as privately owned cattle ranches.

Blue oak woodlands in the Lassen foothills project area cover approximately 300,000 acres and range from dense stands to open savannahs. Scattered grey pine (*Pinus sabiniana*), California buckeye (*Aesculus californica*), and shrubs such as buckbrush (*Ceanothus cuneatus*) are interspersed. The understory is composed primarily of annual grasses and forbs.

The ranches sampled in this study are situated between 500 and 1,500 feet in elevation and vary from 1,000 to 10,000 acres in size. Each ranch was managed for livestock production with similar stocking rates and a long history of cattle grazing. January through May rainfall totaled 17 inches in 2005, and 26 inches in 2006 (California Climate Data Archive 2006). The soils originated from the volcanic Tuscan Formation laid down two to four million years ago over volcanic flows and older marine sediments. The Tuscan Formation is younger than much of the northern Sierra foothills and therefore has thinner soils and more exposed bedrock (California State University, Chico).

### Study Design

We established 73 plots of 10-meter radius (314 m<sup>2</sup>), locating between 12 and 24 plots on each of five recent conservation easement properties in 2005. In 2006 we added four plots for a total of 77 plots in that year, which included 61 blue oak-dominated plots and 14 herbaceous-dominated plots. Plots were located a minimum of 200 m apart to allow for avian point count sampling at the same locations, and to sample within large portions of each property. We collected species composition data in April and May of each year using two methods: point-intercepts and a full plot species list (macroplot). We employed the point-intercept method to provide a quantitative measure of relative cover. Each plot contained 81 point-intercept surveys, located every 0.5 meter along two 20-meter transects that bisected the plot in a North-South and East-West direction. We recorded all plants touching the pin and any overstory species above the pin. The full species list was recorded during a systematic search of each plot. Plots were relocated in 2006 using GPS with the addition of plot markers where private landowners provided permission to leave permanent markers. Plant nomenclature follows Hickman (1993).

## Statistical Analyses

Analysis of sampling effort and error, species diversity (alpha, beta), and community composition was performed in Microsoft Excel and JMP 6.0 (SAS Institute, Inc. 2005). Nonmetric multidimensional scaling (NMS) was performed in PC-ORD 4.2 (McCune and Grace 2002). All species identified in the point-intercept surveys were added to the macroplot data if they were missing from the macroplot species list due to observer error. For the ordination, plants were lumped by genus when not identifiable to species.

For comparisons of species richness we used data from the macroplot surveys. We calculated Shannon (H) diversity at the plot- and property-level using unique species and their proportions of total detections from the point-intercept survey data. For comparisons of beta diversity, we calculated the Jaccard ( $C_j$ ) index from point-intercept surveys, assuming that sample effort was equal among plots. We conducted one-way analyses of variance (ANOVA) to test for differences in mean values of diversity indices among properties. When we detected a significant difference among means, we used a Tukey-Kramer honestly significant difference (HSD) test to identify significant differences between pairs of means. However, the Tukey-Kramer HSD test is slightly conservative and may not detect significant pairwise differences even when the ANOVA result is significant (Gotelli and Ellison 2004).

We used data from the point-intercept surveys for all species composition comparisons, including relative proportions of species in different guilds, proportions of native species, and detections of critical invasive species. We compared functional guild composition for blue oak and herbaceous-dominated plots from 2006. The one plot in pasture and one plot in interior live oak (*Quercus wislizenii*) woodland were excluded from this comparative analysis. We estimated the extent and frequency of medusahead and yellow star-thistle invasions and blue oak seedling presence in all plots. To minimize variation due to seasonal detectability of these species, we pooled results from 2005 and 2006. We conducted one-way ANOVAs to test for differences in invasive species among properties, and used a Tukey-Kramer HSD test to identify significant differences between pairs of means. We conducted a nominal logistic regression to compare the probability of blue oak seedling occurrence among properties for the 61 blue oak woodland plots.

We chose NMS as an ordination method to characterize differences in community composition among plots and correlate community composition with environmental variables (McCune and Grace 2002). We used 2006 point-intercept data for 76 plots (one plot was excluded for lack of vegetation composition data). Environmental data were either extracted from a Geographic Information System (elevation and slope were obtained from a 10m digital elevation model in ArcGIS 9.0) or collected at each plot (vegetation type, property name, aspect, and percent cover of total vegetation, herbaceous vegetation, hardwood overstory, conifer overstory, low tree-tall shrub vegetation, low-mid shrub vegetation, rock, and bare ground). Point-intercept data were included as proportion of relative cover for each plot and species detected in fewer than 4 percent of plots were excluded. Environmental variables were relativized by the mean of each variable. We used the “slow and thorough” autopilot settings for NMS in PC-ORD with Sorensen’s distance measure, a random starting configuration, 40 runs with real data, six dimensions in the original model and three in the final model, and 90 iterations for the final solution. The final solution was considered stable for instability values lower than 0.0001.

