Improving statistical sampling and vegetation monitoring for the NROC reserves in central Orange County: ***Year 2***

2008 Final Report

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EXECUTIVE SUMMARY

Monitoring to detect ecological change is an important component of many environmental and conservation programs. The Nature Reserves of Orange County (NROC) hold 38,000 acres enrolled within the Orange County NCCP. NROC is obligated to monitor the condition of conserved lands through time and has identified vegetation communities as targets for long term monitoring. Monitoring this large and heterogeneous area is scientifically and logistically challenging as well as costly. The objective of this project is to evaluate the cost and accuracy of different sampling designs and field protocols for monitoring coastal sage scrub (CSS), chaparral, and grassland vegetation communities.

This report covers year two of an ongoing project. The current work emphasizes the importance of spatial coverage across the study area. As a result, we increased the number of sites and plots sampled from the first year of the project. We also eliminated the visual cover protocol and decreased the length of the transects and the number of quadrats at each plot. This year we detected a large increase in plant species richness throughout the county. This was driven largely by the increased diversity of forbs at resampled plots. Shrub cover varied spatially but was similar across years. In addition to richness, the cover of native and non-native forbs and grasses increased dramatically.

We used a variance components analysis in order to develop recommendations for optimizing monitoring. We consider three major sources of variation: temporal (interannual), spatial and methodological. Spatial variation includes three nested levels: vegetation community, site and plot. Methodological variation includes two levels: protocol (quadrat vs. point intercept) and team. Several suites of response variables were analyzed including species richness, cover of major functional groups (e.g. native shrubs, non-native forbs), and several example species from each functional group.

Semi-arid shrublands in southern California are highly spatial, with different species and functional groups displaying different degrees of affinity for a specific vegetation type or a different degree of patchiness across sites and plots. As a result allocating a significant amount of effort to spatial coverage is appropriate for most response variables. Some species and groups are also dramatically influenced by annual factors such as rainfall, and will require annual monitoring. Team-to-team variability is small and can be minimized with appropriate training and experience. Transects provide the most accurate and precise estimates of cover for individual species and functional groups. Quadrats provide more information on richness and presence of uncommon or small species, but systematically underestimate cover.

Our data demonstrate that response variables vary across natural spatial gradients and temporal variability, and that the two principal field protocols capture different aspects of the ecosystem. The best monitoring approach must be determined based on the objective(s) and response variable(s) of interest for each individual project. The development of an accurate and efficient monitoring program will require a renewed discussion of the specific goals and objectives of the overall monitoring program.

Table of Contents

List of Tables

List of Figures

INTRODUCTION

Monitoring to detect ecological change is an important component of many environmental and conservation programs. In fact, monitoring seems to be an almost automatic response to any perceived ecological threat (Larsen et al. 2001; McDonald 2003; Legg and Nagy 2006; Sims et al. 2006). Monitoring is a required element of all HCP and NCCP permits and is critical to assess whether large-scale multi-species programs are meeting their stated objectives (Atkinson et al. 2004; Barrows et al. 2005; Rahn et al. 2006; Sims et al. 2006). Developing effective monitoring programs for conservation plans is scientifically and logistically challenging (Fuller 1999; McDonald 2003; Legg and Nagy 2006) and many monitoring programs have been criticized as naïve, inefficient, and in many cases, inadequate (NRC 1995; Legg and Nagy 2006; Rahn et al. 2006). Recently the science and art of monitoring has improved in response to the criticism of earlier efforts (McDonald 2003; Atkinson et al. 2004).

Despite nearly a century of interest in monitoring population dynamics, the process remains challenging (NRC 1995; Fuller 1999; Greer 2003; Barnett 2004). One challenge has been the difficulty in applying traditional statistical theory and methods to biological monitoring. In classical statistical sampling theory, the units under study are usually simple and easy to define (people in an opinion poll or widgets produced by a factory). In biological monitoring, the units sampled are often complex and can take many forms including habitat patches, liters of lake water, or variable-length transects flown from an aircraft. In addition, ecosystems are structured in complex ways based on genetic factors, habitat quality, environmental variability, and accidents of history.

Stevens and Urquhart (2000) distinguish two conceptually separate and distinct aspects of monitoring (see also Larsen et al. 2001). One aspect is the **"sampling design"** which they define as the process of specifying where to select population units or points. The other aspect is the "**response design"** defined as the process of deciding what to measure and how to measure it. This separation of the selection of sampling units (sampling design) from the process of measuring attributes of the selected units (response design) helps clarify the different aspects of monitoring (Larsen, Kinkaid et al. 2001).

The sampling design must address several related questions.

- How many and which sites should be included in the initial sample?
- Whether and how often sites should be revisited?
- Should the sampling design be allowed to change as more data becomes available?
- How should the samples at different times be related?

The answer to these questions depends on the relative importance of description of status vs. detection of trend, and the magnitude and scale of spatial and temporal heterogeneity. Developing an efficient monitoring program requires the matching of sampling effort to variability encountered. In a sense, this is analogous to optimal allocation of sampling effort in stratified random sampling ("Neyman allocation", Barnett 1974). Under this allocation strategy, effort should be allocated to more variable strata and less costly strata. In a monitoring program, allocation of effort for describing status and trend should be proportional to levels of spatial and temporal variability, respectively (Larsen et al. 2001; Sims et al. 2006).

Common designs range from selecting a small number of sites and revisiting them each sampling period which emphasizes estimation of trend, to selecting new sites each period, which emphasizes estimation of status. Many monitoring designs balance the relative effort allocated to estimating status and trend (McDonald 2003). One such design calls for sampling several alternative sets of sites. Typically sites are divided into a few groups, say 3, and then each group is visited in a repeating sequence like 1 – 2 – 3 – 1 – 2 – 3. In this design, all selected sites are revisited, but not during every sampling period.

The response design is defined as determining what to measure, count or observe (Stevens and Urquhart 2000). The response design is often more closely linked to the specific questions being asked (Larsen et al. 2001). Common response designs for vegetation sampling include **visual estimation** (Sykes et al. 1983; Mitchell et al. 1988; Sawyer and Keeler-Wolf 1995; Klimes 2003; Carlsson et al. 2005; Podani 2006; Podani and Csonotos 2006), **quadrats** (Stohlgren et al. 1998; Keeley and Fotheringham 2005; Ringvall et al. 2005; Archaux et al. 2006), **transect or belt transect** (Grant et al. 2004), **or line-intersect** (Floyd and Anderson 1987; Stevens and Urquhart 2000; Kercher et al. 2003). There is tendency among statisticians to overlook the importance of the interaction between the sampling design and the response design. For example, Larsen et al (2001) note "we generally assume that response design issues have been dealt with responsibly, consistent with the organism or phenomenon under consideration …". However, the choice of what to measure and how to measure it can have enormous impact on the sampling design.

Monitoring Objectives

The Nature Reserves of Orange County (NROC) hold 38,000 acres of Natural Community Conservation Planning (NCCP) lands in central Orange County. The reserve system is designed to preserve and protect the conservation values of these properties in perpetuity. The ecological conservation values of the properties include various natural communities, including coastal sage scrub, chaparral, native grasslands, oak woodlands, Tecate cypress forest, riparian forests, and aquatic communities. NROC is obligated to monitor the condition of conservation values through time and has identified vegetation communities as targets for long term monitoring.

Because NROC lands lie directly adjacent to 11,500 acres of conservation easements held by the Nature Conservancy (TNC), and because NROC and TNC both desire to implement 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 analyses.

It is difficult to design and implement a monitoring plan that is scientifically credible and cost-effective. The objective of this project is therefore to evaluate the precision and accuracy of different sampling designs and field protocols for monitoring vegetation communities, primarily coastal sage scrub (CSS), chaparral, and grasslands in central Orange County. It adds to a body of work begun by Franklin et al. (Hierl 2005; Franklin 2006; Regan 2006; Deutschman 2007; Hierl, Deutschman et al. 2007) for the San Diego Multiple Species Conservation Program (MSCP). This effort was structured based on the Atkinson et al 2004 technical report for monitoring multiple species reserves and informed by discussions with scientists and managers from local governments, non profits, and the wildlife agencies.

This project will explore sources of variability and make recommendations to scientists and land managers for the reduction and control of variability in their long-term data. Person-to-person variability in data collection will also be included. This information should help elucidate some of the questions surrounding the selection of both response designs and sampling designs. In addition, the results will provide a foundation for long-term monitoring by collecting baseline data. This effort will complement ongoing work in San Diego funded by the CA Department of Fish and Game and the San Diego Association of Governments. This report will use data from both Orange, San Diego, and Riverside counties to maximize the number of samples presented in the variance components analysis. This report summarizes the results for the second year of the project.

FIELD SAMPLING DESIGN

Our design was stratified across vegetation types, including coastal sage scrub and chaparral. Although the central Orange NCCP areas comprise more vegetation types, CSS and chaparral were prioritized based on the Franklin et al. (Franklin 2006) work in the San Diego MSCP. This year we increased both the number of plots we sampled and the spatial coverage of that sampling. We prioritized the number of plots, and therefore the amount of effort for each vegetation type based on the cost of sampling each one and the amount of new information we expected to glean from each type this year.

Our primary goal this year was to get better spatial coverage across the study area. Plots were selected using a stratified random design. Points were buffered to be located between 30m and 300m of an accessible road, and under a 35 percent slope. A great number more points were generated in order to provide back-up locations if any given point was deemed unsafe or inappropriate for work and for future monitoring. This year we sampled a total of 27 plots throughout Orange County (see Figure 1 and Appendix A). Of the original 8 plots monitored in 2007, 1 CSS and 1 grassland burned in the October 2007 wildfires (Table 1).

Overall, 70 percent of our plots were new this year. We also added coastal CSS and grassland sites this year, in order to improve our description of the west-east vegetation gradient. Ten of the 27 (37%) plots burned and some were included in a post-fire seeding experiment. Burned plots will not be included in the overall variance components analysis, however unburned San Diego and Riverside County plots will be included to add power to the analysis. Six of 8 sentinel sites escaped the fire: 2 CSS, 1 grassland and 3 chaparral.

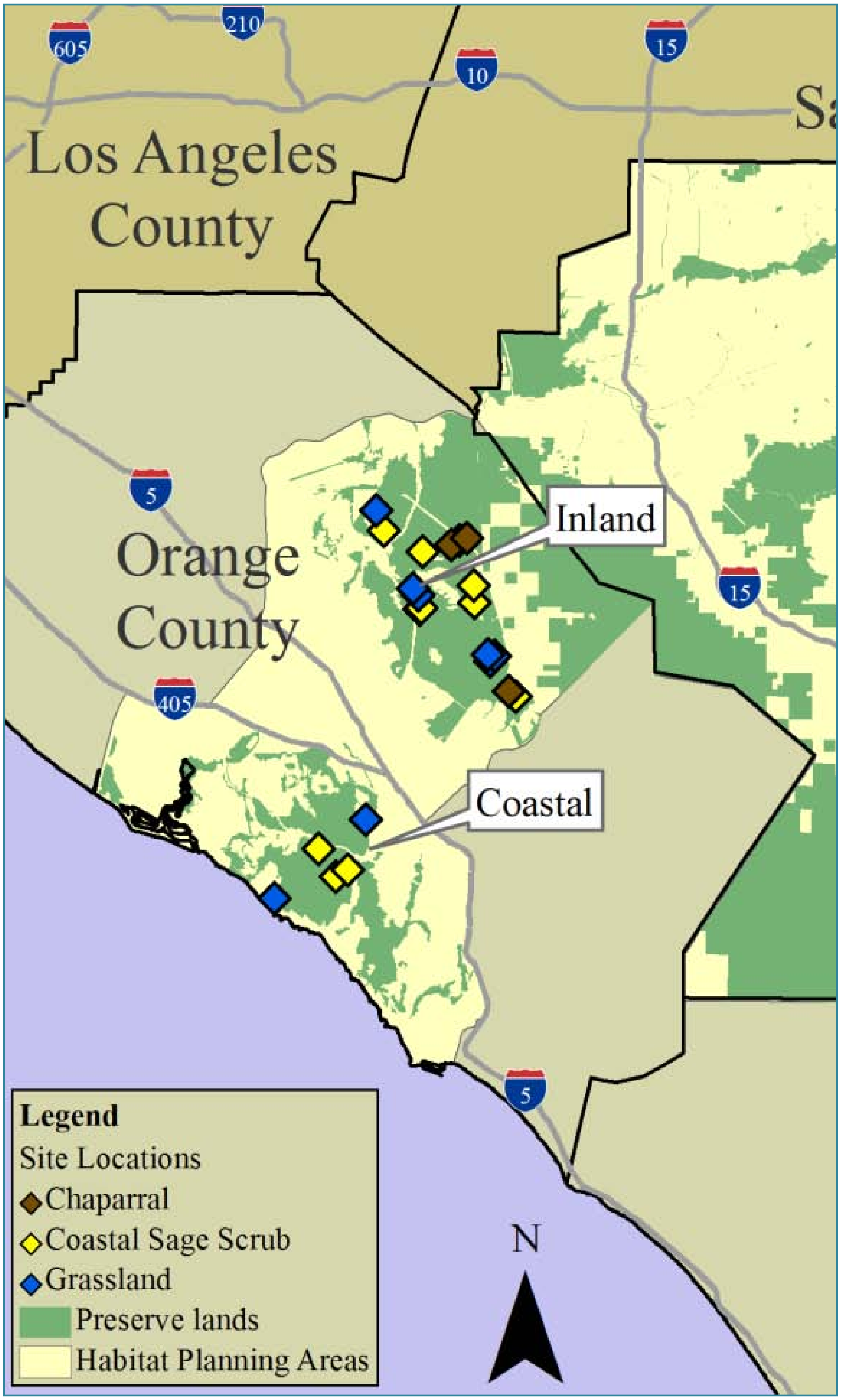

Figure 1: *Location of CSS and chaparral plots in Orange County. Yellow diamonds mark the location of plots in CSS, olive diamonds mark the locations of chaparral plots and blue diamonds mark grassland plots.*

Vegetation Community and Site	New Plots	Sentinel Plots	Total Plots
Coastal Sage Scrub			
Coastal	5	0	5
Inland	6 (3)	3 (1)	9 (4)
Chaparral			
Coastal	0	0	0
Inland	2 (1)	3	5 (1)
Grasslands			
Coastal	2	0	2
Inland	4 (4)	2 (1)	6 (5)
Total	**19**	**8**	**27**
Coastal	7	0	7
Inland	12 (8)	8 (2)	20 (10)

Table 1: *2008 site and plot breakdown. The value in parentheses indicates the number of plots that burned in 2007. Although the new sites provide data for spatial and methodological variance components analysis, we did lose power to describe temporal variation.*

Response Design and Field Protocols

Our field protocols were selected to capture a number of biologically relevant measures of habitat quality, including the richness of the vegetation being sampled and the cover of different species and functional groups. In 2007 we used a modified 0.1ha Keeley plot (Keeley and Fotheringham 2005) which included sub-plots for visual cover estimates. This year we eliminated visual cover sub-plots because they were of limited value at the scale we used them. We also reduced the length of the transect (from 100m to 50m) and the number of quadrats (from 20 to 10; See Figure 2).

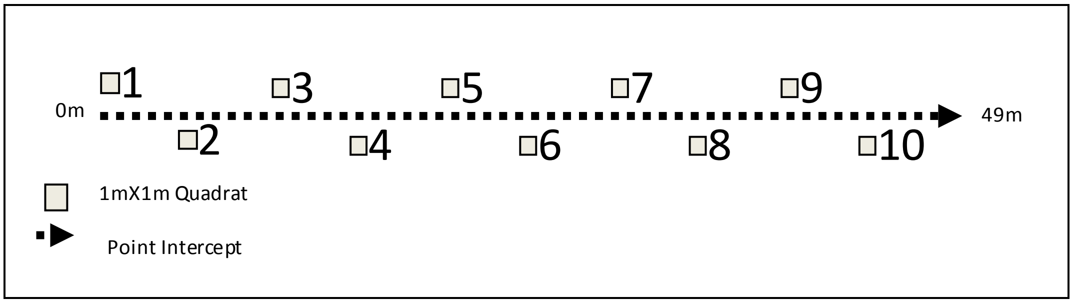

Figure 2: *Transect plot design. Each plot measured 50m in length.*
A single 50m point intercept transect took measurements every meter.
Quadrats were read for percent cover every 5m.

Point intercept sampling was used on the modified 50m transect with observations made every 1m starting at zero. Quadrats were read every five meters on alternating sides, starting on the left (Figure 2; Figure 3). This allowed us to compare the two different protocols at every plot. In order to reduce learning bias, teams collected their data in a strict sequence. First, teams used point intercept transects. During transects, teams did not spend time looking for hidden or cryptic species except for those touching the pole. Second, teams placed the ten $1m^2$ quadrats on alternating sides of the transect, and tried to capture every species inside the quadrat frame.

Figure 3: *Implementation of the two protocols, point-intercept, and quadrats.*

Transects

Point intercept transects tend to under represent very uncommon species, but perform equally well when compared to line and other transect techniques in all other regards, and do so with significant time savings (Elzinga et al. 2001). Of the many transect techniques available, we decided on point intercept because it minimizes decision making time by the field teams. During a point intercept transect the observer drops a dowel perpendicular to the meter tape at a predetermined distance. Each species and ground cover the dowel touches is recorded for that point. Note that multiple species at one point can yield over 100% absolute cover. Absolute cover is calculated for this method by dividing the total number of hits for each species by the total number of points on the transect. This technique also records ground cover, even when overgrown by canopy plants.

Quadrats

Quadrats were located every 5 meters on alternating sides of the transect. We provided our field crew the same general suite of suggestions for making their estimations in quadrats as the 10x10m visual cover plots. For example, we suggested dividing sub-plots into quadrants then estimating cover based on the size of those quadrants, or "squashing" species of the same type together in their mind's eye and using an imaginary 10x10 cm^2 square as a benchmark for 1% cover. We did not use printed transparencies or example handouts to provide scale, although this technique may be explored next year. Since we were measuring absolute cover, remainders were not useful, as species cover estimations were allowed to total over 100. This technique did not require recording of groundcover last year, however this year we instructed teams to record ground cover as a two-dimensional layer totaling 100% cover.

A thorough effort was made to find all the species inside each quadrat. In general, quadrat techniques take more time than visual cover or transect techniques due to the importance placed on detecting every species present.

Response Variables

Based on previous work conducted for the San Diego MSCP by Franklin, Deutschman and others (Franklin 2006; Deutschman 2007), we selected four key types of response variables for our data analysis. These include species richness, the cover of different plant functional groups such as native shrubs and exotic forbs, and the cover of individual species (e.g. *Eriogonum fasciculatum, Artemisia californica, Erodium botrys, Nassella pulchra*. Species richness was a simple count of the number of species detected in each plot. Absolute cover estimates for functional groups and individual species were calculated by averaging the cover in each quadrat for the entire plot, and evaluated at the plot level. Absolute cover for transects was calculated by dividing the number of hits of each functional group or species on the transect by the total number of possible hits.

We quantified different sources of variability in these response variables by estimating the different components of variance (Urquhart et al. 1998; Larsen et al. 2001; Sims et al. 2006). This variance decomposition along with the cost estimates are necessary to develop an optimal monitoring plan and to estimate statistical power. A formal power analysis will not be conducted until the third year of this study, because it requires more robust information about temporal variability.

Field Work Performed

In 2007 we identified inter-observer bias as an important source of variability for several response variables including species richness, and the cover of less common species. We therefore implemented an expanded, three stage training program in 2008. The first part of the training program was a lecture and question/answer session given by one of the senior project biologists. The project was introduced, goals were explained, and methods were discussed. Field teams also took time to experiment and practice with GPS units. For the second stage of training, teams sampled a test plot at Mission Trails Regional Park, in San Diego. In this exercise, teams located their plot by GPS coordinates, setup the transects, and collected data using both methods. Once they returned from the field, the teams entered their data at the lab. A senior project biologist worked with each team to ensure that methodological and taxonomic questions were addressed. The third stage of the training was to have each team accompanied on the first day by a senior project biologist, who provided taxonomic and methodological assistance.

In addition to an improved training program, we also made an effort to re-hire members of the 2007 field crew where possible. Ultimately we had three field teams, one with two senior project biologists, and two with one new and one returning team member. Although we had two fewer field teams than in 2007, these three teams had, on average, more field experience and worked the entire field season.

SITE VISITS

Training for all teams began on February 25th and was completed on March 1st. We visited all unburned plots in the third and fourth weeks of March when vegetation was peaking. We returned in the second week of April to sample the burned vegetation plots.