We evaluated our sampling effort and error using data from both the point-intercept and full-plot species composition surveys. We compared the number of species detected using each sampling method and fit a species accumulation curve to the 2006 point-intercept surveys to estimate the total number of species occurring in each plot. We also compared the species composition for each plot between 2005 and 2006. We then ran a forward stepwise regression to determine whether the proportion of species shared between 2005 and 2006 was predicted by the difference in date sampled each year and by a categorical variable indicating our confidence in returning to the same spatial location both years (the 2006 plot was either within inches of the 2005 plot, within several meters of the 2005 plot, or was located solely based on GPS and therefore within about 10 m of the 2005 plot).

## Results

### *Species Diversity*

We detected  $43.3 \pm 9.2$  (mean  $\pm$  SD) species in each macroplot surveyed in 2005, and  $43.3 \pm 9.9$  (mean  $\pm$  SD) species in 2006. We did not detect a significant difference in mean species richness among the five easement properties in 2005 ( $F_{4,68} = 1.63$ ,  $p = 0.18$ ). In 2006, we did detect a significant difference in mean species richness among properties ( $F_{4,72} = 2.92$ ,  $p < 0.05$ ). Ranch A ( $S = 47.1$ ) and Ranch E ( $S = 38.1$ ) properties had the greatest difference in mean species richness; however, a Tukey-Kramer HSD test did not reveal significant differences between any pairs of means.

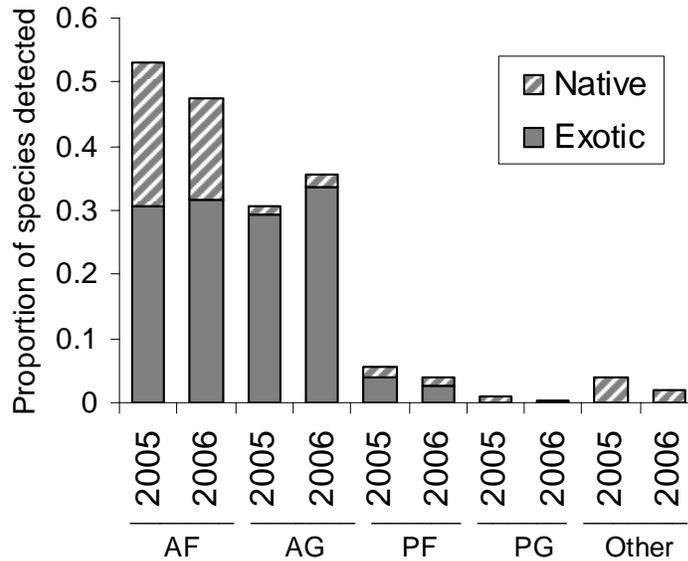
We also used the Shannon (H) index to test for differences in species diversity among plots and properties, accounting for both the number and relative dominance of species. Because we did not detect a significant difference in species richness between years, we limited our analysis to data collected in 2006. Shannon (H) diversity values were not significantly different among properties ( $F_{4,72} = 0.62$ ,  $p = 0.65$ ), with a plot value of 2.24 and a property value of 3.03.

Finally, we tested for differences in species turnover among plots on each property, using the Jaccard index ( $C_j$ ) of beta diversity. Values of the Jaccard index are one when all species are shared among plots, and zero when no species are shared. Jaccard values were significantly different among properties ( $F_{4,621} = 16.5$ ,  $p < 0.001$ ). Plots on Ranch E had significantly greater similarity (Mean( $C_j$ ) = 0.35) than the other four properties, while pairs of plots on Ranch C shared significantly fewer species (Mean( $C_j$ ) = 0.20) than the other four properties.

### *Functional Guilds*

We assessed community composition by functional guild for native and non-native annual and perennial grasses, annual and perennial forbs, ferns, non-graminoids, and shrubs. Annual forbs and grasses dominated the vegetative cover on all properties (*fig. 1*). Annual forbs were 53 percent and annual grasses were 31 percent of relative cover in 2005, and 48 percent and 36 percent, respectively, in 2006. In 2005, there were no significant differences in the mean proportion of annual forb species among properties ( $F_{4,68} = 2.14$ ,  $p = 0.09$ ), but we did find a significant difference in the mean proportion of annual grasses ( $F_{4,68} = 5.94$ ,  $p < 0.001$ ). Plots on Ranch A had a significantly lower proportion of annual grasses ( $P_{AG} = 0.247$ ) than plots on Ranch E ( $P_{AG} = 0.334$ ), Ranch D ( $P_{AG} = 0.325$ ), or Ranch C ( $P_{AG} = 0.322$ ). In 2006, we found

significant differences in the mean proportions of annual forbs ( $F_{4,72} = 3.23$ ,  $p < 0.05$ ) and annual grasses ( $F_{4,72} = 11.00$ ,  $p < 0.001$ ) among properties. Plots on Ranch A had a significantly greater proportion of annual forbs ( $P_{AF} = 0.533$ ) than plots on Ranch E ( $P_{AF} = 0.436$ ). Plots on Ranch A also had a significantly lower proportion of annual grasses ( $P_{AG} = 0.265$ ) than the other four properties.



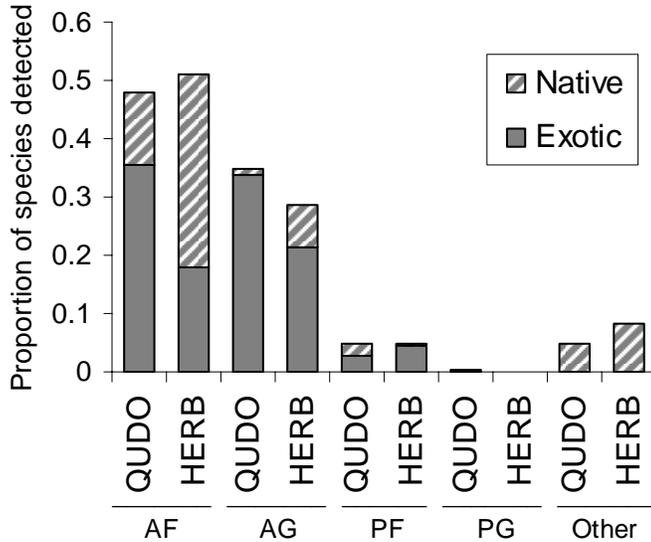
**Figure 1**—Mean relative cover of different functional guilds, for all properties, in 2005 and 2006 from point-intercept data. Proportions of native and exotic species are indicated for each guild. (AF = annual forb, AG = annual grass, PF = perennial forb, PG = perennial grass, Other = ferns, non-graminoids and shrubs.)

Our surveys indicated that all five properties were substantially invaded by non-native species. Native species comprised 30 percent of cover in 2005 and 22 percent in 2006 (*fig. 1*). In 2005, we detected a significant difference in mean proportions of native species among properties ( $F_{4,68} = 4.89$ ,  $p < 0.01$ ). Plots on Ranch A had a significantly greater proportion of native species ( $P_{NATIVE} = 0.387$ ) than Ranch E ( $P_{NATIVE} = 0.235$ ) and Ranch B ( $P_{NATIVE} = 0.226$ ). In 2006, we did not detect a significant difference in mean proportions of native species among properties ( $F_{4,72} = 1.39$ ,  $p = 0.25$ ), but the rank order of properties was the same as in 2005.

The ten most abundant species made up more than half (59 percent) of relative cover in both 2005 and 2006. Nine of the ten most abundant species each year were in the top ten both years. These were all non-native species: *Bromus hordeaceus*, *Bromus diandrus*, *Taeniatherum caput-medusae*, *Trifolium hirtum*, *Erodium botrys*, *Avena barbata*, *Aira caryophylla*, *Geranium molle*, and *Trifolium dubium*. While native cover was low, native diversity was high: native species made up 157 of 212 species detected in the macroplots in 2006.