EFFORT

Time spent in the field is an important constraint to consider when designing a vegetation monitoring program (Figure 4). Set-up time (plot selection, navigation to plot, permanent marking) is significant, but can be completed prior to the start of the field season given enough forward planning. While data entry time is also important to a monitoring effort, time spent entering data is more flexible in terms of scheduling and staff. In our time budgets, we assumed that the field day began when a field team left a designated meeting site and traveled to a plot.

Last year we observed that point intercept transects were much faster than quadrats. This year that trend continued, although the difference between the two methods was less pronounced (Figure 4). Unexpectedly it took us much longer to cover 50m and 10 quadrats this year than it did to cover 100m and 20 quadrats last year. This is due to the tremendous increase in cover and diversity associated with this year's increased rainfall.

Data entry time was expected to be cut roughly in half, and in general our expectations were met, although increased diversity added some time. Unlike last year, when it took significantly more time to enter transect data than quadrat data, this year the two methods took about the same time to enter.

This year we discovered another factor limiting the number of plots that could be sampled in a day- diversity. Last year was a relatively dry year, and sites had far fewer species than they did this year. This year we averaged about 20 minutes for every 50m point intercept transect, about 45 percent more time than last year (Figure 5).

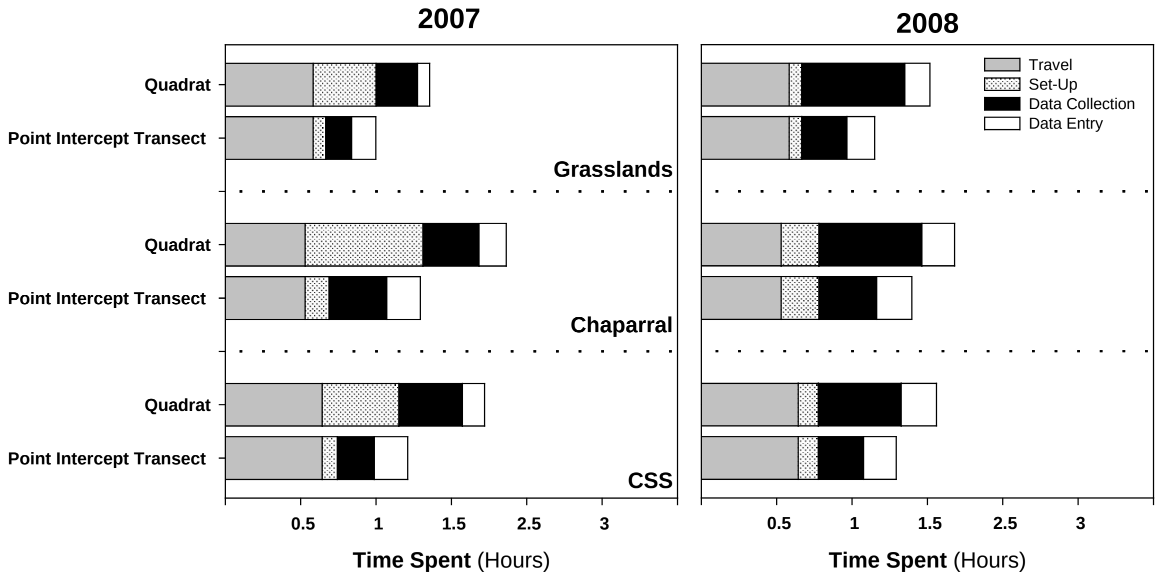

Figure 4: *Average time (hours) in unburned plots spent on two protocols (50m transects, and 10 quadrats). Quadrats were more time consuming in the field than point intercept transects.*

Quadrats were more affected by higher diversity increasing from 24 to 37 minutes per plot, a 56 percent difference. The increase in time for both methods, but especially quadrats, probably has to do with the time it takes not only to call out and record more species, but to find them. Teams were very careful when searching quadrats, and attempted to catch all species, even if they made up less than one percent cover. This process took some time, and had the potential to increase observer fatigue substantially as a result.

Contrary to our expectations teams were only able to complete two to three plots per day, the same number as last year. We were able to cover many more sites and plots by starting earlier in the season, and reducing the amount of double sampling across the sites.

Vegetation Communities

CSS and chaparral communities were sampled throughout the MSCP. At sites where CSS and chaparral were mixed, transects were located in the dominant vegetation type. In this section we will first address how the monitoring protocols quantified species richness throughout our sites and plots. We will then focus on how the different protocols quantified the absolute cover of plant functional groups and some important individual species.

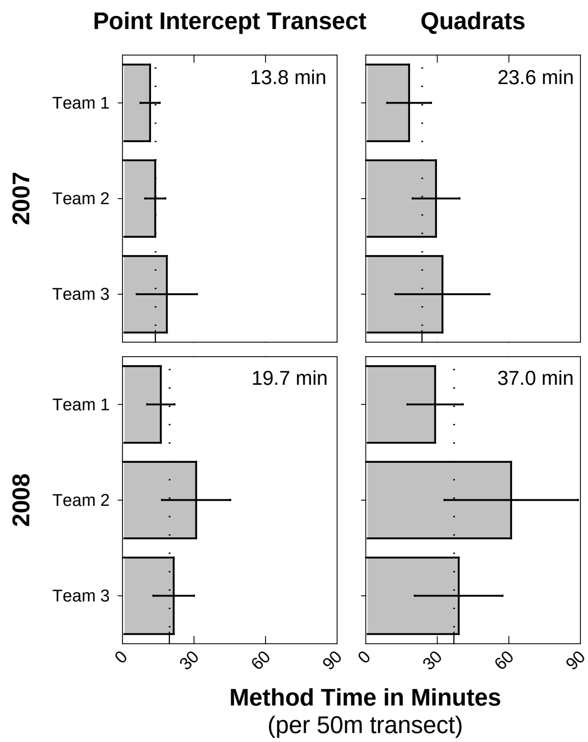

Figure 5: *Method times for primary teams compared. Team 1 had the same members in 2007 and 2008 and teams 2 and 3 had one returning member each from 2007.*

Species Richness

This year we detected 146 (Table 2) species throughout the county. This figure is higher than 2007 when we identified 66 species. In Orange County, CSS sites as a whole contained many more species than chaparral sites, although the average richness per plot was not significantly different (Table 2). There were more native forbs (64) than any other functional group in both CSS and chaparral. Non-native forbs were less rich as a group than native forbs.

This dramatic increase in richness can potentially be attributed to three factors which converged this year: (1) we sampled a much larger extent by increasing the number of plots and adding coastal plots. (2) The 2007 fire storms may have influenced the richness of burned sites by eliminating shrub species, but stimulating fire following annual species. (3) The increased rainfall seen in 2007-2008, while still below average, contributed to greater germination and growth of forbs and grasses.

In order to understand the source of this change we compared richness in 2007 to richness in 2008 at all unburned sites that were sampled in both years. In Figure 10, if the richness at a site was the same in both years, the value for that site would lie directly on the 1:1 line (diagonal). Instead, most of the points lie well above the 1:1 line, indicating that richness was consistently greater in 2008 (Figure 6).

Species Richness	All Species		Native Shrub		Native Forb		Native Grass		Non-native Forb		Non-native Grass		Other Species	
All Plots	146	66	31	30	64	10	6	5	25	6	12	7	7	8
CSS	99	34	21	17	44	1	5	4	13	5	9	3	7	4
Chaparral	74	38	19	23	30	9	1	1	14	1	5	2	5	2
Grasslands	86	24	10	11	39	2	3	3	22	4	9	2	3	2

***Table 2:** Species richness in Orange County. Unburned plots in black, burned plots in gray. Vegetation type and overall sums include both burned and unburned plots.*

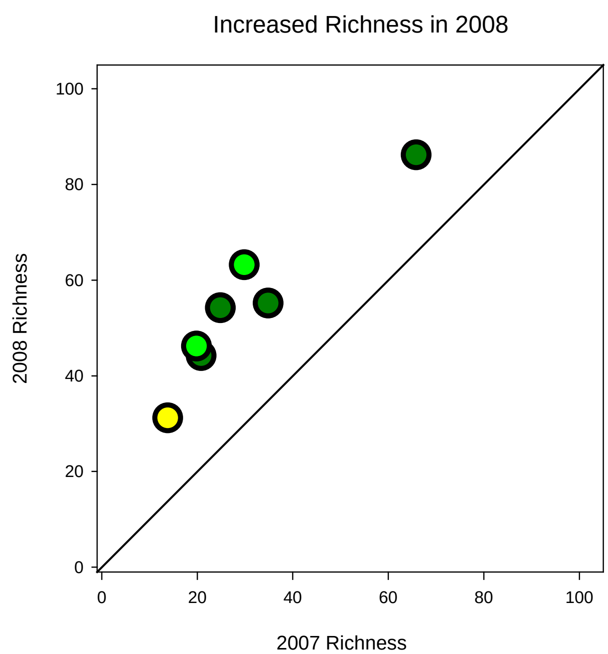

***Figure 6:** Increased richness at unburned sites sampled in both 2007 and 2008. Points lying on the line indicate unchanged richness, points lying above the line indicate increased richness in 2008. Dark green circles are chaparral sites, light green circles are CSS sites and yellow circles are grassland sites. This graphic represents both Orange County and San Diego data.*

This result demonstrates that the wildfires and our increased sampling effort were not the only reason for the observed increase in richness. Much of the year-to-year change in richness was almost certainly due to increased rainfall. It does not suggest that spatial extent and fire are unimportant, but does indicate that temporal variability in this system alone is on its own a major factor in vegetation dynamics. In order to see how different functional groups, with different life strategies, responded to interannual variability we regrouped the same data and summed species richness by functional group (Figure 7).

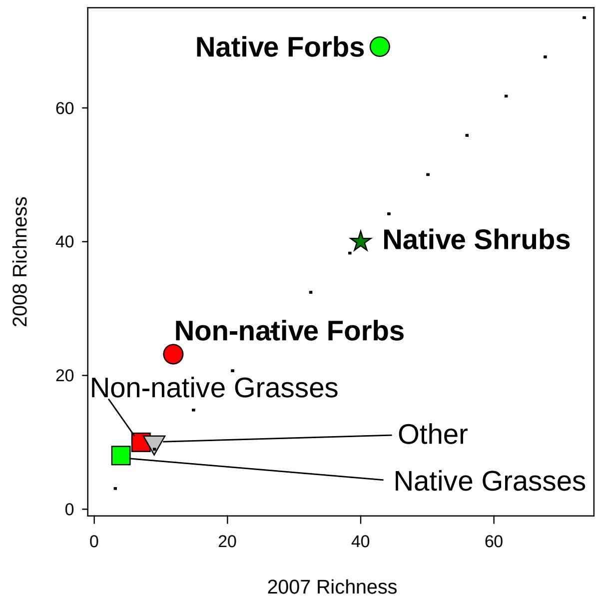

Figure 7: *Increased richness by functional group at unburned sites and plots which were sampled in both 2007 and 2008. The 1:1 line is dashed. Points lying on the line indicate unchanged richness, points lying above the line indicate increased richness in 2008.*

The comparison of species richness for functional groups yields intriguing results. First, both native and non-native grasses only experienced a small increase richness. These were the least rich groups to begin with. Second, the number of native shrub species did not change at all. However non-native and especially native forbs saw dramatic increase in species richness. The majority of the increase in richness overall is largely attributable to forbs, which also makes biological sense as they have a rapid lifecycle and respond to rainfall.

Dominant Species

We define dominant species as those with high average absolute cover, relative to other species. For this analysis we used absolute cover calculated by plot, averaging transects and quadrat estimates for all teams. For point intercept transects the total number of times a species is recorded is divided by the total number of points on the transect. Absolute cover is calculated for quadrats by averaging the estimated cover of a species across the entire plot.

In order to make realistic comparisons from year to year we have excluded burned plots from this analysis, and plots that were sampled for the first time this year. This allows us to make comparisons across years without confounding our results with the effect of fire or widened spatial extent. Note that the sample is weighted toward chaparral plots since we lost 1 CSS and 1 grassland plot in the 2007 fires. In addition since we only set up two grassland plots in 2007 and lost one in the fires, grassland results are of limited reliability. Appendix 7 characterizes the burned vegetation.

There was a dramatic increase in the cover of herbaceous species from 2007 to 2008 (Figure 8). Native and non-native forb species showed a particularly dramatic increase in cover. For example the native herbs *Cryptantha* species and *Calandrinia ciliata* were observed at trace amounts (<0.1%) in 2007, but accounted for significant average cover in 2008. There were also similar increases in the cover of non-native forbs. The non-native grass, *Bromus madritensis,* was not present in appreciable amounts in 2007, but had high average cover values in 2008. The same was true for the non-native forb species: *Hirschfeldia incana* and *Erodium* species. Shrub species maintained their cover and rank order in terms of dominance from 2007-2008.

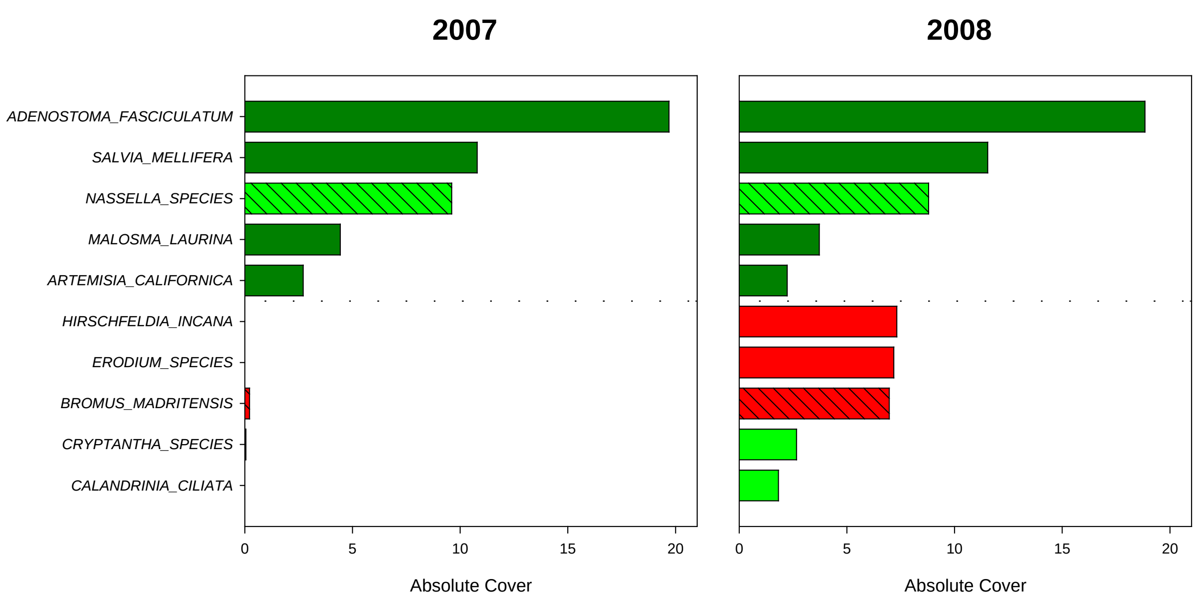

Figure 8: *Increased absolute cover of dominant species at unburned sites and plots which were sampled in both 2007 and 2008. Dashed line represents the division between species that were selected because they were dominant in both years and species that were dominant only in 2008. Dark green bars are native shrub species, light green bars are native forb, light green bars with a hatch are native grasses. Red bars are non-native forbs and red bars with a cross hatch are non-native grasses.*

Coastal Sage Scrub

We were only able to look at year to year changes in CSS at the two initial unburned plots in the interior of the open space system. The dominant shrub maintained about the same cover and rank order between 2007 and 2008 (Figure 9).

Last year no single native forb was dominant, however in 2008 *Lotus* species, was fairly prolific compared to other native annuals. The non-native forbs *Hirschfeldia incana* and *Erodium* species were not detected last year, but occurred at very high average cover in 2008. Likewise the non-native grass *Bromus madritensis* and non-native forb *Centaurea melitensis* were detected last year at low cover, and increased many times over in 2008 (Figure 9).

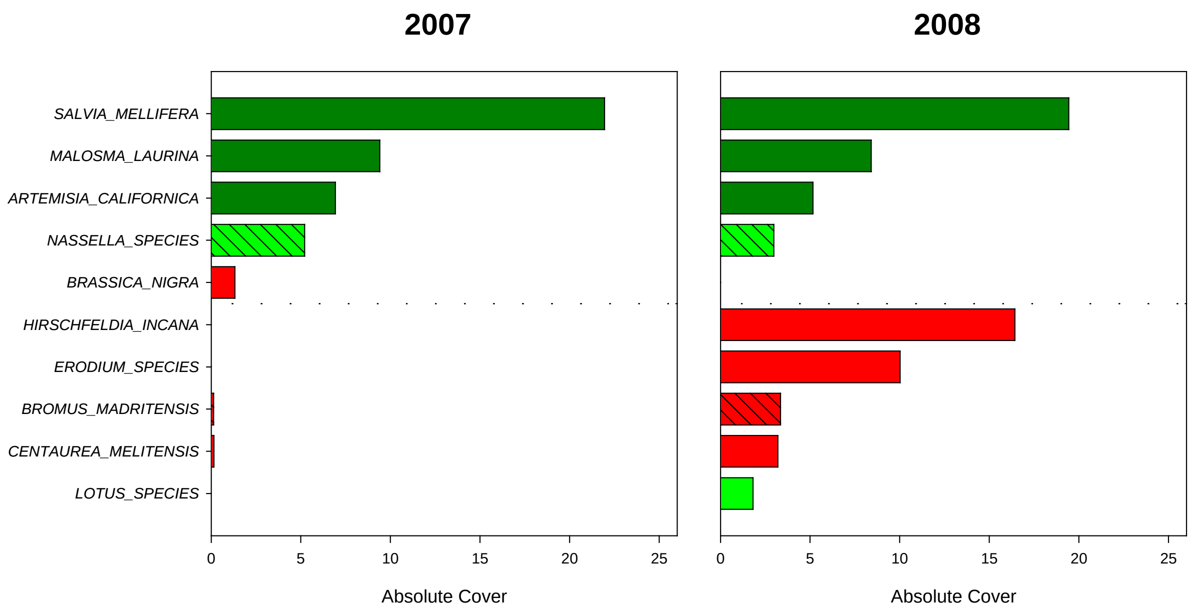

Figure 9: *Increased absolute cover of dominant species in unburned CSS which sampled in both 2007 and 2008. Non-native species are common, all annual species were favored this year. Colors and bar shading as in previous figure.*

The cover of species at the two different CSS plots varied dramatically. While the cover of native shrub species did not change dramatically from 2007 to 2008, there was signficaant plot-to-plot variability in shrubs and other functional groups. For example, *Salvia mellifera* occurred at around 15% at plot one and around 30% in plot 2 (Figure 10). The native herb *Lotus* species varied most dramatically by year (as it was totally absent in 2007), but still showed significant differences in cover between plots in 2008. The same was true for *Erodium* species whose cover also varied both by year and by plot.

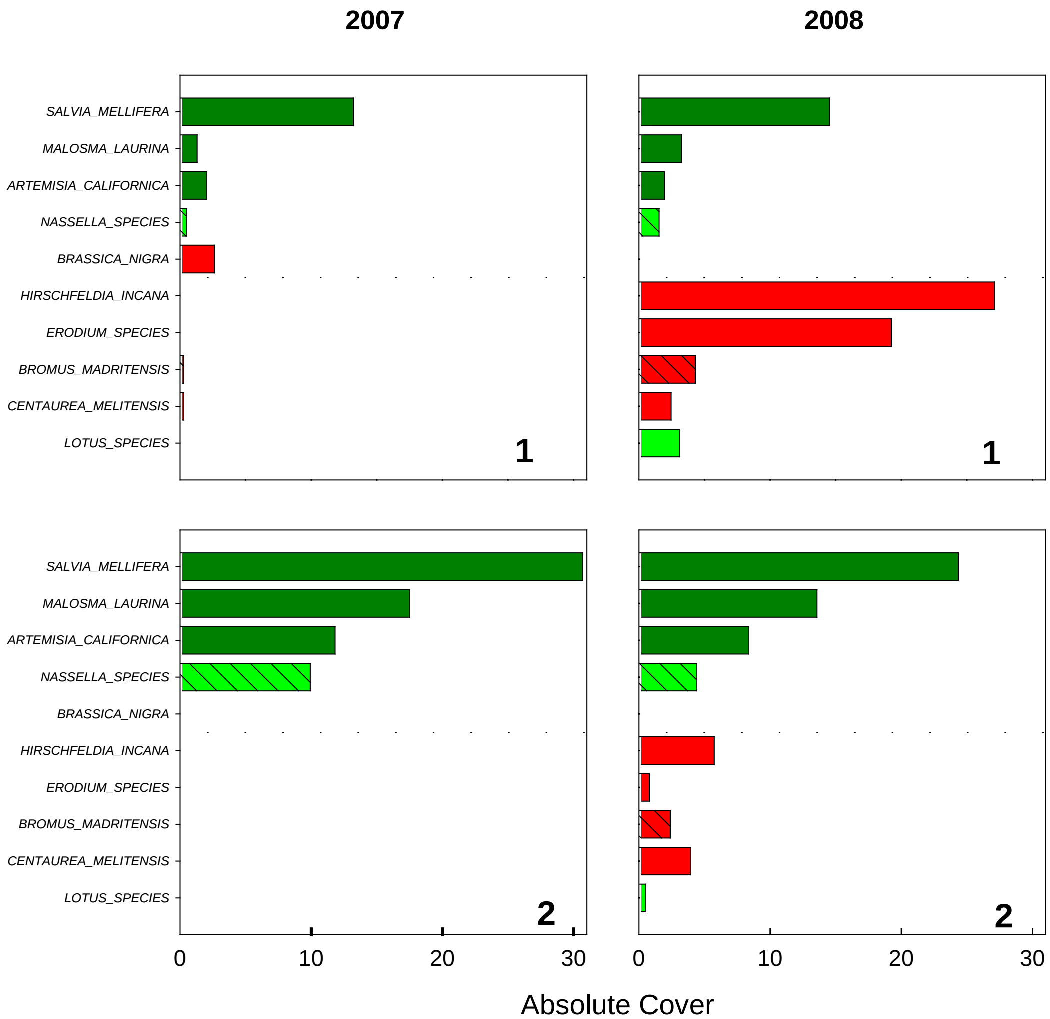

Figure 10*: Different cover of dominant CSS species at two plots which were sampled in 2007 and 2008. Colors and bar shading as in previous figures.*

Chaparral Species

We sampled three chaparral plots in both years. As seen in the CSS plots, the cover of dominant native shrub species were fairly consistent from year to year. Some native which had not occurred in 2007 appeared at high cover values in 2008 (Figure 11). The non-native grass *Bromus madritensis* increased dramatically from 2007 to 2008.

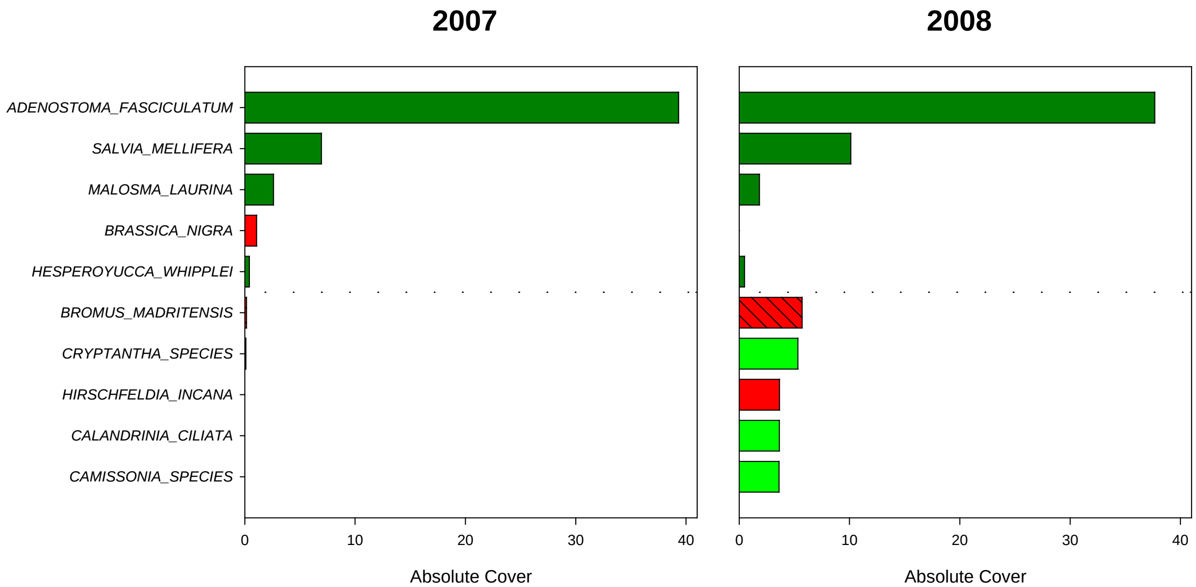

Figure 11: *Absolute cover of dominant chaparral species at unburned plots which were sampled in both 2007 and 2008. Native Non-native species are less common, all annual species are favored. Colors and bar shading as in previous figures.*

The average absolute cover of different plant species varied from plot to plot in the chaparral (Figure 12). *Adenostoma fasciculatum* consistently had higher cover than most other shrub species, but by varying degrees. At plot 1, which is recovering from the 2006 Sierra fire, *Adenostoma fasciculatum* was the clear dominant, but only occurred at around 10% cover. At plot 2, which is in a 12 year old stand, *Adenostoma fasciculatum* occur at around 45%. Plot 3, which is the closest to a climax state has about 55% cover of *Adensostoma fasciculatum*. Plots 2 and 3 also have higher cover values of the other dominant shrub species (*Salvia mellifera* and *Malosma laurina*).

As an anecdotal note, plot 2 (12 years) looks very open to the naked eye, where as plot 3 (climax) looks much more closed and impenetrable. It is intriguing that they only vary by 10% cover of the dominant shrub. Plot 2 actually has higher cover of most of the other common shrubs. This difference, and the difficulty estimating cover with the naked eye is probably due to over lapping canopy cover and how mixed species were in each plot. Plot 2 had a lot of *Salvia mellifera* mixed in and under the *Adenostoma fasciculatum* regularly, where as plot 3 had scattered individual plants of different species. This may be a function of succession in chaparral, as shorter shrubs eventually get out competed, and taller shrubs come to occupy the entire vertical area from soil to canopy. This anecdote emphasizes the areas where visual cover estimation can be problematic, even to experienced observers.

Herbaceous species also varied from plot to plot, as well as year to year (Figure 12). In 2007 the non-native forb *Brassica nigra* occurred at low levels in plots 1 and 2 but not 3. This year the cover of *Brassica nigra* went down over all, but a number of other non-native forbs and grasses were found at significant cover values including *Bromus madritensis* and *Hirschfeldia incana*. *Brassica nigra* cover may have gone down this year because we visited Orange County earlier in the season.

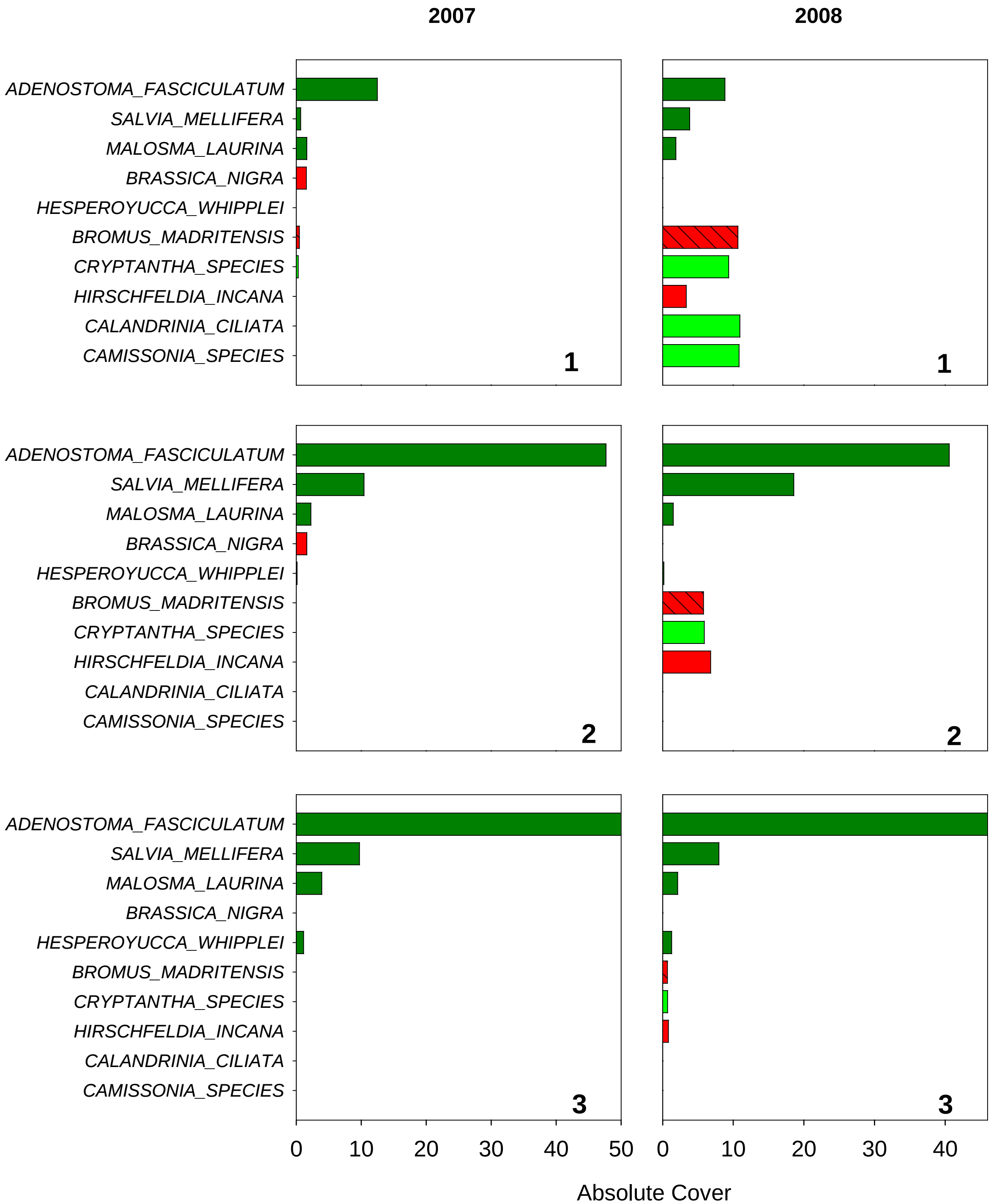

Figure 12: *Dominant species differed at different chaparral plots (1is two years old, 2 is 12 years old, and 3 is in a climax state). Colors and bar shading as in previous figures.*

Grassland Species

These results are for the single unburned grassland plot sampled in both 2007 and 2008, and should not be considered as a reflection of grasslands throughout the open space in Orange County. Results in the grassland were similar to the other vegetation types. Native shrubs and the dominant perennial grass retained about the same cover from one year to the next, however native non-native herbaceous species that either occurred at low values last year or were not present often occurred at very high cover values this year. Some native herbs also appeared, but in general non-natives were favored. Unfortunately what looked like a non-invaded grassland last year appeared to have a more substantial issue with non-natives this year. This result really demonstrates the importance of multi-year sampling programs, particularly in systems dominated by herbaceous species.

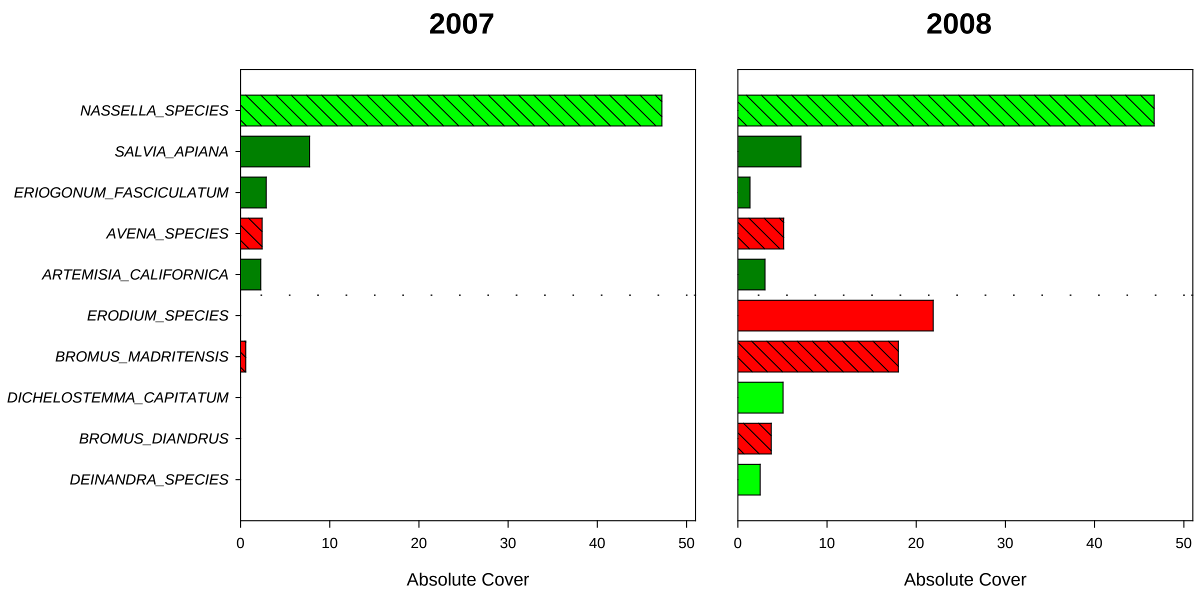

Figure 13: *Dominant species at the single unburned grassland plot. Colors and bar shading as in previous figures.*

Functional Group Cover

The aggregate cover for each functional group was calculated by summing the cover of all the species in that functional group by plot. Combining species into functional groups avoids analysis problems with rare, small and infrequent species. Coarsening the data by functional group supports the major patterns we saw at the species level (previous sections). Shrub cover varied among plots, but was similar in 2007 and 2008. Native forbs and grasses were all but absent in 2007. They were more common in 2008, with native forb cover far exceeding native grass cover. Exotic forbs and grasses were patchy in 2007 and more ubiquitous in 2008 (Figure 14).

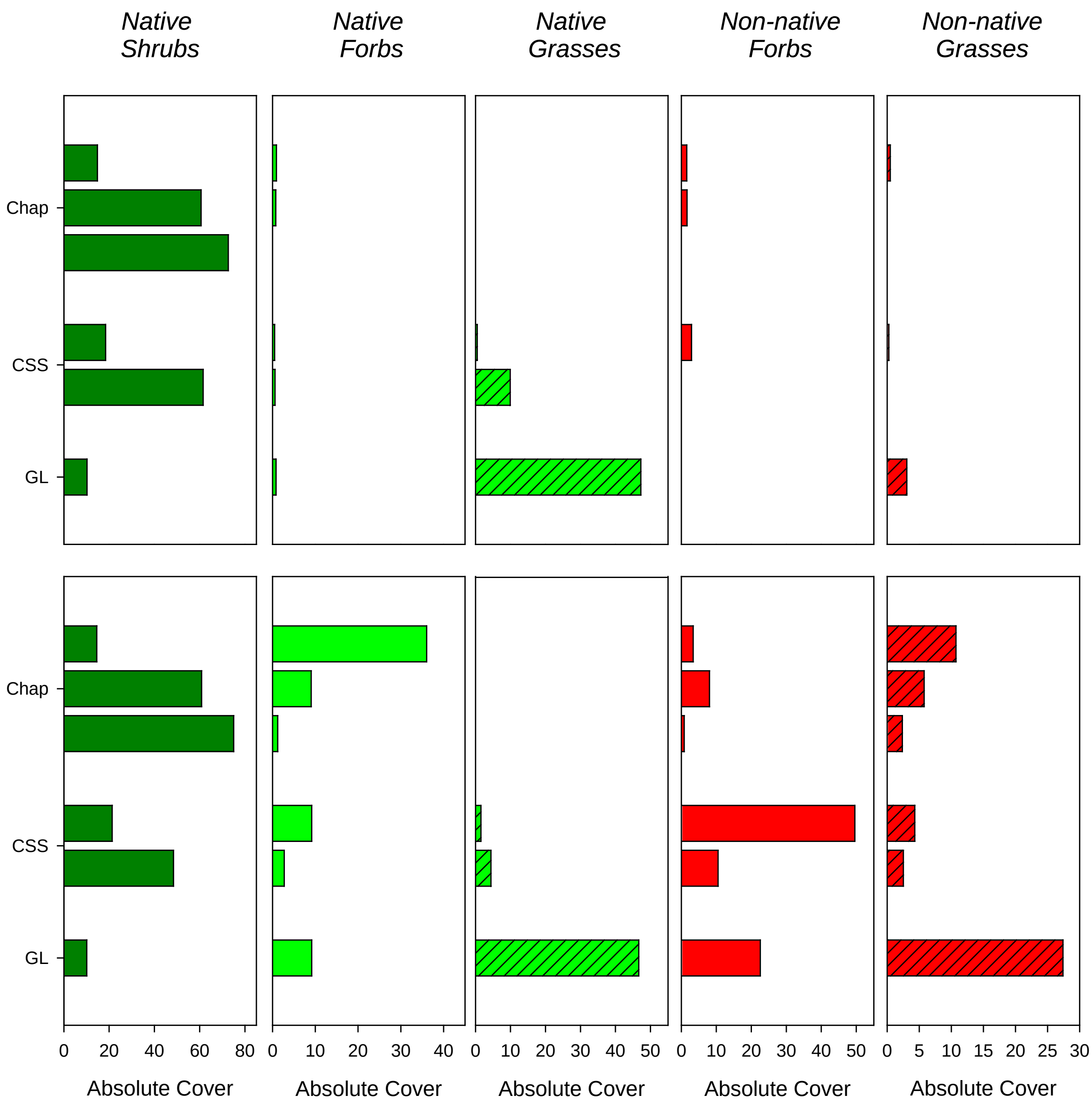

Figure 14: *Cover of functional groups at plots which were sampled in 2007 (upper) and 2008 (lower). Note the scale on the X axis (cover) varies among functional groups. In particular, native grass cover was quite low.*

VARIANCE COMPONENTS ANALYSIS

We quantified different sources of variability by estimating the different components of variance (Urquhart et al. 1998, Larsen et al. 2001, Sims et al. 2006). This variance decomposition along with the effort analysis are necessary to develop a efficient monitoring plan and to estimate statistical power. For the remainder of the analysis San Diego and Riverside data will be combined with Orange County data in order to increase the sample size and power of the analysis. In addition, combining these data will allow us to look at monitoring in a regional context, which should provide a more robust and coherent set of recommendations.

SOURCES OF VARIATION

The variance components analysis that we present has three major sources of variation: temporal or interannual, spatial and methodological (Figure 15). Spatial variation includes three nested levels: vegetation community, site and plot. Methodological variation includes two levels: protocol (quadrat vs. point intercept) and team.

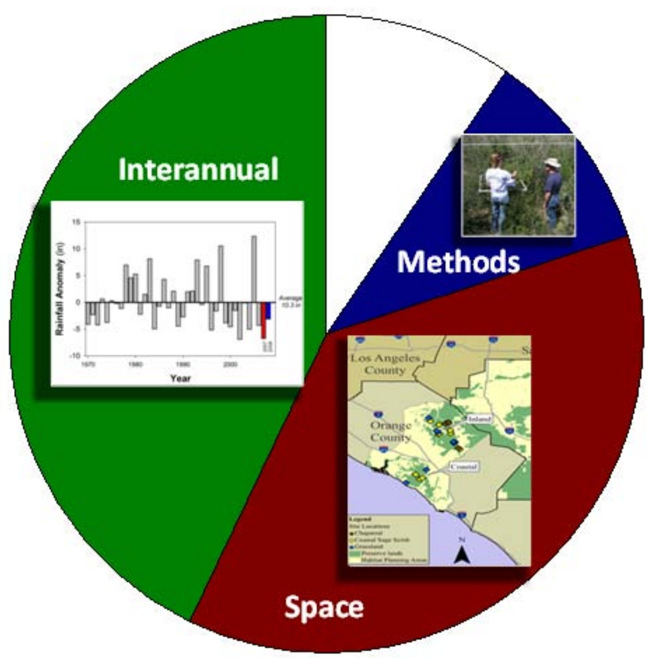

Figure 15: *Major sources of variation. The green slice represents interannual variability, the red slice represents spatial variability, the blue slice represents methodological variability and the white slice represents the unexplained variation.*

Interannual Variability

We quantified interannual variability using data from plots sampled in 2007 and 2008 that were also not burned in 2007. This allows us to look at interannual variability without confounding the effect of fire. Given the importance of water on the California landscape, our interannual component is probably closely linked to rainfall. 2007 was one of the driest years southern California has experienced since 1970, second only to 2003 (Figure 16). Both of these years saw major fires and unusually low germination rates. While still below average, 2008 was by comparison a relatively wet year.