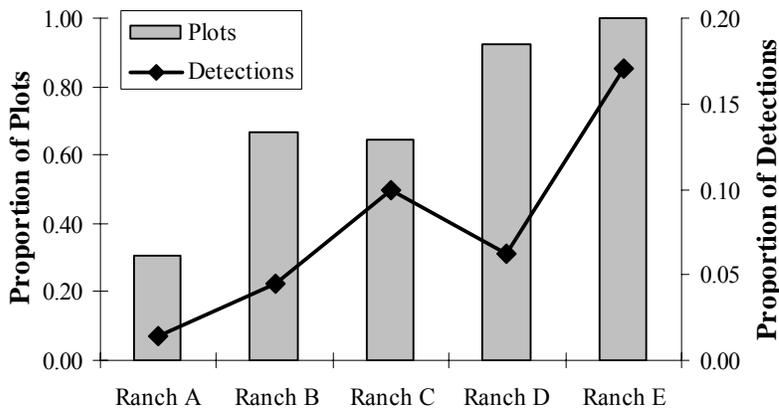
We did not detect a significant difference in the mean proportion of annual forb species between herbaceous- and blue oak-dominated plots ( $t_{73} = 1.03$ ,  $p = 0.31$ ), but we did detect a significant difference in the mean proportion of annual grass species ( $t_{73} = 2.28$ ,  $p < 0.05$ ) (*fig. 2*). Plots under the blue oak canopy had a significantly greater proportion of annual grasses ( $P_{AG} = 0.347$ ) than plots in herbaceous-dominated areas ( $P_{AG} = 0.287$ ). We also detected a significant difference in mean

proportions of native species between plots in different vegetation community types ( $t_{73} = 8.63, p < 0.001$ ). Plots in herbaceous-dominated areas had a significantly greater proportion of native species ( $P_{\text{NATIVE}} = 0.492$ ) than plots under the blue oak canopy ( $P_{\text{NATIVE}} = 0.214$ ).



**Figure 2**—Mean relative cover of different functional guilds for the 14 herbaceous plots (HERB) and 61 blue oak-dominated plots (QUDO) in 2006. (AF = annual forb, AG = annual grass, PF = perennial forb, PG = perennial grass, Other = ferns, non-graminoids and shrubs.)

Overall, we detected medusahead on 64 percent of plots, ranging from 31 percent of plots on Ranch A to 100 percent of plots on Ranch E. We found significant differences in the relative cover of medusahead among properties ( $F_{4,72} = 11.61, p < 0.001$ ). Medusahead accounted for a significantly greater proportion of detections on Ranch E ( $P_{\text{TCM}} = 0.170$ ) and Ranch C ( $P_{\text{TCM}} = 0.100$ ) than on the other three properties (fig. 3).



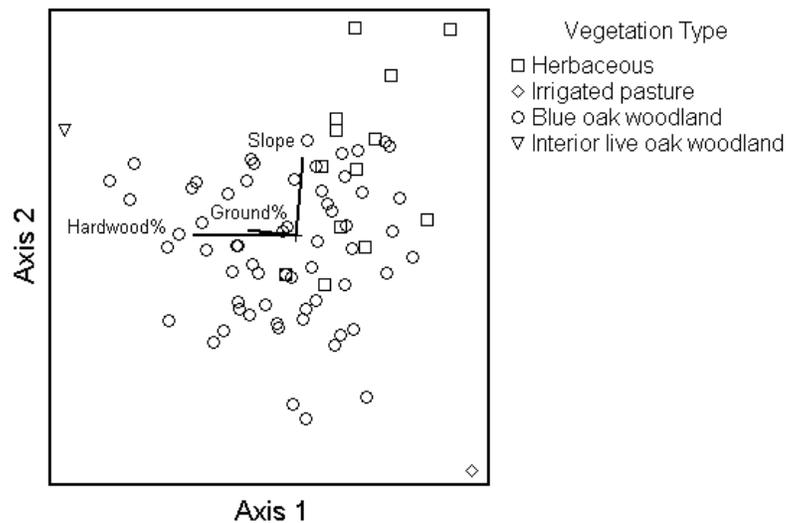
**Figure 3**—Prevalence of medusahead (*Taeniatherum caput-medusae*) on all properties from pooled data for 2005 and 2006.

We detected yellow star thistle on 9 percent of plots on all properties, ranging from no plots on Ranch E to 25 percent of plots on Ranch B. We did not find a significant difference in the relative cover of yellow star thistle among properties ( $F_{4,72} = 0.582, p = 0.68$ ). We did not find the invasive species goat grass (*Aegilops triuncialis*) or false brome (*Brachypodium distachyon*).

Blue oak seedlings were found in 69 percent of all plots. We found significant differences in the presence of blue oak seedlings among properties on blue oak woodland plots ( $\chi^2_{4,56} = 10.54, p = 0.03$ ). Of blue oak woodland plots, 100 percent contained a blue oak seedling on Ranch E in either 2005 or 2006, followed by 91 percent on Ranch D, 71 percent on Ranch A, 64 percent on Ranch B, and 60 percent on Ranch C.

### Ordination—Community Composition

The NMS ordination plot indicates the structure of species composition by vegetation type (fig. 4). The three environmental variables that had the strongest correlation with the ordination axes were slope, percent hardwood canopy cover, and percent cover of bare ground. Elevation, aspect, shrub percent cover, total vegetation cover, and rock cover were not influential factors in the ordination analysis, with  $r^2$  values less than 0.2.

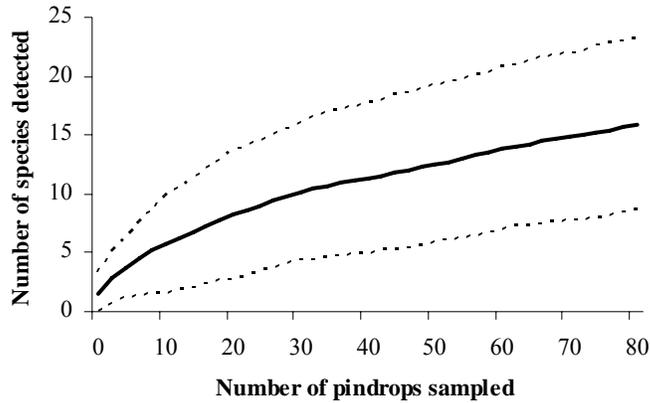


**Figure 4**—Nonmetric multidimensional scaling graph. Plots farther apart have greater differences in species composition. The three environmental variables depicted in the chart are correlated with species composition.

The NMS model indicated that herbaceous plots share the composition of dominant species. As we expected, cover of hardwood vegetation, mostly blue oaks, was strongly correlated with understory species composition. Our final model had a stress level of 15.95, which is typical for ecological research; values above 20 indicate questionable models (McCune and Grace 2002).

### Sampling Effort and Error

The mean sample accumulation curve for all plots in 2006 had a positive slope (*fig. 5*), indicating that point-intercept surveys were not adequate to detect the complete species community present in the plot.



**Figure 5**—Species accumulation curve for point-intercept surveys, averaged for all plots in 2006. The mean and 95 percent confidence intervals of the cumulative number of species detected are plotted against the number of points sampled in each plot.

Point-intercept surveys identified a mean of 36 percent of species found in the macroplot (*table 1*). In order to detect all species with point-intercepts that we found in the macroplots, we estimated needing to increase our effort from 81 to approximately 80,000 hits per plot.

**Table 1**—Mean numbers of species detected in macroplots and with point-intercept surveys in 2006. On average, point-intercept surveys detected 36 percent of species identified in macroplots.

| Property | n<br>(Plots) | Macroplots<br>(Mean/plot) | Point-intercept<br>(Mean/plot) |
|----------|--------------|---------------------------|--------------------------------|
| Ranch A  | 26           | 47.1                      | 16.1                           |
| Ranch B  | 12           | 42.0                      | 15.7                           |
| Ranch C  | 14           | 45.6                      | 15.9                           |
| Ranch D  | 13           | 39.1                      | 15.1                           |
| Ranch E  | 12           | 38.1                      | 14.0                           |
| Mean     | 15.4         | 42.4                      | 15.3                           |

We found substantial error in the species detected between years; a mean of 55 percent of total species detected at each plot were found in both the 2005 and 2006 macroplot surveys (*table 2*).

**Table 2**—Between-year variation in species detected in macroplot surveys. “Total species” is the total number of unique species detected in a plot over two years (2005 and 2006), and “shared species” is the number of those species that were detected in both years. The mean proportion of species shared between 2005 and 2006 is 0.55 for all properties.

| <b>Property</b> | <b>n (Plots)</b> | <b>Total species (Mean/plot)</b> | <b>Shared species (Mean/plot)</b> | <b>P(Shared) (Mean/plot)</b> |
|-----------------|------------------|----------------------------------|-----------------------------------|------------------------------|
| Ranch A         | 24               | 59.3                             | 34.6                              | 0.58                         |
| Ranch B         | 12               | 50.8                             | 29.9                              | 0.59                         |
| Ranch C         | 13               | 56.1                             | 33.0                              | 0.61                         |
| Ranch D         | 12               | 53.6                             | 27.9                              | 0.52                         |
| Ranch E         | 12               | 54.3                             | 25.0                              | 0.46                         |
| Mean            | 14.6             | 54.8                             | 30.1                              | 0.55                         |

Proportion of overlap in species found each year was correlated with difference between the date sampled each year ( $r^2_{\text{adj}} = 0.14$ ,  $p = 0.001$ ). This relationship is driven by six plots sampled in early April 2005 and mid May 2006. We expected that a higher level of confidence in returning to the same spatial location as the previous year’s plot would be significantly correlated with the proportion of shared species, but this was not the case, even when the effect of difference in date sampled was accounted for in the model ( $F_{2,68} = 0.91$ ,  $p = 0.34$ ).