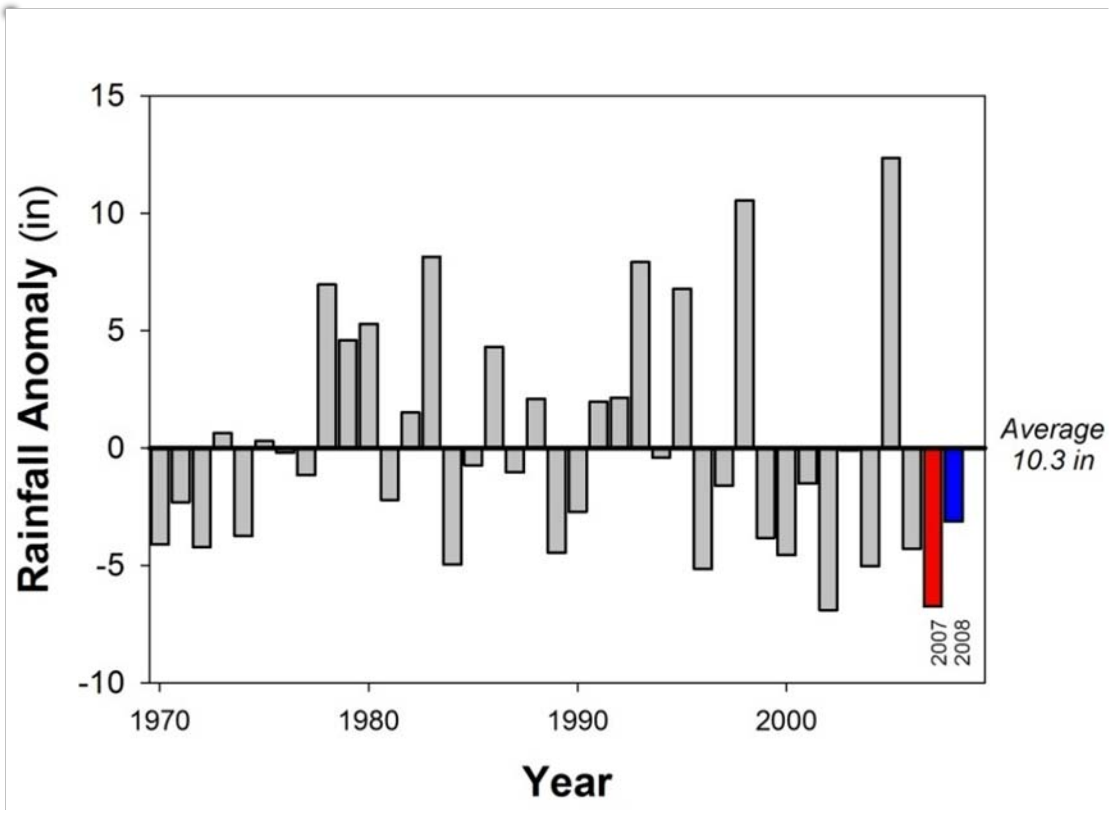

Figure 16: *Rainfall Anomaly from 1970 to 2008 in inches.*
2007 was much drier than 2008, although both were below average.

Spatial Variability

The total magnitude of the spatial component of variance was estimated from the sentinel plots visited in both years. We refined our understanding of variation within and among sites using the much larger sample of plots from 2008. By hybridizing the results in this way we are able to increase our sample size and thus precision in our estimates within the large umbrella of spatial variability.

Spatial variability was described in three nested levels. Vegetation community was the first and coarsest level. Sites were nested within each vegetation community, and plots were nested within sites (Figure 17). It is important to recognize that these levels are a simplification designed to reflect processes which likely vary across a continuous gradient. These three levels help provide a robust sampling design and allow us insight into processes happening at scales ranging from a square meter to tens of kilometers.

Sites were nested within each vegetation community, and plots were nested within sites. Sites were defined as sections of conservation lands that tended to be contiguous. Generally speaking different reserves were considered different sites. In general, sites were separated by developed land use, major roads and highways, long distances or any combination of those factors. In Orange County sites were defined coarsely as inland or coastal given the large degree of connectedness in the county's open space. Plots were defined as the actual point locations where we took data. Plots were located using a stratified semi-random design as discussed in the "Field Sampling Design" section.

METHODOLOGICAL VARIABILITY

As with spatial variability, we quantified methodological variability using data from all of the unburned plots sampled in 2008. We then scaled the values to reflect the correct proportion of spatial variability that was identified in the interannual analysis. By hybridizing the results in this way we are able to escape the decreased power associated with having lost many of the 2007 plots to fire.

We considered two sources of methodological variability: method or field protocol and team. These two factors do not nest inside each other, but are crossed (fully factorial) because every team used both protocols at every plot they visited (Figure 18). For our purposes we entered method first in the model as the methodological decision is generally made independently of hiring team members. This detail is minor, and did not have a dramatic effect on our results.

Figure 18: *Different teams and different protocols. Every team used both protocols at every plot they visited. Right: Dr. Marie Meroe and Dr. Janet Franklin using point intercept. Left: Marguerite Mauritz and Christina Burnett reading quadrats.*

VARIANCE COMPONENTS ILLUSTRATED

The variance components analysis for species richness is used to illustrate how we present the results from this type of analysis. Figure 19 shows the average species richness detected in each year at the three different spatial levels. In 2007 species richness was much lower across all three spatial levels than in 2008. Interannual variability accounts for 43% of the variability in average richness. Richness was not especially variable across vegetation communities in either year accounting for only 0.1% of the variability. Some sites were significantly richer on average than others (for example Carmel Mountain and Crestridge). Sites explained 20% more variance in the model. In addition at some sites, certain plots were more rich than others (for example Tijuana River Valley), accounting for 17% more variance.

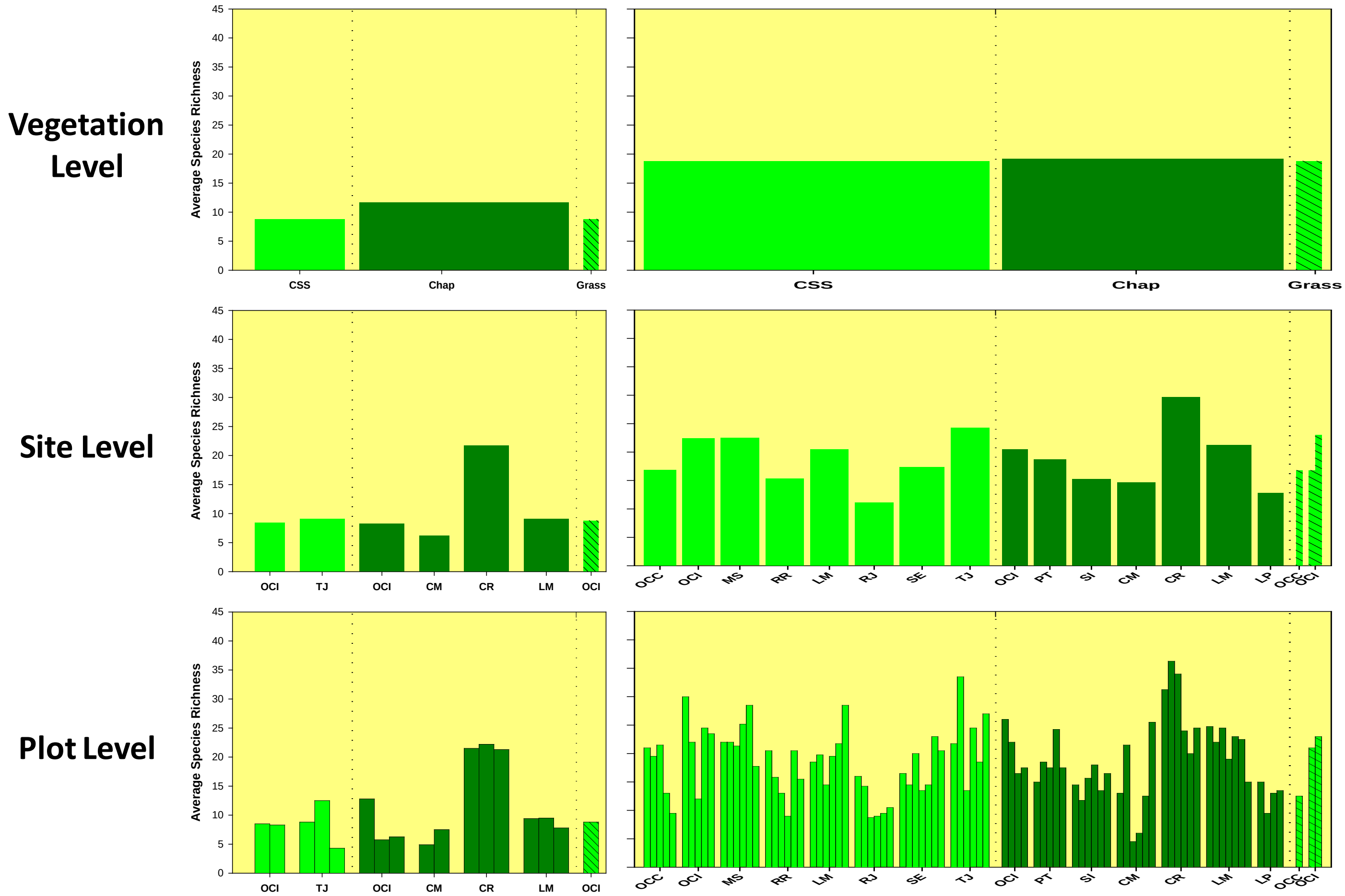

Figure 19: *The interannual and spatial variance components illustrated for species richness. Light green bars are CSS, dark green bars are chaparral and light green bars with hatch marks are grasslands. Unburned plots measured in 2007 (left column) and 2008 (right column) were used to estimate the interannual variability and all unburned plots in 2008 (left column) were used to estimate the spatial variance components.*

Figure 19 presents species richness averaged across teams and methods. In Figure 20, we show the same average values, however the top segment contrasts the richness values detected by the two different protocols. Quadrats (squares) typically captured more species than the point intercept technique (diamonds), with method accounting for 10% of the variation in richness data. Different teams, indicated by different shapes and colors, tended to capture about the same average richness in each plot. Team only accounted for 1% of the variation in richness data.

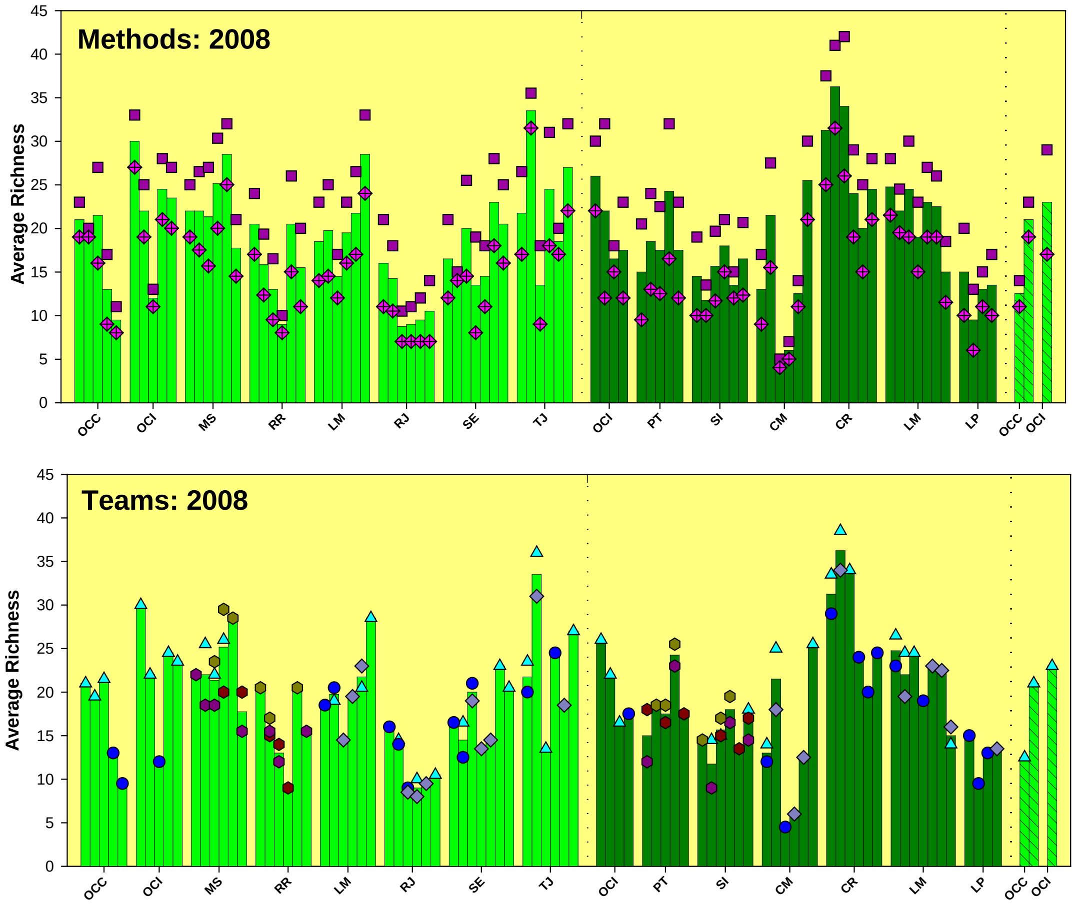

Figure 20: *The methodological variance components illustrated for species richness. Light green bars are CSS, dark green bars are chaparral and light green bars with hatch marks are grasslands. Methods are illustrated in the top row (squares are quadrats, diamonds with cross hatch are point intercept). Teams are compared in the bottom row, and are differentiated by different combinations of shapes and colors.*

These results are interesting but do not address which of the levels we identified can be controlled by the monitoring and sampling designs, and how to control for variability in a monitoring program. Figure 21 breaks down the major sources of variation, interannual, spatial and methodological, in a pie chart, and then shows the relative contribution of each level of spatial and methodological variability as a percentage of the major category. Interannual variability will affect the periodicity of sampling efforts, but beyond planning revisits there is little we can do to reduce inter annual variability (Figure 21). We are able to control our spatial coverage. Considering the relative contribution of vegetation community, sites and plots to the entire spatial component we know that planning on visiting many sites and several plots per site will be appropriate (Figure 21). Although methodology did not contribute the largest slice of the pie, it is one thing we can readily adjust about our response design. We see that the majority of that variability is accounted for by method, and are able to conclude that it is important to select the correct protocol for sampling richness, in this case quadrats. It should be noted that this particular conclusion is contingent on teams having the same amount of experience as the teams we used for this study.

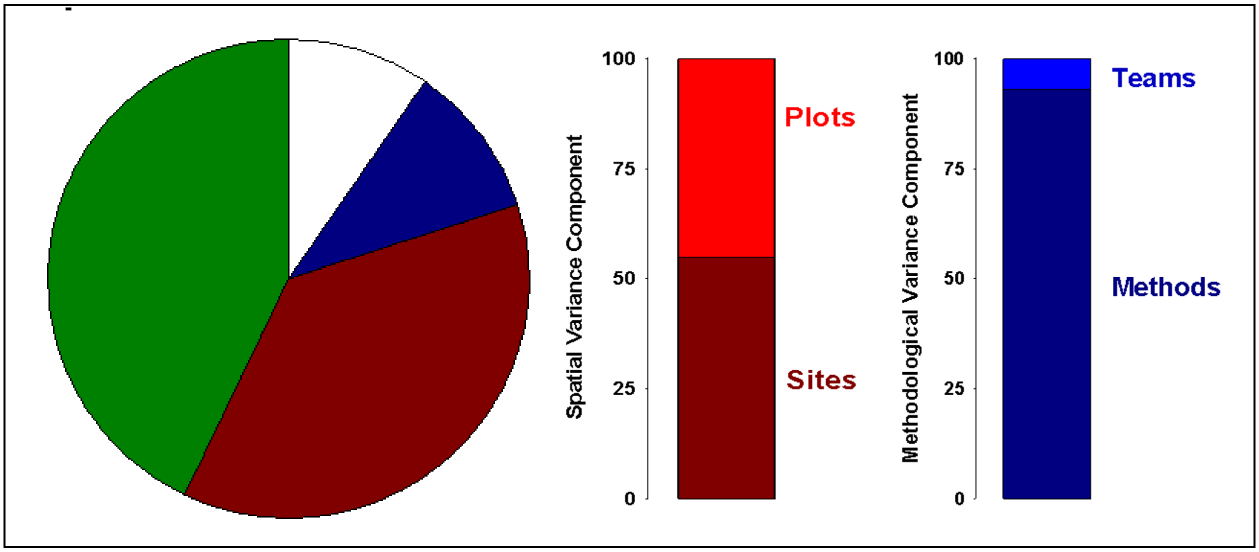

Figure 21: *The major sources of variation in species richness data. The pie chart shows the major components: interannual variability (green), spatial variability (red), and methodological variability (blue). Spatial variability and methodological variability are further broken down in bar charts to the left, which show the relative contribution of each level. Pink is vegetation community, dark red is sites, red is plots, dark blue is methods and light blue is teams. Note that vegetation community contributed so little variation to species richness that it does not appear in the spatial (center, red) bar graph.*

From these results we conclude that year-to-year variation is the dominant source of variation in species richness. The second largest source of variation is site to site variation, followed by plot to plot variability. In addition, quadrats were significantly better at capturing species than point intercepts and contributed a significant amount of variability to the data. We are able to apply this information to our sampling and response designs in the following way: A monitoring program whose main objective concerned species richness would require visiting many sites and many plots for several years, using quadrats.

Full Analysis

Several suites of variables were analyzed using variance components. In addition to species richness, we also analyzed the variance decomposition of the major functional groups: native shrubs, native herbs, native grasses, non-native forbs and non-native grasses. We analyzed several example species from each functional group individually. Example species were selected because they were either prevalent at many sites or dominant in terms of cover. The variance decomposition values for each of the selected group is given in Table 3.

[redacted]

Table 3: *Variance decomposition for selected groups. Cells are shaded from light to dark based on the percentage of variability in each cell. Ranking for shading was preformed within each major source of variability. Also see Figure 12*

All of the groups and species selected for individual analysis varied across space. The spatial component was different for each group, but generally the site and plot levels were more important than vegetation community (Table 3, Figure 22). This is likely because each group lives on a slightly different spatial scale, and with a different degree of selectivity for different habitat types and because we are representing a continuum of three chosen levels.

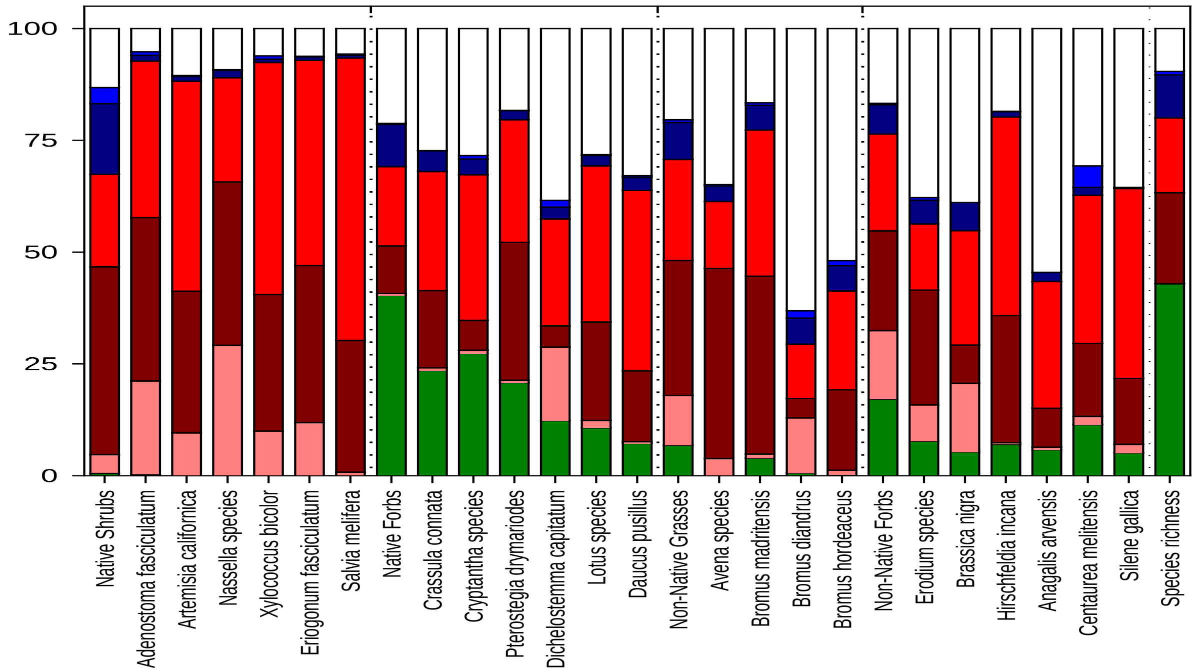

Figure 22: *Full variance decomposition of selected groups (see table 5 for values). Stacked bars represent interannual (green), vegetation community (pink), site (dark red), plot (red), methodological (dark blue) and team to team (blue) variability. The white section of the bar represents the proportion of variance unexplained by the model*

The species selected for individual analysis fell roughly into three groups: spatial responders, temporal responders, and mixed responders (Figure 22). Spatial responders were defined as species or groups that responded strongly to space to the exclusion of all other factors. For example *Nassella* species occurred in the highest density in grasslands but was also scattered throughout the other two vegetation types at much lower levels. In comparison *Salvia mellifera* tended to occur in both CSS and chaparral, but tended to prefer some plots over others. *Xylococcus biolor* had a larger team to team component than any of the other native perennial species. The overall effect of methodology was so small as to make this issue negligible. Temporal factors don't effect these species as much because they tend to be slow growers, and methodological factors probably effect them less because they are easy to identify and hard to miss.

Temporal responders were defined as species that showed a large interannual component relative to other components of variance. While space was still a large contributor to the model for temporal responders, the annual component was large enough to suggest that not considering temporal variation would lead to egregious design mistakes and misinterpretation of data. Most native and non-native forb species were strong annual responders (Figure 22). For example, *Crypthanta* species showed greater than 27% of their variation in the temporal factor.

Cryptantha species also occurred at high densities in some plots, and not at all in others regardless of vegetation community. *Dichelostemma capitatum* showed less interannual variability than some of the other native annuals, however it had a spatial component similar to the other temporal responders with a larger unexplained component.

Mixed responders are a troublesome group that fit together in several general ways—often more about how they differ from the other groups than similarities between them. The models for mixed responders tend to explain less than 60% of the variation in cover data for the specific species (Figure 22). In addition to being moderately spatial they usually contain some interannual variability, and often have slightly higher degrees of methodological variability than members of the other groups. This suggests that some of the unexplained variation may be contained in interaction terms that were not included in the model. Such interactions could be team and year, team and plot or team and method. Three of four non-native grasses analyzed were mixed responders. For example, the model for *Bromus diandrus* left the majority of the variation unexplained (63%). The variation that was explained from the model was distributed more evenly between all the factors than other groups. Of all the selected example species it had the largest methodological component at 6%.

Despite the differences the response variables, several strong general conclusions can be reached. Semi-arid scrublands in southern California are highly spatial, with different species and groups displaying different degrees of affinity for a specific vegetation type or a different degree of patchiness across sites and plots. Some species and groups are also dramatically influenced by annual factors such as rainfall. In addition point intercepts and quadrats return different results for richness, cover values for individual species and cover values for functional groups.

DISCUSSION

Sampling was conducted by two teams at 27 plots in Orange County, located in two spatially distinct regions, coastal and inland. Field teams had at least one member that had one or more years of experience and a college level plant taxonomy course. All sampling was conducted between the first week of March and the first week of May. Field protocols were modified for 2008 based on the results from the previous year's results.

We compared point intercept transects and quadrats for precision and efficiency. Due to higher rainfall and the resulting increases in plant cover and richness, field work took about twice as long as it did in 2007. Point intersect transects were faster than quadrats and returned precise cover estimates that were repeatable across teams. This methodology was less adequate when evaluating species richness. In contrast, we found that quadrats systematically underestimated cover values, but captured higher richness values.

This year we observed 146 species, up from 66 in 2007. Herbaceous cover and diversity were up, although shrub cover either stayed the same or went down slightly in unburned plots. This increase in richness holds true when new sites and plots are eliminated from the analysis. The most influential group contributing to the increase of richness was native forbs. We expected to see more observer bias as teams struggled to identify and quantify species they had not encountered last year, but this turned out not to be the case. Teams performed about equally for both cover and richness estimates. Instead we saw a striking difference between the two protocols. Non-native grasses and forbs, also increased in richness, but by a smaller margin, perhaps because successful non-native species tend to be robust generalists, and as a result a single species can occupy a wide suite of conditions and niches.

Adenostoma fasciculatum was the dominant shrub at all the unburned chaparral plots and was some times mixed with *Salvia mellifera*. *Salvia mellifera* was the most prevalent native shrub in the CSS and was often found in association with *Malosma laurina* and *Artemisia californica*. Raw cover values demonstrated a high degree of spatial variability in shrubs at the vegetation community, site and plot levels. *Bromus madritensis* was the most ubiquitous non-native species throughout Orange County, occurring in a majority of plots.

Herbs, particularly native forbs, also showed strong spatial variability, in addition to a major temporal aspect. Our analysis of interannual variability may be biased toward chaparral sites since we had to use unburned sites and more CSS sites were burned in 2007. Despite this limitation we saw dramatic and coherent increases in the richness and cover of herbaceous species from 2007 to 2008.

Species richness was effected about equally by interannual variability (42.9%) and spatial variability (37.1%). Site was the primary source of spatial variability, although plot also played a significant role. The protocol used contributed another 9.6% to the model, with point intercept consistently under estimating richness.

The main source of variability for most groups and individual species was space. Shrub species taken individually and as a functional group showed little interannual variability. Cover of the shrub functional group was affected significantly by the response design. Quadrats consistently underestimated cover, probably due to overlap and layering of vegetation. Teams may have been estimating something akin to relative cover in quadrats instead of absolute cover, which was often over 300% at individual points or presumably quadrats. This methodological effect is similar for other functional groups, but is not so pronounced for most individual species. This is probably due to compounding the error when the cover of multiple species is added together to yield the value for the functional group.

Different species can be broken out into rough groups of spatial responders, temporal responders and mixed responders depending on how influential different components are. Most shrubs are spatial responders, with a miniscule amount of temporal and methodological variability. Most native forbs are temporal responders, which respond strongly to year in addition to spatial factors. Functional groups as variables tend to be mixed and have a large component associated with method. This is due to compounding estimation error in quadrats where there is difficulty estimating overlapping layers.

A large proportion of the variability in mixed responders is unexplained by our model, and the majority of the explained variability is often distributed diffusely across the different components. One hypothesis to be explored in more detail as the project continues is if the mixed responders tend to be extreme generalists and therefore have fewer limitations in terms of moisture requirements and site requirements.

CONCLUSIONS:

Our data demonstrate that response variables vary across natural gradients, and that methods capture data so differently, that the best monitoring approach must be determined based on the objective(s) and response variable(s) of interest for each individual project. In this document we provide a suite of recommendations, or toolbox, to help guide the monitoring design process.

It is important that the objectives and response targets of a monitoring program are refined prior to creating a final monitoring plan, regardless of the response variables in question. A monitoring program that assumes species richness is the most important factor in determining habitat suitability should be very different from a monitoring project that assumes that non-native grass cover is the most important determinant of habitat degradation. Many monitoring projects will ask multiple questions and will therefore be well served by hybrid designs. These use a combination of protocols and a rotating panel design balanced to maximize information on the most appropriate temporal and spatial scales.

In southern California semi-arid shrublands allocating a significant amount of effort to spatial coverage is probably appropriate for most response variables (Table 4). We have found that a large number of plots are necessary to assess different sites inside a conservation plan, and that many sites need to be visited to assess the status of the reserve system.

Some response variables change dramatically across years, while others do not. The periodicity with which a variable should be monitored is inherently tied to its life cycle. Native forbs, for example, should be monitored yearly. However, a monitoring project most interested in shrub cover would likely be well served by a monitoring cycle of 5 years (Table 4).

Team-to-team variability can be minimized with appropriate training and experience. Our field teams had at least one member with a minimum of one field season and one college level plant taxonomy course. We also conducted training both in the lab and in the field to help minimize ambiguity in terms of adherence to protocols across teams.

Quadrats and point intercept protocols have opposite strengths for different response variables. Transects provide the most accurate and precise estimates of cover for individual species and functional groups (Table 4). Quadrats provide more information on richness and presence of uncommon or small species, but systematically underestimate cover. In some cases the sampling and response designs we tested will not be adequate to address the monitoring objective—for example, populations of rare plant species or small and patchy species.

Example Objective	Time	Spatial Extent	Method	Team
Shrub cover for target species	Infrequently	Coarse	PI	Less Experienced
Exotic forb and grass cover (as a group)	Frequently	Moderate	PI	Less Experienced
Plant species diversity	Frequently	Moderate	QD	More Experienced
Any single non-obvious herb species	Frequently	Fine	QD	More Experienced
Emergent invaders	Frequently	Fine	QD	More Experienced
Host plants for target species (common)	Frequently	Fine	QD	Less Experienced
Rare plant species	*Species specific protocol is recommended*			
Host plants for target species (patchy/rare)	*Species specific protocol is recommended*			

Table 4: *General recommendations for sampling and response designs for example objectives. PI refers to point intercept transects. QD refer to quadrats.*

FURTHER STUDY

It remains difficult to estimate the cost of monitoring. Due to the extreme drought in 2007 our baseline data may represent the arid extreme in southern California, but is not adequate on its own as baseline data. The time and cost it took to complete monitoring this year was higher than we originally estimated due to dramatically increased richness and herbaceous cover. The region received higher rainfall in 2008 than 2007, but was still well under the long-term average. Climactic factors in Southern California are wide and varied, and we have yet to conduct monitoring over a particularly wet year, or a year with extremely early or late rainfall. Given the size of the interannual variation we observed for some groups, more data is needed to evaluate components of a comprehensive monitoring program.

In addition, several subsequent years are required to recover from the loss of three-quarters of our initial CSS sites from the 2007 fires, which led to a sample in which chaparral was over-represented. Post fire monitoring is important, and as a regular phenomena should be considered inside a monitoring program, but post fire monitoring is a long term issue that we are just beginning to address.

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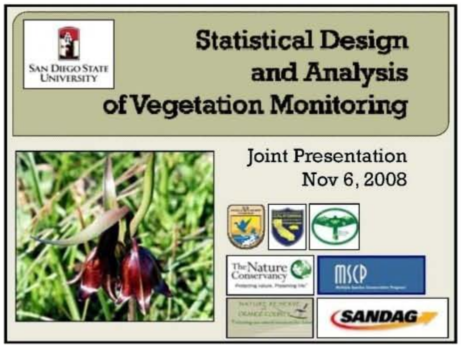
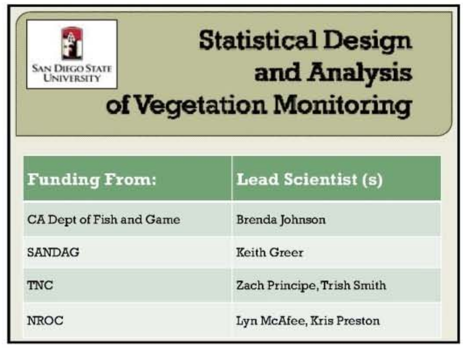
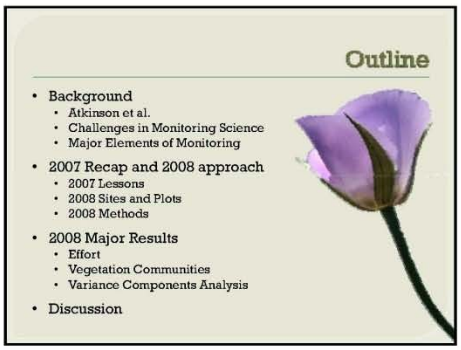
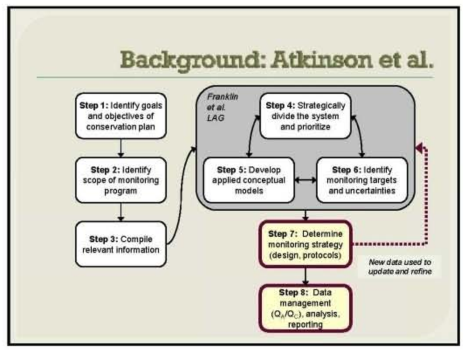
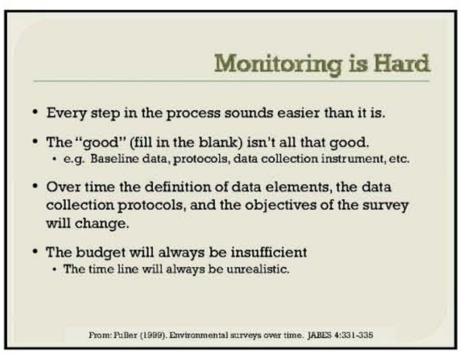
APPENDIX 1: NOVEMBER 2008 FINAL PRESENTATION

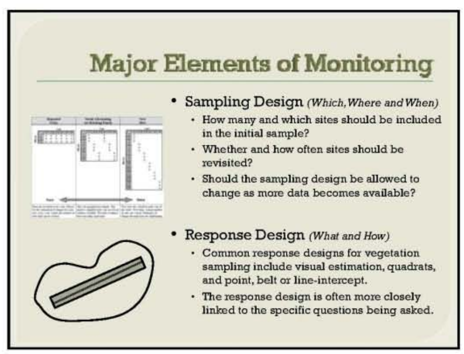

Statistical Design
and Analysis
of Vegetation Monitoring
San Diego State University
Joint Presentation
Nov 6, 2008
The Nature Conservancy
MSCP
SANDAG

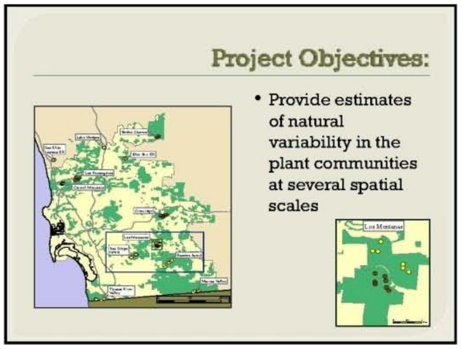

Statistical Design
and Analysis
of Vegetation Monitoring
San Diego State University
Funding From:
Lead Scientist (s)
CA Dept of Fish and Game
Brenda Johnson
SANDAG
Keith Greer
TNC
Zach Principe, Trish Smith
NROC
Lyn McAfee, Kris Preston

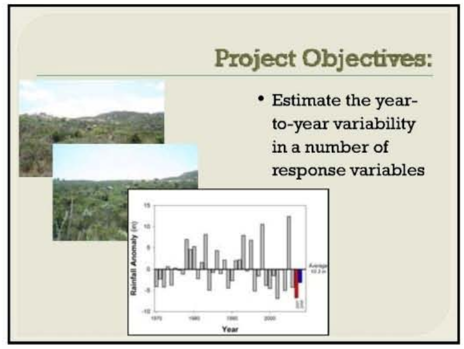

Outline
Background
Atkinson et al.
Challenges in Monitoring Science
Major Elements of Monitoring
2007 Recap and 2008 approach
2007 Lessons
2008 Sites and Plots
2008 Methods
2008 Major Results
Effort
Vegetation Communities
Variance Components Analysis
Discussion

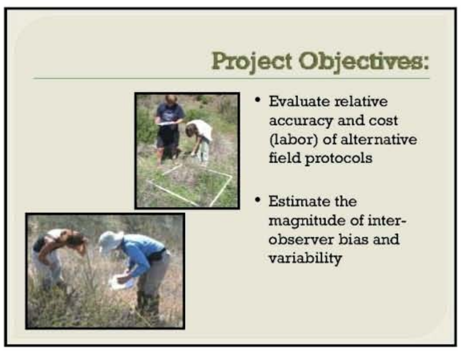

Background: Atkinson et al.
Step 1: Identify goals and objectives of conservation plan
Step 2: Identify scope of monitoring program
Step 3: Compile relevant information
Franklin et al. LAG
Step 4: Strategically divide the system and prioritize
Step 5: Develop applied conceptual models
Step 6: Identify monitoring targets and uncertainties
Step 7: Determine monitoring strategy (design, protocols)
New data used to update and refine
Step 8: Data management (QA/QC), analysis, reporting

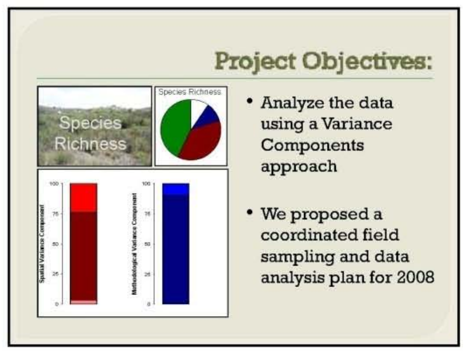

Monitoring is Hard
Every step in the process sounds easier than it is.
The "good" (fill in the blank) isn't all that good.
e.g. Baseline data, protocols, data collection instrument, etc.
Over time the definition of data elements, the data collection protocols, and the objectives of the survey will change.
The budget will always be insufficient
The time line will always be unrealistic.
From: Fuller (1999). Environmental surveys over time. JABES 4:331-335

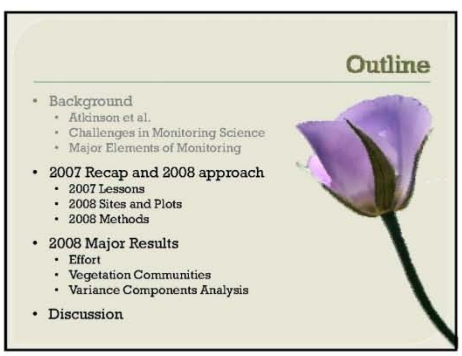

Major Elements of Monitoring
Sampling Design (Which, Where and When)
How many and which sites should be included in the initial sample?
Whether and how often sites should be revisited?
Should the sampling design be allowed to change as more data becomes available?
Response Design (What and How)
Common response designs for vegetation sampling include visual estimation, quadrats, and point, belt or line-intercept.
The response design is often more closely linked to the specific questions being asked.