## Discussion

### ***Species Diversity and Functional Guilds***

Like most California oak woodlands, the properties we surveyed were dominated by non-native annual grasses and forbs but still contained considerable richness of native species, particularly native annual forbs. The species richness we detected is consistent with an estimate of species richness for grazed California oak savannah (Keeley and Fotheringham 2003). Total plant richness did not differ significantly among properties, although some properties showed differences in functional guilds. Ranch A, located at lower elevation and farther south than Ranches B-E, had a higher proportion of annual forbs and lower proportion of annual grasses than the other ranches, perhaps because of its thinner soils and steeper slopes.

California oak woodlands have experienced dramatic shifts in dominant species over the past century (Heise and Merenlender 2002). While we found considerable variability in species composition between years, the dominant species remained consistent. Our sampling design provides a quantitative estimate for dominant species abundance that can be used as a baseline for future change.

Conservation of blue oaks and native plants are both important goals for easement acquisitions. We found that native plant richness is highest in plots without blue oak canopy. Because these two conservation goals are not compatible at small spatial scales, the properties best able to meet both of these goals will contain a patchwork of blue oak stands and herbaceous areas of high native diversity.

### **Medusahead and Yellow Star Thistle**

Identifying infestations of problematic invasive plants such as medusahead and yellow star thistle can help managers and landowners direct prescribed fire and grazing management programs. Medusahead is widespread on the properties, while yellow star thistle is less common and variable among properties. One study of experimental grazing and fire treatments on Lassen foothills easements indicates that medusahead can be reduced through early summer prescribed burning and winter-spring grazing programs although effects vary by site and native richness may not increase in the short-term (Caroline Christian unpublished data). Communities with lower functional diversity may be more susceptible to invasion from yellow star thistle (Zavaleta and Hulvey 2004) although the relationship between species diversity and invasion appears to be scale dependent (Davies and others 2005).

The absence of goat grass or false brome either on- or off-plot provides important baseline information. Because goat grass can thrive in poor, thin soils it poses a significant threat to the areas of highest plant diversity on the easement properties (DiTomaso and others 2001).

### **Rare Species and Blue Oak Regeneration**

The study was not explicitly designed to sample habitat for rare species, but several rare plants were detected in or between plots, including three California Native Plant Society list 4.3 species, *Polygonum bidwelliae*, *Mimulus glaucescens*, and *Astragalus pauperculus*. Regeneration and recruitment of blue oaks is another significant issue in California oak woodlands, as several studies report a decline in blue oak woodlands due to adult mortality without sufficient recruitment of young oak trees (for example, Bartolome 1987). Blue oak seedlings were common in woodland plots but we found few blue oak, interior live oak, grey pine, or buckeye saplings. Further study of oak woodland population structure could indicate the rates of oak regeneration and oak mortality on the easement properties.

### **Ordination**

Slope, hardwood percent cover, and bare ground cover were significant factors in the ordination analysis of understory community composition. Plots in pasture and interior live oak woodland were clearly separated in composition from the other plots. Some herbaceous plots shared similar species composition as plots under a blue oak canopy, but most had distinctive species composition that separated them from blue oak plots. Other factors we did not measure that could be significant in an analysis of environmental variables include soil moisture, soil depth, soil nutrients, fire history, and current and historic grazing pressure.

### **Sampling Error and Data Limitations**

Improving monitoring protocols requires an understanding of the limitations of collected data. The point-intercept sample-effort curves continued to rise, indicating that the point-intercept method did not capture all understory species within the blue oak woodland and herbaceous communities. We did not anticipate quantifying all species with the point-intercept analysis, and therefore complimented the quantitative point-intercept surveys with the qualitative macroplot, as well as an off-plot species list for understory plants not observed in the plots. One major source of error in

comparing data between years is that some landowners did not want permanent markers left on their ranches—52 percent of plots were relocated using only a GPS location, and could have been 10 m from their location the previous year. While this was not a significant variable in the analysis of species difference between 2005 and 2006, it clearly limits the ability to detect change over time using plot data. We were ultimately able to mark plots at the end of the study, using either tree tags or buried metal objects, in addition to site establishment photos, which will allow the plots to be relocated in future years. Differences in phenology between years could also cause errors in detection of species change. Working on private land presents many challenges for site access, including the added logistical difficulty of revisiting sites at the optimal time to match phenology between years. In this case, The Nature Conservancy facilitated ecological research on the easement properties, but not all non-profit or government easement holders have the right to undertake such monitoring on their conservation easements.