Project Objectives:
• Provide estimates of natural variability in the plant communities at several spatial scales
Los Montanas


Project Objectives:
• Estimate the year-to-year variability in a number of response variables
Rainfall Anomaly (in)
Year


Project Objectives:
• Evaluate relative accuracy and cost (labor) of alternative field protocols
• Estimate the magnitude of inter-observer bias and variability


Project Objectives:
Species Richness
Species Richness
• Analyze the data using a Variance Components approach
• We proposed a coordinated field sampling and data analysis plan for 2008


Outline
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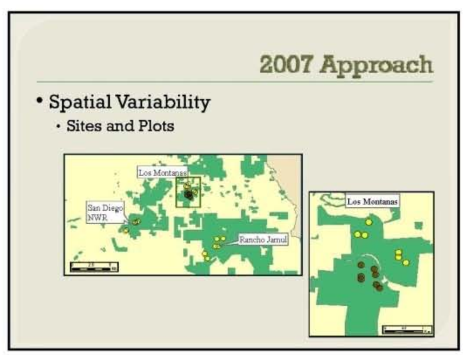
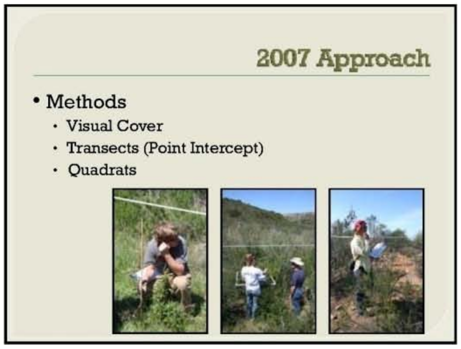
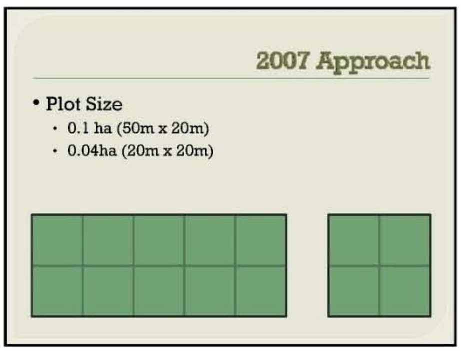
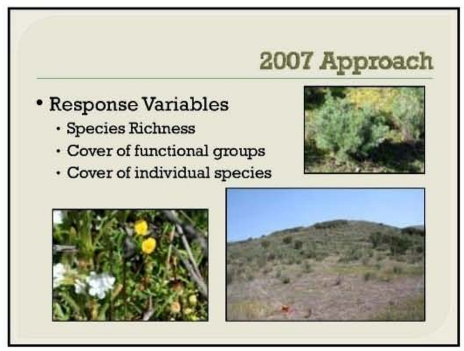
• 2007 Lessons
• 2008 Sites and Plots
• 2008 Methods
• 2008 Major Results
• Effort
• Vegetation Communities
• Variance Components Analysis
• Discussion

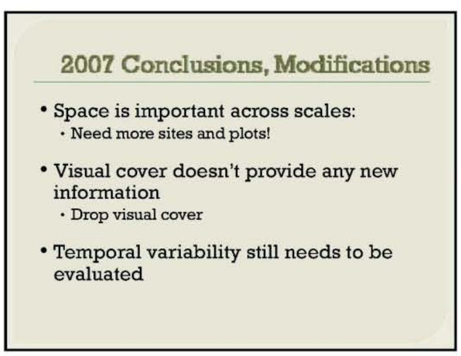

2007 Approach
• Spatial Variability
• Sites and Plots
Los Montanas
San Diego NWR
Rancho Jamul
Los Montanas


2007 Approach
• Methods
• Visual Cover
• Transects (Point Intercept)
• Quadrats

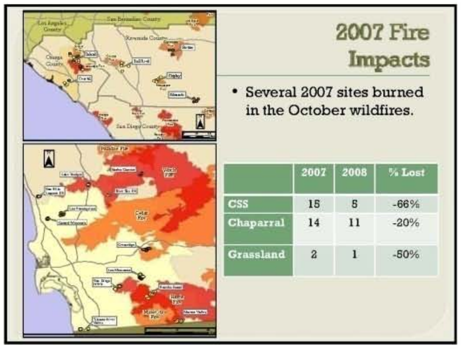

2007 Approach
• Inter-observer variability
• Multiple Teams

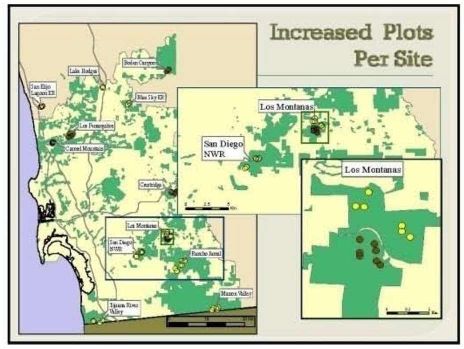

2007 Approach
• Plot Size
• 0.1 ha (50m x 20m)
• 0.04ha (20m x 20m)

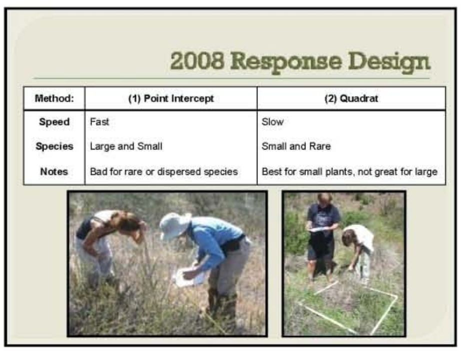

2007 Approach
• Response Variables
• Species Richness
• Cover of functional groups
• Cover of individual species

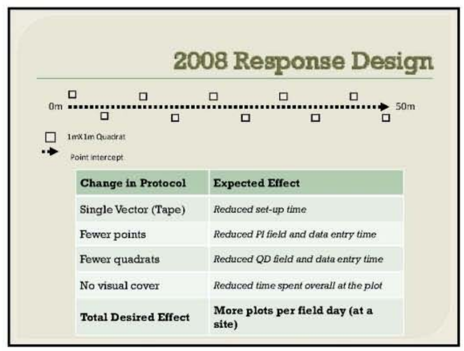

2007 Conclusions, Modifications
• Space is important across scales:
• Need more sites and plots!
• Visual cover doesn't provide any new information
• Drop visual cover
• Temporal variability still needs to be evaluated

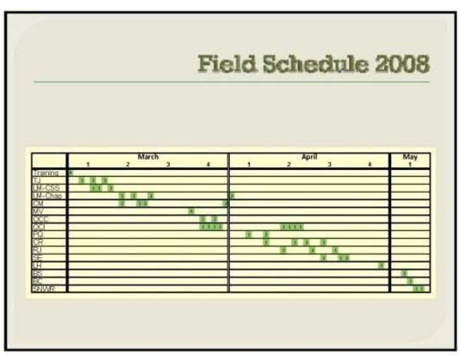

Additional Sites and Plots
• New sites added in Orange, and San Diego County
• Coordinated sampling in Riverside County
• More plots visited at each site

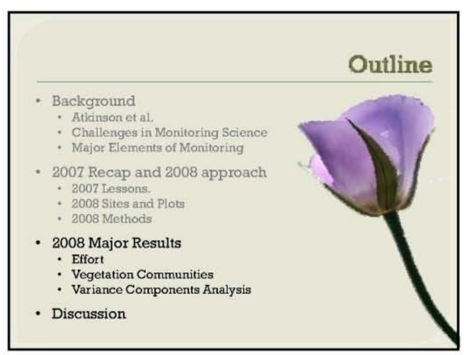

2007 Fire Impacts
• Several 2007 sites burned in the October wildfires.
2007 | 2008 | % Lost
CSS | 15 | 5 | -66%
Chaparral | 14 | 11 | -20%
Grassland | 2 | 1 | -50%


Increased Plots Per Site
Los Montanas
San Diego NWR
Los Montanas


2008 Response Design
Method: | (1) Point Intercept | (2) Quadrat
Speed | Fast | Slow
Species | Large and Small | Small and Rare
Notes | Bad for rare or dispersed species | Best for small plants, not great for large


2008 Response Design
0m
50m
1mX1m Quadrat
Point intercept
Change in Protocol | Expected Effect
Single Vector (Tape) | Reduced set-up time
Fewer points | Reduced PI field and data entry time
Fewer quadrats | Reduced QD field and data entry time
No visual cover | Reduced time spent overall at the plot
Total Desired Effect | More plots per field day (at a site)


Field Schedule 2008
March
April
May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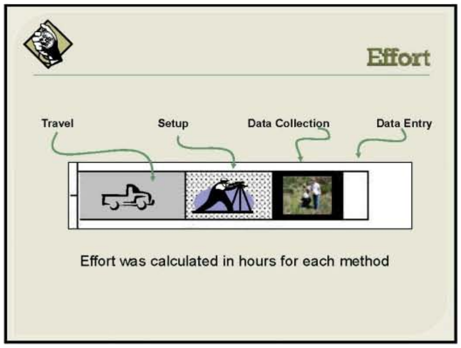
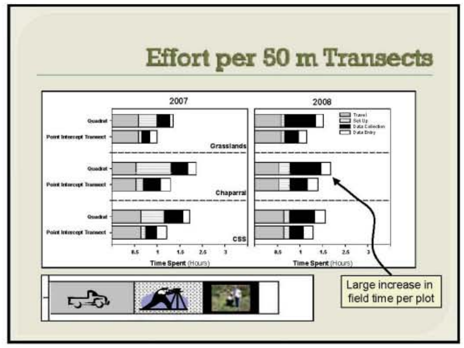
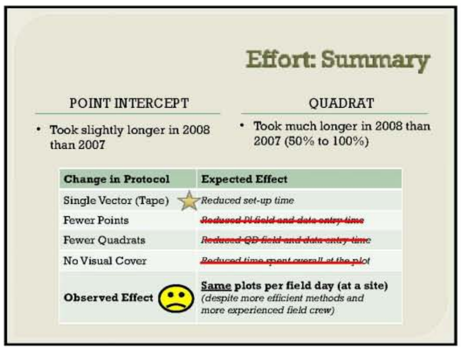


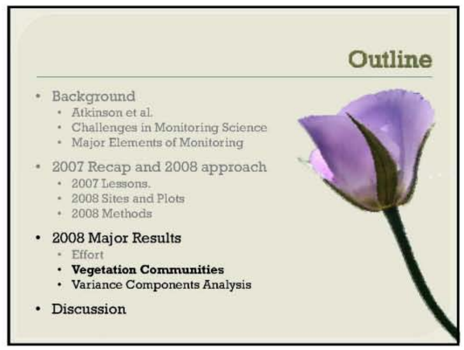
Effort
Travel
Setup
Data Collection
Data Entry
Effort was calculated in hours for each method



Effort per 50 m Transects
2007
2008
Travel
Set Up
Data Collection
Data Entry
Quadrat
Point Intercept Transect
Grasslands
Chaparral
CSS
Time Spent (Hours)
Large increase in field time per plot



Effort: Summary
POINT INTERCEPT
• Took slightly longer in 2008 than 2007
QUADRAT
• Took much longer in 2008 than 2007 (50% to 100%)
Change in Protocol | Expected Effect
Single Vector (Tape) | Reduced set-up time
Fewer Points | ~~Reduced PI field and data entry time~~
Fewer Quadrats | ~~Reduced QD field and data entry time~~
No Visual Cover | ~~Reduced time spent overall at the plot~~
Observed Effect | Same plots per field day (at a site) (despite more efficient methods and more experienced field crew)



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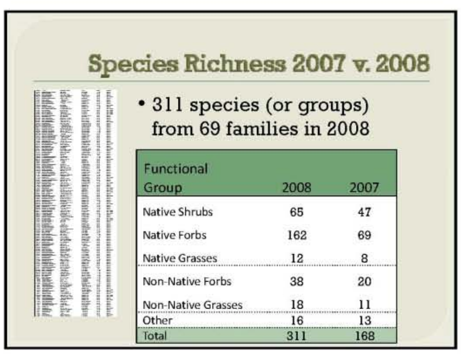
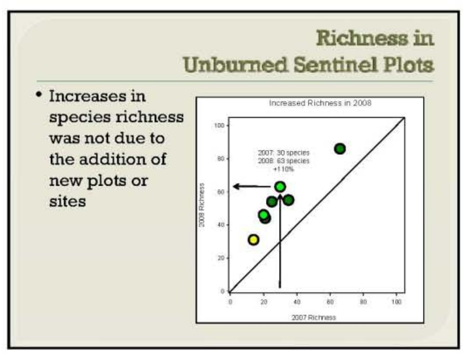
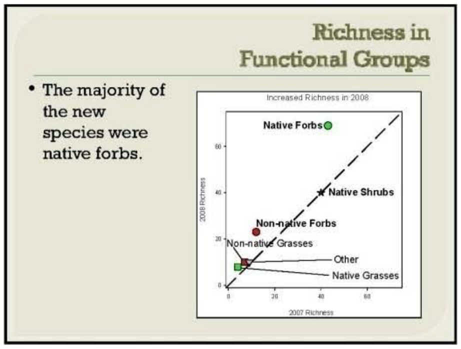
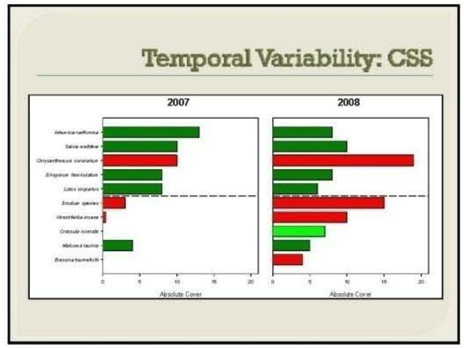


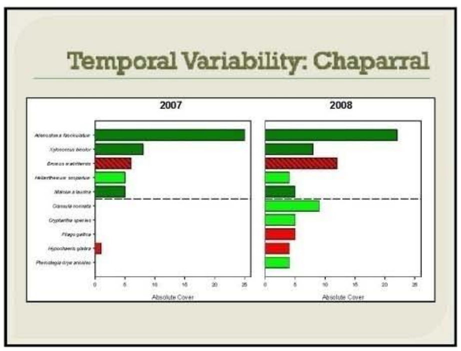
Species Richness 2007 v. 2008
• 311 species (or groups) from 69 families in 2008
Functional Group | 2008 | 2007
Native Shrubs | 65 | 47
Native Forbs | 162 | 69
Native Grasses | 12 | 8
Non-Native Forbs | 38 | 20
Non-Native Grasses | 18 | 11
Other | 16 | 13
Total | 311 | 168

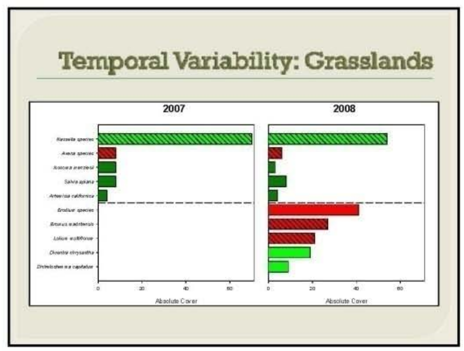


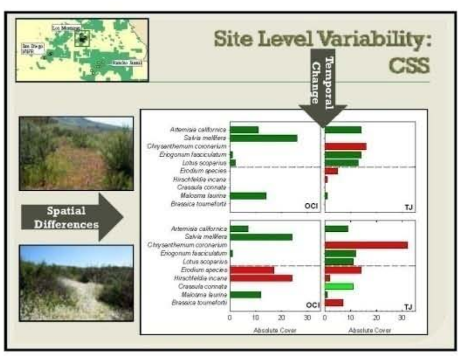
Richness in Unburned Sentinel Plots
• Increases in species richness was not due to the addition of new plots or sites
Increased Richness in 2008
2007: 30 species
2008: 63 species
+110%
2008 Richness
2007 Richness

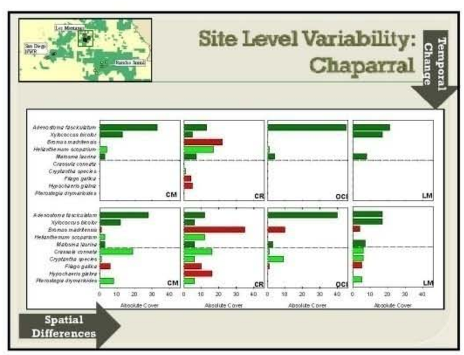

Richness in Functional Groups
• The majority of the new species were native forbs.
Increased Richness in 2008
Native Forbs
Native Shrubs
Non-native Forbs
Non-native Grasses
Other
Native Grasses
2008 Richness
2007 Richness


Temporal Variability: CSS
2007
2008
Absolute Cover

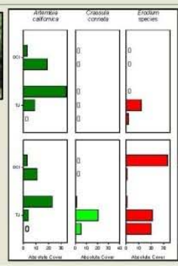

Temporal Variability: Chaparral
2007
2008
Absolute Cover


Temporal Variability: Grasslands
2007
2008
Absolute Cover

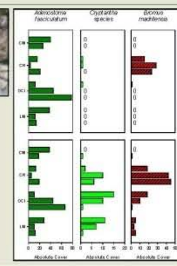

Site Level Variability: CSS
Temporal Change
Spatial Differences
Artemisia californica
Salvia mellifera
Chrysanthemum coronarium
Eriogonum fasciculatum
Lotus scoparius
Erodium species
Hirschfeldia incana
Crassula connata
Malcoma laurina
Brassica tournefortii
OCI
TJ
Absolute Cover

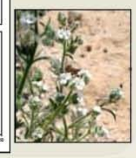

Site Level Variability: Chaparral
Temporal Change
Spatial Differences
CM
CR
OCI
LM
Absolute Cover

Plot Level Variability: CSS



Plot Level Variability: Chaparral





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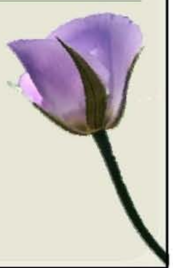
- 2008 Major Results
  - Effort
  - Vegetation Communities
  - **Variance Components Analysis**
- Discussion



Variance Components

Designs for evaluating local and regional scale trends. DP Larsen, TM Kincaid, SE Jacobs, NS Urquhart. Bioscience; Dec 2001, 51(12):1069-1078

"… knowing the relative magnitude of an attribute's temporal, spatial, and residual variation is crucial for making efficient design decisions. Thus, estimating the magnitude of the components of variation and assessing their implications for trend detection is an important part of developing and evaluating monitoring designs."

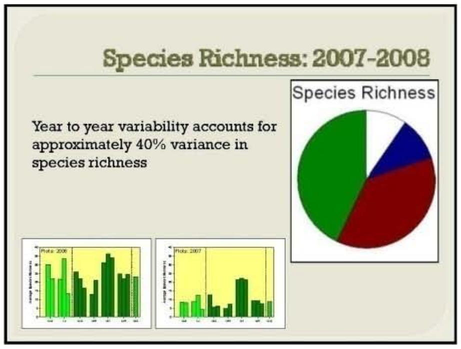
Variance Components

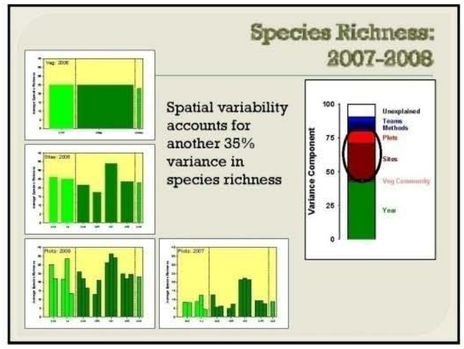
Evaluating the power of monitoring plot designs for detecting long-term trends in the numbers of common guillemots. M Sims, S Wanless, MP Harris, PI Mitchell, DA Elston. Journal of Applied Ecology; 2006, 43:537–546

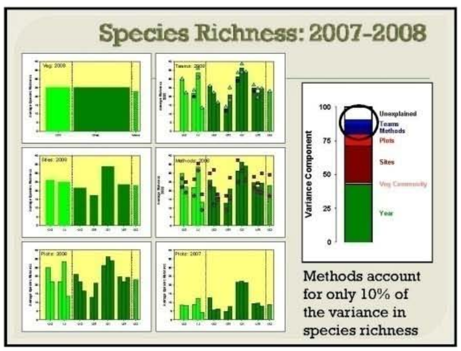
"We examined different sampling design options for monitoring common guillemots by evaluating the power to detect trends in abundance. …It is clear that some useful improvements could be made without a substantial increase in observer effort."

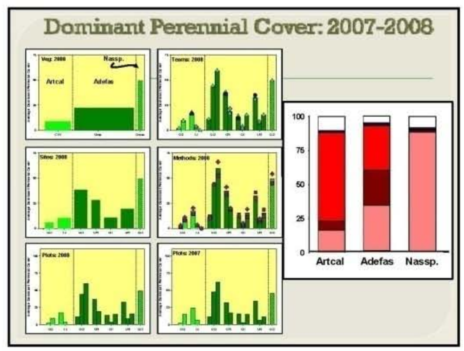
Sources of Variability in Our Data

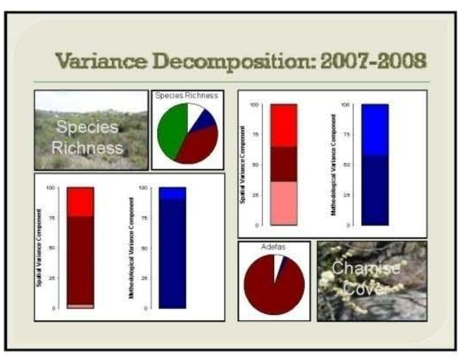
- Temporal
  - 2007 v 2008 unburned sentinel sites
  - Burned sites were excluded for this analysis
- Spatial
  - Vegetation Community
  - Site
  - Plot
- Methodological
  - Inter-Observer
  - Method

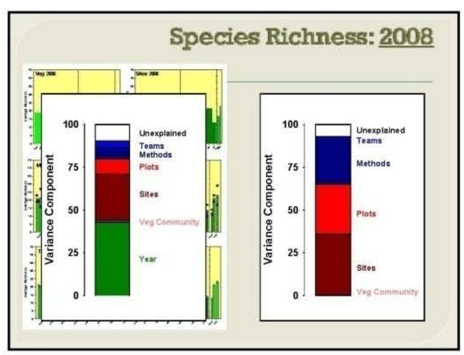

Species Richness: 2007-2008
Year to year variability accounts for approximately 40% variance in species richness
Species Richness

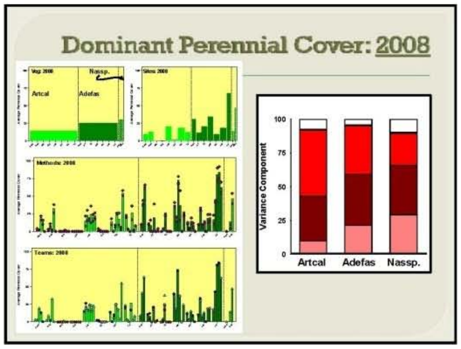

Species Richness: 2007-2008
Spatial variability accounts for another 35% variance in species richness
Variance Component
Unexplained
Teams
Methods
Plots
Sites
Veg Community
Year

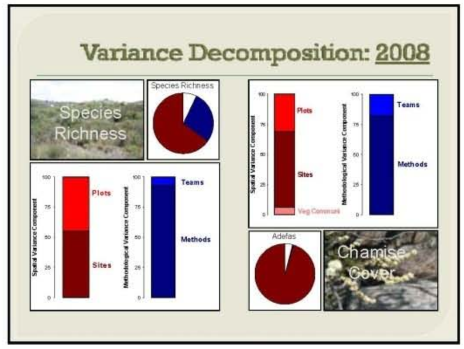

Species Richness: 2007-2008
Variance Component
Unexplained
Teams
Methods
Plots
Sites
Veg Community
Year
Methods account for only 10% of the variance in species richness


Dominant Perennial Cover: 2007-2008
Artcal
Adefas
Nassp.