### ***Recommendations for Conservation Easement Monitoring in Oak Woodlands***

Repeatable ground vegetation measurements are of great value as baselines for conservation areas, and early investment in this type of data is critical. Monitoring should be long term, and permanent plot markers should be considered to allow for greater change detection over time. Allowances for permanent plot markers could become a standard part of conservation easements agreements in which protection of understory diversity is an important concern. Although the availability and quality of satellite imagery and aerial photography will continue to improve over time, understory species diversity must be captured through field surveys in a relatively short time window during the peak blooming season. California oak woodlands have high inter-annual variability and are a non-equilibrium system in which changes in plant cover are expected to follow a state and transition model with steady vegetative states punctuated by rapid changes in plant composition (Jackson and Bartolome 2002, Westoby and others 1989). Design of a monitoring program must therefore anticipate high variability at a small spatial scale as well as the possibility of dramatic shifts in vegetation composition.

One drawback for selecting random sites for avian point counts and then using these points for vegetation sampling was that some plots were heterogeneous from a plant community perspective. When combining bird and plant sampling, it may be important to design the sampling first with plants in mind as they respond to finer changes in geology and overstory composition and then locate the plots far enough apart to allow for independent avian point counts.

Combining the point-intercept method with an inventory of all plants in a plot provides an efficient quantitative estimate of cover and a complete species list that is more likely to capture rare species. In addition, this type of monitoring can provide important information on change in species diversity and abundance over time. Evaluating easement effectiveness in protecting biodiversity may also require research on grazing and fire effects to determine the causes of biodiversity change in combination with long-term monitoring data. It is reasonable to expect that land management practices influencing plant diversity could be controlled by a conservation easement. However, landscape scale changes from climate change, species invasions, and pollution may be beyond the reach of an easement to control. Understory diversity surveys in oak woodlands can provide an important baseline for

future change and help quantify the benefits of conservation easements as a conservation strategy.

## Acknowledgements

We thank Adina Merenlender of UC Berkeley for support throughout the project. Ryan Burnett of PRBO Conservation Science consulted on study design; Todd Keeler-Wolf and California Native Plant Society staff Julie Evens and Josie Crawford provided vegetation sampling training; Barbara Allen-Diaz of UC Berkeley assisted with ordination analysis; Peter Hujik provided logistical support through the Dye Creek Preserve; and landowners provided access to their ranches. This research was funded through The Nature Conservancy by the United States Fish and Wildlife Service and the CALFED Bay-Delta Program. A.R.R. was funded by the National Science Foundation Graduate Research Fellowship Program.

## References

- Anderson, R.C.; Fralish, J.S.; Baskin, J.M. 1999. **Savannas, barrens and rock outcrop communities of North America**. Cambridge, United Kingdom: Cambridge University Press; 480 p.
- Bartolome, J.W. 1987. **California annual grassland and oak savannah**. *Rangelands* 9(3): 122-125.
- Byers, E.; Ponte, K.M. 2005. **The conservation easement handbook, 2<sup>nd</sup> edition**. San Francisco, California: The Trust for Public Land and Washington D.C.: Land Trust Alliance.
- California Climate Data Archive. **Coleman fisheries station**. <http://calclim.dri.edu/data.html> Accessed online October, 2006.
- California State University, Chico. **Virtual field trip: Geologic lessons in the Northern California foothills, Tuscan Formation**. <http://www.csuchico.edu/atec/projects/tigers/site/formations/tuscan.html> Accessed online August, 2006.
- Davies, K.F.; Chesson, P.; Harrison, S.; Inouye, B.D.; Melbourne, B.A.; Rice, K.J. 2005. **Spatial heterogeneity explains the scale dependences of the native-exotic diversity relationship**. *Ecology* 86(6): 1602-1610.
- DiTomaso, J.M.; Heise, K.L.; Kyser, G.B.; Merenlender, A.M.; Keiffer, R.J. 2001. **Carefully timed burning can control barb goatgrass**. *California Agriculture*. Volume 55(6): 47-53.
- Gotelli, N.J.; Ellison, A.M. 2004. **A primer of ecological statistics**. Sunderland, MA: Sinauer Associates Inc.; 510 p.
- Gustanski, J.A.; Squires, R.H. 2000. **Protecting the land: conservation easements past, present, and future**. Washington D.C.: Island Press.
- Heise, K.L.; Merenlender, A.M. 2002. **Monitoring a half-century of change in a hardwood rangeland**. *Journal of Range Management* 55:412-419.
- Hickman, J.C. 1993. **The Jepson manual: higher plants of California**. Berkeley, CA: University of California Press; 1400 p.
- Jackson, R.D.; Bartolome, J.W. 2002. **A state-transition approach to understanding nonequilibrium plant community dynamics in Californian grasslands**. *Plant Ecology* 162: 49-65.