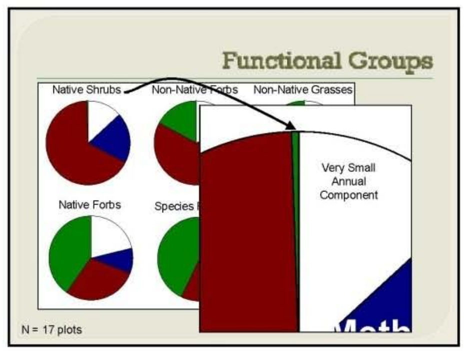

Variance Decomposition: 2007-2008
Species Richness
Species Richness
Adefas
Chamise Cover

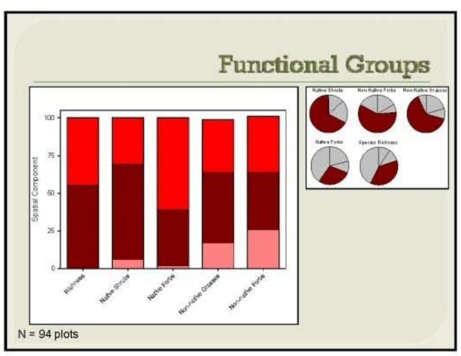

Species Richness: 2008
Variance Component
Unexplained
Teams
Methods
Plots
Sites
Veg Community
Year
Variance Component
Unexplained
Teams
Methods
Plots
Sites
Veg Community

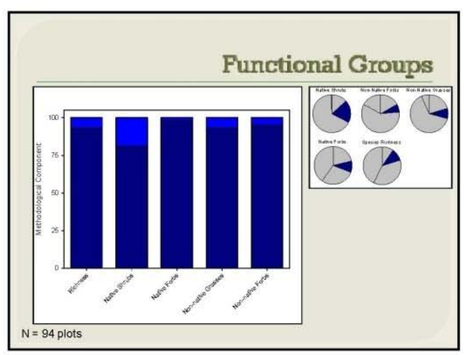

Dominant Perennial Cover: 2008
Variance Component
100
75
50
25
0
Artcal
Adefas
Nassp.

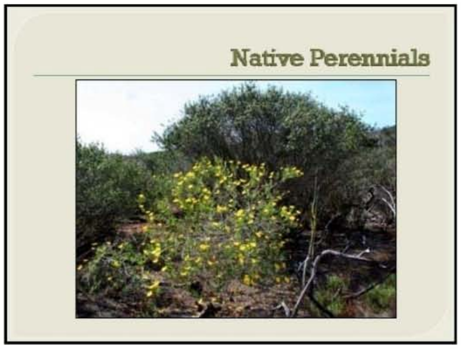

Variance Decomposition: 2008
Species Richness
Species Richness
Plots
Sites
Teams
Methods
Veg Component
Adefas
Chamise Cover

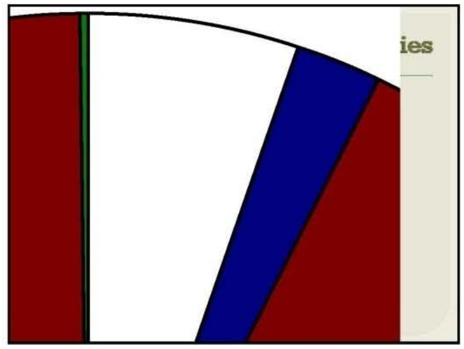

Functional Groups

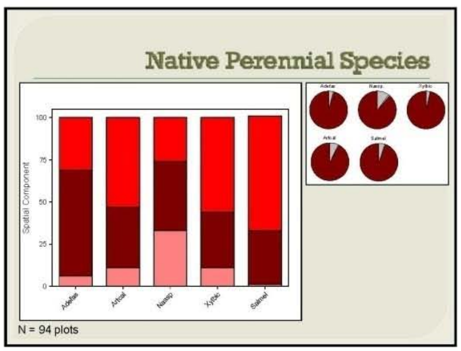

Functional Groups
Native Shrubs
Non-Native Forbs
Non-Native Grasses
Native Forbs
Very Small
Annual
Component
N = 17 plots

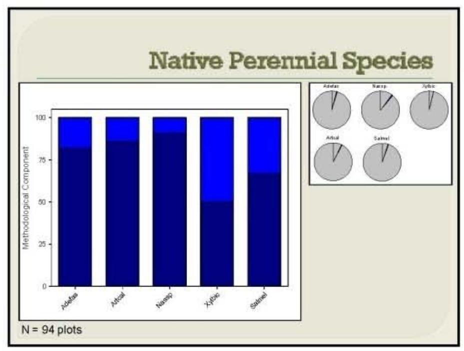

Functional Groups
N = 94 plots


Functional Groups
N = 94 plots

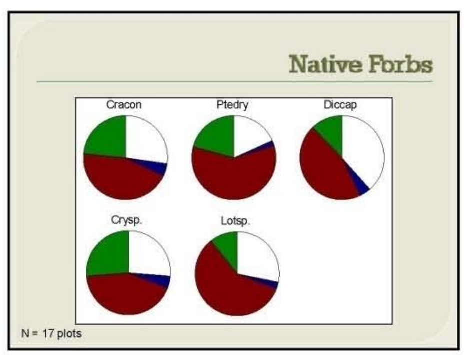

Native Perennials

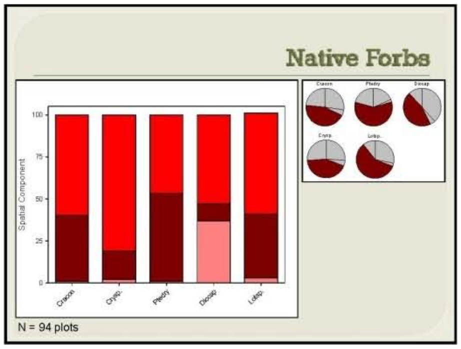


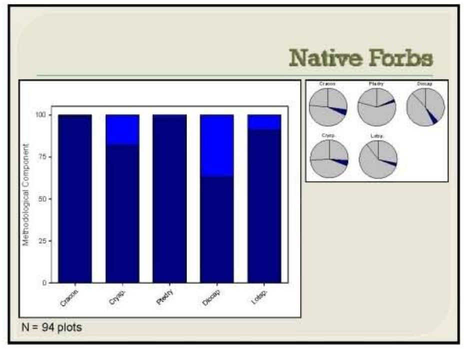

Native Perennial Species
Spatial Component
N = 94 plots


Native Perennial Species
Methodological Component
N = 94 plots

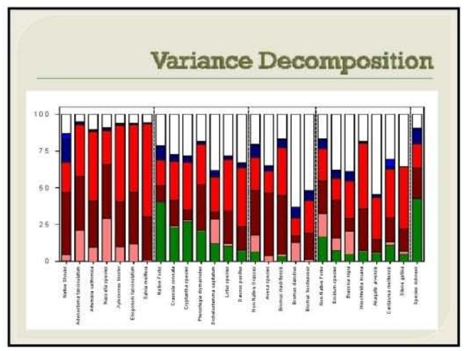

Native Forbs

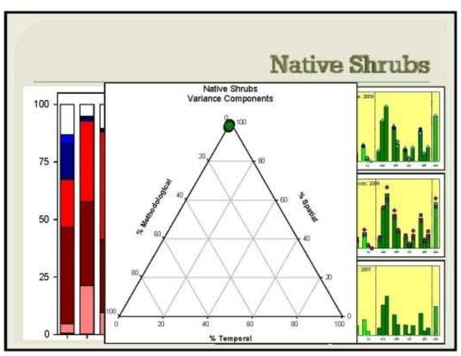

Native Forbs
Cracon
Ptedry
Diccap
Crysp.
Lotsp.
N = 17 plots

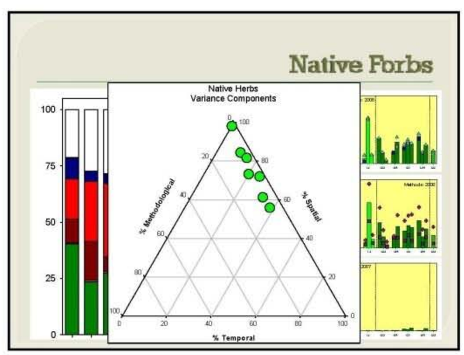

Native Forbs
Spatial Component
N = 94 plots

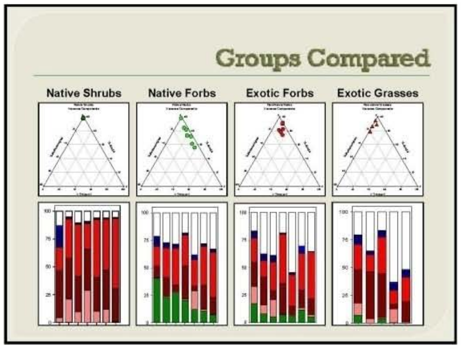

Native Forbs
Methodological Component
N = 94 plots

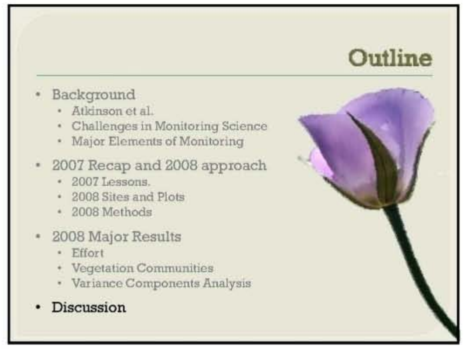

Selected Groups

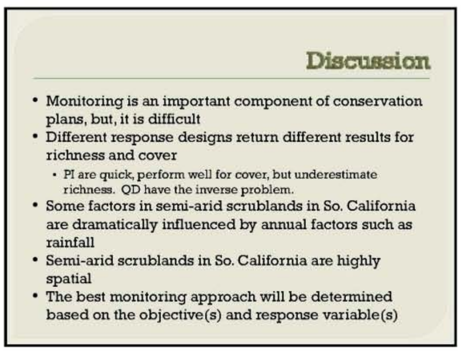

Variance Decomposition

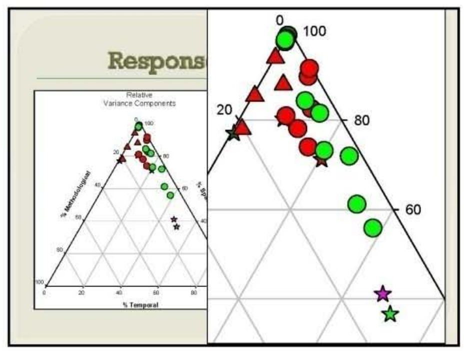

Native Shrubs
Native Shrubs
Variance Components
% Methodological
% Spatial
% Temporal

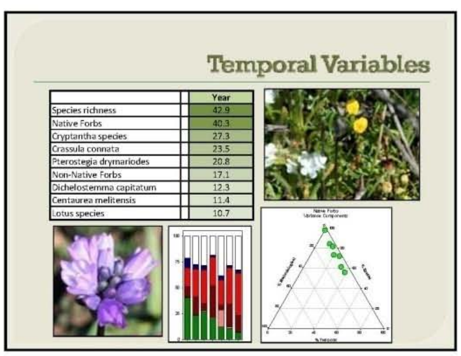

Native Forbs
Native Herbs
Variance Components
% Methodological
% Spatial
% Temporal



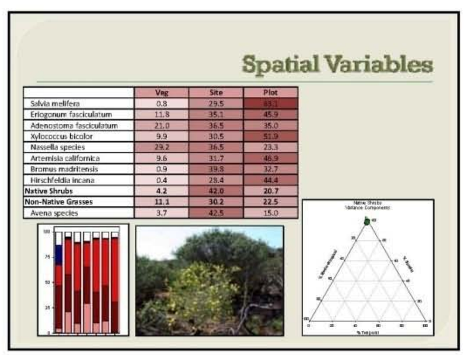




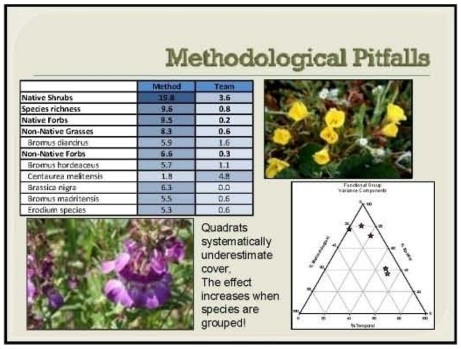




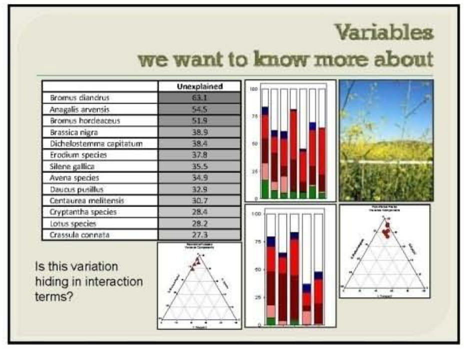
		Year
Species richness		42.9
Native Forbs		40.3
Cryptantha species		27.3
Crassula connata		23.5
Pterostegia drymariodes		20.8
Non-Native Forbs		17.1
Dichelostemma capitatum		12.3
Centaurea melitensis		11.4
Lotus species		10.7



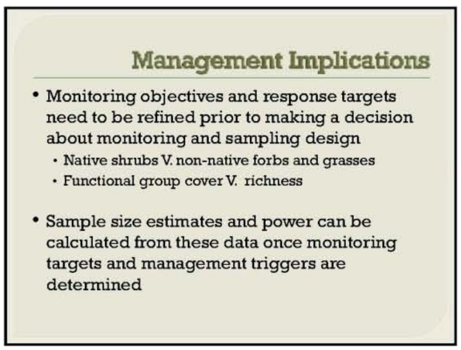
	Veg	Site	Plot
Salvia melifera	0.8	29.5	[illegible]
Eriogonum fasciculatum	11.8	35.1	45.9
Adenostoma fasciculatum	21.0	36.5	35.0
Xylococcus bicolor	9.9	30.5	51.9
Nassella species	29.2	36.5	23.3
Artemisia californica	9.6	31.7	46.9
Bromus madritensis	0.9	39.8	32.7
Hirschfeldia incana	0.4	28.4	44.4
Native Shrubs	**4.2**	**42.0**	**20.7**
Non-Native Grasses	**11.1**	**30.2**	**22.5**
Avena species	3.7	42.5	15.0

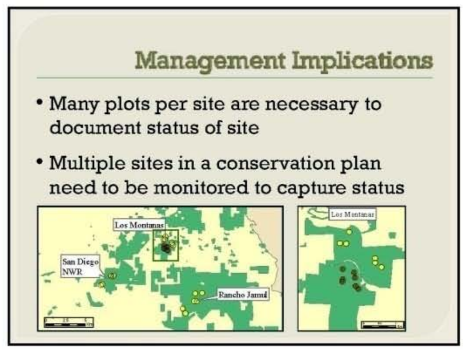


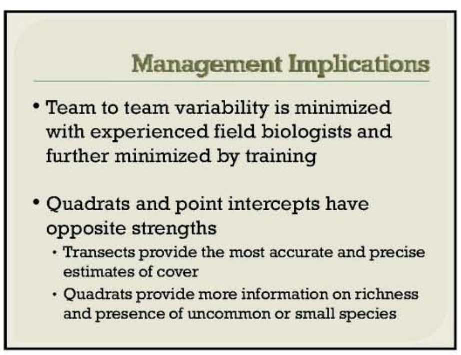
	Method	Team
Native Shrubs	15.8	3.6
Species richness	9.6	0.8
Native Forbs	9.5	0.2
Non-Native Grasses	8.3	0.6
Bromus diandrus	5.9	1.6
Non-Native Forbs	6.6	0.3
Bromus hordeaceus	5.7	1.1
Centaurea melitensis	1.8	4.8
Brassica nigra	6.3	0.0
Bromus madritensis	5.5	0.6
Erodium species	5.3	0.6

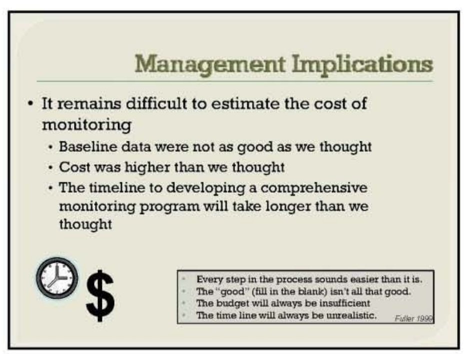


	Unexplained
Bromus diandrus	63.1
Anagalis arvensis	54.5
Bromus hordeaceus	51.9
Brassica nigra	38.9
Dichelostemma capitatum	38.4
Erodium species	37.8
Silene gallica	35.5
Avena species	34.9
Daucus pusillus	32.9
Centaurea melitensis	30.7
Cryptantha species	28.4
Lotus species	28.2
Crassula connata	27.3









Summary of Recomendations

Example Objective	Time	Spatial Extent	Method	Team
Shrub cover for target species	Infrequently	Coarse	PI	Less Experienced
Exotic forb and grass cover (as a group)	Frequently	Moderate	PI	Less Experienced
Plant species diversity	Frequently	Moderate	QD	More Experienced
Any single non-obvious herb species	Frequently	Fine	QD	More Experienced
Emergent invaders	Frequently	Fine	QD	More Experienced
Host plants for target species (common)	Frequently	Fine	QD	Less Experienced
Rare plant species	*Species specific protocol is recommended*			
Host plants for target species (patchy/rare)	*Species specific protocol is recommended*			

Limitations

- Only two years of data
  - Climatic factors in San Diego County are wider and more varied
- Post fire monitoring is important, but is a long term issue
- Fire unbalanced the 2007 design
  - Temporal signal based primarily on chaparral plots
- Several simplifying assumptions made in the variance decomposition
- Power calculations will likely be complex models not simple calculations

Additional Needs

- More yearly data
  - to fill in the gaps in the temporal analysis left by the 2007 fires
  - To rectify how dramatically different 2007 and 2008 were
- More post-fire monitoring:
  - At what point is each method most appropriate?
  - How frequently must you monitor post fire to understand the system response?
- Compare this decomposition with one adjusting for varying sample sizes.

Acknowledgements

- Sponsoring Agencies and Organizations
- Our field and data analysis crew:
  Dave Bailey, Alissa Brown, Kellie Uyeda, Erin Harold, Marie Moreau, Elizabeth Santos
- Karin Cleary-Rose and the WRMSHCP monitoring staff
- Brenda Johnson, DFG
- Clark Winchell, FWS
- Keith Greer, SANDAG
- Trish Smith and Zach Principe, TNC
- Kristine Preston and Lyn McAfee, NROC
- Our audience today!