- Jimerson, T.M.; Carothers, S.K. 2002. **Northwest California oak woodlands: environment, species composition and ecological status.** USDA Forest Service Gen. Tech. Rep. PSW-GTR-184.
- Keeley, J.E.; Fotheringham, C.J. 2003. **Species-area relationships in Mediterranean-climate plant communities.** *Journal of Biogeography* 30(11): 1629-1657.
- Kiesecker, J.M.; Amaon, G.; Comendant, T.; Grandmason, T.; Gray, E.; Hall, C.; Hilsenbeck, R.; Kareiva, P.; Lozier, L.; Naehu, P.; Rissman, A.R.; Shaw, M.R.; Zankel, M. 2007. **Conservation easements in context: a quantitative analysis of their use by The Nature Conservancy.** *Frontiers in Ecology and the Environment* 5(3): 125-130.
- McCune, B.; Grace, J. 2002. **Analysis of Ecological Communities.** MjM Software Design.
- Merenlender, A.M.; Huntsinger, L.; Guthey, G.; Fairfax, S.K. 2004. **Land trusts and conservation easements: who is conserving what for whom?** *Conservation Biology* 18: 65-75.
- Pavlik, B.M.; Muick, P.C.; Johnson, S.G.; Popper, M. 1991. **Oaks of California.** Los Olivos, CA: Cachuma Press, Inc.; 184 p.
- Reiner, R.; Underwood, E.; Niles, J.O. 2001. **Monitoring conservation success in a large oak woodland landscape.** 5<sup>th</sup> Oak Woodland Symposium Proceedings. October 22-25, 2001. San Diego, California.
- Reiterman, T. 2005. **Ranch's easement spawns controversy.** *Los Angeles Times* August 15 2005.
- Rissman, A.R.; Lozier, L.; Comendant, T.; Kareiva, P.; Kiesecker, J.M.; Shaw, M.R.; Merenlender, A.M. 2007a. **Conservation easements: biodiversity protection and private use.** *Conservation Biology* 2007, 21(3): 709-718.
- Rissman, A.R.; Reiner, R.; Merenlender, A.M. 2007b. **Monitoring natural resources on rangeland conservation easements.** *Rangelands* 2007, 29(3): 21-26.
- SAS Institute, Inc. 2005. **JMP user's guide.** Cary, NC: SAS Institute, Inc.
- Spellerberg, I.F. 2005. **Monitoring ecological change, 2<sup>nd</sup> edition.** Cambridge, United Kingdom: Cambridge University Press; 410 p.
- Stephens, J.; Ottaway, D.B. 2003. **Donors reap tax incentive by giving to land trusts, but critics fear abuse of system.** *The Washington Post*; Dec 21, 2003.
- Sulak, A.; Huntsinger, L.; Standiford, R.; Merenlender, A.; Fairfax, S.K. 2004. **A strategy for oak woodland conservation: The conservation easement in California** In: Symposium on Sustainability of Dehesas, Montados and other Agrosilvopastoral Systems, September 21 -24, 2003, Caceres, Spain. *Advances in Geoecology*: 353-364.
- The Nature Conservancy. 2006. **Lassen foothills webpage.**  
<http://www.nature.org/wherewework/northamerica/states/california/preserves/> Accessed online August, 2006.
- Westoby, M.; Walker, B.; Noy-Meir, I. 1989. **Opportunistic management for rangelands not at equilibrium.** *Journal of Range Management*. 42(4): 266-274.
- Zavaleta, E.S.; Hulvey, K.B. 2004. **Realistic species losses disproportionately reduce grassland resistance to biological invaders.** *Science* 306: 1175-1177.

Continue