APPENDIX 2:
PRESENTATION PARTICIPANTS AND RESPONSE TO COMMENTS

Last Name	First Name	Agency
Bailey	Dave	SDSU
Bech	Michael	Endangered Habitats League
Brennen	Chris	SD City
Brown	Alissa	SDSU
Carnavale	Sue	SANDAG
Chason	Caithin	SDSU Geography
Cleary-Rose	Karin	WRMSHCP
Deutschman	Doug	SDSU
Dunn	Jonathan	EDAW
Erselr	Bob	County of SD
Fege	Anne	SDNHM
Fleming	Genie	SDNHM
Garcia	Joshua	
Gordon-Reedy	Patricia	
Grady	Mary	DFG
Greer	Keith	SANDAG
Haines	Jennifer	SD County
Hamada	Yuki	SDSU
Hamilton	Megan	County of SD
Hawke	Mary Ann	County of SD
Hillary	Richard	SERG
Hogan	Jenifer	DFG
Hoshi	Junko	DFG
Humphrey	Rosanne	TAIC
Itoga	Stuart	CDFG
Jennings	Megan	SDSU/CNF
Johnson	Aaron	ERA
Johnson	Arne	CNPS
Johnson	Brenda	CDFG
Kraft	Clayton	ERA
Lincer	Jeff	WRI
Malisch	Adam	WRMSHCP
Martin	John	USFWS
Mayer	David	CDFG
McConnell	Patrick	CNLM
McEachern	Kathryn	USGS
Menuz	Diane	WRMSHCP
Miller	Betsy	City of SD
Miller	William	USFWS
Morin	Dana	EDAW
Newton-Reed	Steve	CDFG
Norton	Jessica	SD Parks and Rec

Last Name	First Name	Agency
Oberbauer	Tom	SD County
O'Leary	John	SDSU
Parisi	Monica	DFG
Paver	Sean	USFWS
Preston	Kris	NROC
Principe	Zach	TNC
Rempel	Ron	Private Contractor
Rodriguez	Randy	DFG
Rom	Catharine	DFG
Root	Brian	FWS
Schafer	Christina	TAIC
Schlachter	Joyce	BLM
Shanney	Christina	SERG
Simonsen-Marchant	Julie	ERA
Smith	Trish	TNC
Spears-Lebrum	Linnea	EDAW
Stallcup	Jerre	CBI
Stow	Doug	SDSU
Strahm	Spring	SDSU
Talluto	Matt	WRMSHCP
Thompson	Andrew	FWS
Vinje	Jessie	CNLM
Winchell	Clark	USFWS
Wynn	Susan	USFWS

#	First	Last	Organization	Comment	Response
1	Linnea	Spears-Leburn	EDAW	I have one comment/question: The previous two years of monitoring have focused on CSS, chaparral, and grasslands. What about wetland/riparian systems and other sensitive communities (vernal pools) that are part of the preserve although in much smaller acreages? Will these communities be part of the larger preserve monitoring design in the future?	A similar study could certainly be conducted for other vegetation types, however at this time we have not been approached to do so for riparian/wetland/vernal pool types yet. The logic for focusing on CSS and chaparral goes back to the initial Franklin et al. reports prioritizing vegetation types—CSS and chaparral have the largest number of covered species and/or have the most acreage inside the MSCP. In addition the study might be very different in specifics for a point feature such as vernal pools.

#	First	Last	Organization	Comment	Response
2	Mary Ann	Hawke	SDNHM	To follow up on the question that arose about marking the quadrats to make it easier to estimate cover, I just wanted to mention a classic paper (that you are probably already aware of, since he extensively studied and compared different methods of analyzing vegetation in shrub-dominated systems in the 1950s) by Daubenmire in 1959 called “A Canopy-Coverage Method of Vegetational Analysis” in Northwest Science 33(1):43-64. His Figure 1 (attached) illustrates one way of painting the frame of a small quadrat to help with standardizing visual assessments of cover. I used his small (20 x 50 cm) quadrats along line transects very successfully in arid shrub-steppe systems to do cover estimates of small plants and biological soil crusts (using line intercept to capture larger plants and point-quarter to do shrubs). I also experimented with stringing the quadrat frame with fishing line to form a grid of smaller squares, but that only worked well with very short low-growing species.	I agree that painting or otherwise marking guides on out quadrats will help estimate cover visually. I suspect guides will likely reduce team-to-team variability the most (although I could be wrong), which we have found is a pretty small effect if the field crew is somewhat experienced. The method-to-method variability we saw in cover estimations was slightly more important for some functional groups with quadrats underestimating cover. The relationship between point intercept estimation and quadrats is so tight and predictable (high R) it leads me to think that the underestimation is consistent and attributable to the method interacting with how our brains process visual information. I think our first step needs to be to convince the field crews that over 200% cover is actually okay, and to look at each species completely independently from the others-which is actually counter to some tips given by CNPS for visual estimation methods. I think after that guides will be a huge confidence builder and will really help the teams make precise estimates.

#	First	Last	Organization	Comment	Response
3	John	O'Leary	SDSU Geography	Did you stratify by chaparral type?	No, we did not. We used the same vegetation categories that were used during the planning phase of the MSCP, which were pretty coarse. Franklin et al. also used these categories to do their analysis of priorities which we used as a guide. That being said, and it being clear that chaparral exists on a continuum of dominance by different species, it is also unclear at what level we might actually stratify by. This question is likely functional and is best answered by the agencies responsible from administering the MSCP.
4	John	O'Leary	SDSU Geography	How do you define species richness?	Simply the count of species encountered at the stated experimental unit (usually the plot). In 2007 it was the number of species encountered in a 20X50M Keeley plot, in 2008 the number of species encountered along a 50m transect.
5	Unknown			Did you collect ground cover information?	Yes. We have not analyzed it yet, however it can be used to evaluate if the non-shrub covered regions in the habitat types are bare or filled in with thatch, which may have ramifications for ecosystem health and specific animal species.

#	First	Last	Organization	Comment	Response
6	Will	Miller	FWS	How many more years will it take to be sure your recommendations won't change?	It depends on a number of factors, including rainfall and the timing of rainfall. We feel very comfortable about shrubs at this time. We know that native and exotic forbs will always have a large annual component, and need to assess the magnitude of that component. We still have a lot of information gathering to do in regards to exotic grasses.
7	Jonathan	Dunn	EDAW	Asked about plot fatigue	Plot fatigue is a reasonable concern, particularly in deep chaparral. We are responding to these concerns by reducing the number of teams revisiting a plot. Once we have enough annual data we will likely make recommendations about a rotating panel design--A hybrid design such as sampling a panel for multiple years and then retiring it combined with a rotating panel of long-term plots that will be sampled every few years is one possible recommendation
8	John	O'Leary	SDSU Geography	Post fire monitoring impacts?	We are aware that monitoring after a fire may introduce more non-native species to a plot than would occur naturally. We will likely rest our fire plots for a year or two before returning. This is another argument for a hybrid design as mentioned in comment 7.

#	First	Last	Organization	Comment	Response
9	Jerry	Sullivan	CBI	Are there situations when letting the design influence the question would be appropriate?	Probably not, with qualifications. The danger is collecting data because we can V. because we have to address specific questions. This question highlights the importance of the Atkinson et al approach, which allows you to set up goals, objectives and questions in a synthetic framework, then modify your design or questions based on the information you collect. EG a monitoring technique should not be static given new results, but does need to have driving goals and objectives to guide the effort.
10	Michael	Beck		Is the data available on-line?	We hope to have it in bios soon, however we did not until recently have the GIS power and time to deliver it to them in a GIS format.
11	Michael	Beck		Can or is this data being correlated with animal species.	Not yet. We have some Hermes copper data and will have some small mammal data. We have discussed putting out wildlife cameras, tracking stations, and other passive monitoring stations to begin this process, however we have not yet made any decisions.
12	Dana	Morin		Have you looked at other indices of diversity	We have not made the calculations. Our richness values are on one extreme of diversity calculations.
13	Genie	Fleming		See diagram.	

#	First	Last	Organization	Comment	Response
14	Betsy	Miller		I have a question about the scale of the sampling: How does the project design allow us to take data from, for example, a 50 meter transect and scale it up to provide meaningful information about the MHPA preserve as a whole? I'm concerned about the size of the area over which we need information, and the scope that would be required in order to have data to feed back into our adaptive management loop.	

APPENDIX 3: PLOT LOCATIONS

Plot_Name	County	Site	Habitat	Plot	2007_Fire	TX_Length	Sentinal	Ownership	Northing	Westing
OC_C_CSS_1	OC	C	CSS	1	UB	50	N	NROC/LCWP	33.5978	-117.7879
OC_C_CSS_2	OC	C	CSS	2	UB	50	N	NROC/LCWP	33.5805	-117.7747
OC_C_CSS_3	OC	C	CSS	3	UB	50	N	NROC/LCWP	33.5848	-117.7657
OC_C_CSS_4	OC	C	CSS	4	UB	50	N	NROC/LCWP	33.6070	-117.7745
OC_C_CSS_5	OC	C	CSS	5	UB	50	N	NROC/LCWP	33.6100	-117.7636
OC_C_GL_1	OC	C	GL	1	UB	50	N	NROC/CCSP	33.5658	-117.8204
OC_C_GL_2	OC	C	GL	2	UB	50	N	TNC Easement	33.6165	-117.7523
OC_I_CHAP_1	OC	I	CHAP	1	UB	100	Y	TNC Easement	33.7939	-117.6845
OC_I_CHAP_2	OC	I	CHAP	2	UB	100	Y	TNC Easement	33.7908	-117.6907
OC_I_CHAP_3	OC	I	CHAP	3	UB	100	Y	TNC Easement	33.7953	-117.6787
OC_I_CHAP_4	OC	I	CHAP	4	UB	50	N	TNC Easement	33.8047	-117.7088
OC_I_CHAP_5	OC	I	CHAP	5	B	50	N	NROC/LWWP	33.6987	-117.6455
OC_I_CSS_1	OC	I	CSS	1	UB	100	Y	TNC Easement	33.7865	-117.7121
OC_I_CSS_2	OC	I	CSS	2	UB	100	Y	TNC Easement	33.7993	-117.7418
OC_I_CSS_3	OC	I	CSS	3	B	100	Y	TNC Easement	33.7501	-117.7137
OC_I_CSS_4	OC	I	CSS	4	B	100	N	TNC Easement	33.7499	-117.7137
OC_I_CSS_5	OC	I	CSS	5	B	100	N	TNC Easement	33.7508	-117.7127
OC_I_CSS_6	OC	I	CSS	6	UB	50	N	TNC Easement	33.8017	-117.7141
OC_I_CSS_7	OC	I	CSS	7	UB	50	N	TNC Easement	33.7545	-117.6725
OC_I_CSS_8	OC	I	CSS	8	UB	50	N	TNC Easement	33.7652	-117.6732
OC_I_CSS_9	OC	I	CSS	9	B	50	N	NROC/LWWP	33.6958	-117.6404
OC_I_GL_1	OC	I	GL	1	UB	100	Y	TNC Easement	33.8120	-117.7477
OC_I_GL_2	OC	I	GL	2	B	100	Y	NROC/LWWP	33.7178	-117.6599
OC_I_GL_3	OC	I	GL	3	B	100	N	NROC/LWWP	33.7209	-117.6569
OC_I_GL_4	OC	I	GL	4	B	100	N	NROC/LWWP	33.7220	-117.6616
OC_I_GL_5	OC	I	GL	5	B	100	N	TNC Easement	33.7588	-117.7152
OC_I_GL_6	OC	I	GL	6	B	100	N	TNC Easement	33.7632	-117.7190

APPENDIX 4: THREE COUNTY SPECIES LIST

Species	Family	Functional Group
Acourtia microcephala	Asteraceae	Native Herb
Adenophyllum porophylloides	Asteraceae	Native Herb
Adenostoma fasciculatum	Rosaceae	Native Shrub
Adenostoma sparsifolium	Rosaceae	Native Shrub
Agrostis species	Poaceae	Unknown
Allium amplectens	Alliaceae	Native Herb
Allium peninsulare	Alliaceae	Native Herb
Allium praecox	Alliaceae	Native Herb
Allophyllum glutinosum	Polomoniaceae	Native Herb
Ambrosia psilostachya	Asteraceae	Native Herb
Amsinkia menziesii	Boraginaceae	Native Herb
Anagalis arvensis	Primulaceae	Non-native Herb
Anemopsis californica	Saururaceae	Native Herb
Antirrhinum coulterianum	Plantaginaceae	Native Herb
Antirrhinum kelloggii	Plantaginaceae	Native Herb
Antirrhinum nuttallianum	Plantaginaceae	Native Herb
Antirrhinum species	Plantaginaceae	Native Herb
Apiastrum angustifolium	Apiaceae	Native Herb
Apiastrum species	Apiaceae	Native Herb
Arabis glabra	Brassicaceae	Native Herb
Arabis sparsiflora	Brassicaceae	Native Herb
Arctostaphylos glandulosa	Ericaceae	Native Shrub
Arctostaphylos glauca	Ericaceae	Native Shrub
Arctostaphylos species	Ericaceae	Native Shrub
Aristida species	Poaceae	Native Grass
Artemisia californica	Asteraceae	Native Shrub
Artemisia palmeri	Asteraceae	Native Herb
Artemisia tridentata	Asteraceae	Native Shrub
Athysanus pusillus	Brassicaceae	Native Herb
Avena species	Poaceae	Non-native Grass
Baccharis emoryi	Asteraceae	Native Shrub
Baccharis pilularis	Asteraceae	Native Shrub
Baccharis sarathroides	Asteraceae	Native Shrub
Bahiopsis laciniata	Asteraceae	Native Shrub
Bebbia juncea	Asteraceae	Native Shrub
Bloomeria crocea	Orchidaceae	Native Herb
Bowlesia incana	Apiaceae	Native Herb

Species	Family	Functional Group
Brachypodium distachyon	Poaceae	Non-native Grass
Brassica geniculata	Brassicaceae	Native Herb
Brassica nigra	Brassicaceae	Non-native Herb
Brassica species	Brassicaceae	Non-native Herb
Brassica tournefortii	Brassicaceae	Non-native Herb
Bromus diandrus	Poaceae	Non-native Grass
Bromus hordeaceus	Poaceae	Non-native Grass
Bromus madritensis	Poaceae	Non-native Grass
Bromus species	Poaceae	Non-native Grass
Bromus tectorum	Poaceae	Non-native Grass
Calandrinia ciliata	Portulacaceae	Native Herb
Calochortus catalinae	Liliaceae	Native Herb
Calochortus concolor	Liliaceae	Native Herb
Calochortus species	Liliaceae	Native Herb
Calochortus splendens	Liliaceae	Native Herb
Calyptridium monandrum	Portulacaceae	Native Herb
Calystegia macrostegia	Convolvulaceae	Native Vine
Camissonia species	Onagraceae	Native Herb
Capsella bursa-pastoris	Brassicaceae	Non-native Herb
Cardionema ramosissimum	Carophyllaceae	Native Herb
Carex species	Cyperaceae	Native Grass
Castilleja affinis	Orobanchaceae	Native Herb
Castilleja applegatei	Orobanchaceae	Native Herb
Castilleja exserta	Orobanchaceae	Native Herb
Caulanthus heterophyllus	Brassicaceae	Native Herb
Caulanthus simulans	Brassicaceae	Native Herb
Caulanthus species	Brassicaceae	Native Herb
Ceanothus crassifolius	Rhamnaceae	Native Shrub
Ceanothus greggii	Rhamnaceae	Native Shrub
Ceanothus leucodermis	Rhamnaceae	Native Shrub
Ceanothus species	Rhamnaceae	Native Shrub
Ceanothus tomentosus	Rhamnaceae	Native Shrub
Ceanothus verrucosus	Rhamnaceae	Native Shrub
Centaurea melitensis	Asteraceae	Non-native Herb
Centaurium venustum	Gentianaceae	Native Herb
Cerastium glomeratum	Carophyllaceae	Non-native Herb
Cercocarpus betuloides	Rosaceae	Native Shrub
Cercocarpus minutiflorus	Rosaceae	Native Shrub
Chaenactis glabriuscula	Asteraceae	Native Herb
Chamaesyce albomarginata	Euphorbiaceae	Native Herb

Species	Family	Functional Group
Chamaesyce micromera	Euphorbiaceae	Native Herb
Chamaesyce polycarpa	Euphorbiaceae	Native Herb
Chamomilla suaveolens	Asteraceae	Non-native Herb
Chenopodium californicum	Amaranthaceae	Native Herb
Chenopodium multifidum	Amaranthaceae	Non-native Herb
Chenopodium murale	Amaranthaceae	Non-native Herb
Chlorogalum species	Hyacinthaceae	Native Herb
Chorizanthe species	Polygonaceae	Native Herb
Chrysanthemum coronarium	Asteraceae	Non-native Herb
Cirsium occidentale	Asteraceae	Native Herb
Cirsium species	Asteraceae	Non-native Herb
Clarkia epiloboides	Onagraceae	Native Herb
Clarkia purpurea	Onagraceae	Native Herb
Claytonia parviflora	Portulacaceae	Native Herb
Claytonia perfoliata	Portulacaceae	Native Herb
Cneoridium dumosum	Rutaceae	Native Shrub
Collinsia concolor	Plantaginaceae	Native Herb
Collinsia heterophylla	Plantaginaceae	Native Herb
Convolvulus arvensis	Convolvulaceae	Non-native Vine
Conyza canadensis	Asteraceae	Native Herb
Cordylanthus rigidus	Orobanchaceae	Native Herb
Coreopsis gigantea	Asteraceae	Non-native Herb
Coreopsis maritima	Asteraceae	Native Herb
Corethrogyne filaginifolia	Asteraceae	Native Herb
Crassula connata	Crassulaceae	Native Herb
Croton californicus	Euphorbiaceae	Native Herb
Cryptantha species	Boraginaceae	Native Herb
Cuscuta species	Convolvulaceae	Native Vine
Cylindropuntia bigelovii	Cactaceae	Native Shrub
Cylindropuntia californica	Cactaceae	Native Shrub
Cylindropuntia prolifera	Cactaceae	Native Shrub
Cynara cardunculus	Asteraceae	Non-native Herb
Cynodon dactylon	Poaceae	Non-native Grass
Daucus pusillus	Apiaceae	Native Herb
Dautura wrightii	Solanaceae	Native Herb
Deinandra species	Asteraceae	Native Herb
Delphinium parryi	Ranunculaceae	Native Herb
Dendromecon rigida	Papaveraceae	Native Shrub
Descurainia pinnata	Brassicaceae	Native Herb
Dicentra chrysantha	Papaveraceae	Native Herb

Species	Family	Functional Group
Dichelostemma capitatum	Themidaceae	Native Herb
Dichelostemma pulchellum	Themidaceae	Native Herb
Distichlis spicata	Poaceae	Native Grass
Ehrharta calycina	Poaceae	Non-native Grass
Elymus species	Poaceae	Native Grass
Emmenanthe penduliflora	Boraginaceae	Native Herb
Encelia californica	Asteraceae	Native Shrub
Encelia farnosa	Asteraceae	Native Shrub
Ephedra californica	Ephedraceae	Native Shrub
Epilobium canum	Onagraceae	Native Herb
Eremocarpus setigerus	Euphorbiaceae	Native Herb
Eriastrum sapphirinum	Polemoniaceae	Native Herb
Ericameria palmeri	Asteraceae	Native Shrub
Erigeron foliosus	Asteraceae	Native Herb
Eriodictyon crassifolium	Hydrophyllaceae	Native Shrub
Eriogonum davidsonii	Polygonaceae	Native Herb
Eriogonum elongatum	Polygonaceae	Native Herb
Eriogonum fasciculatum	Polygonaceae	Native Shrub
Eriogonum species	Polygonaceae	Unknown
Eriophyllum confertiflorum	Asteraceae	Native Herb
Erodium species	Geraniaceae	Non-native Herb
Eschscholzia californica	Papaveraceae	Native Herb
Eucrypta species	Boraginaceae	Native Herb
Euphorbia misera	Euphorbiaceae	Native Shrub
Euphorbia peplus	Euphorbiaceae	Non-native Herb
Ferocactus viridescens	Cactaceaea	Native Shrub
Filago species	Asteraceae	Unknown
Galium andrewsii	Rubiaceae	Native Herb
Galium angustifolium	Rubiaceae	Native Herb
Galium aparine	Rubiaceae	Non-native Herb
Galium nuttallii	Rubiaceae	Native Herb
Galium species	Rubiaceae	Native Herb
Gastridium ventricosum	Poaceae	Non-native Grass
Geranium dissectum	Geraniaceae	Non-native Herb
Gilia angelensis	Polemoniaceae	Native Herb
Gilia aparane	Polemoniaceae	Native Herb
Gilia capitata	Polemoniaceae	Native Herb
Gilia diegensis	Polemoniaceae	Native Herb
Gilia species	Polemoniaceae	Native Herb
Gillia stellata	Polemoniaceae	Native Herb

Species	Family	Functional Group
Gnaphallium bicolor	Asteraceae	Native Herb
Gnaphallium californicum	Asteraceae	Native Herb
Gnaphallium species	Asteraceae	Native Herb
Gutierrezia species	Asteraceae	Native Herb
Hazardia squarrosa	Asteraceae	Native Shrub
Hedypnois cretica	Asteraceae	Non-native Herb
Helianthemum scoparium	Cistaceae	Native Shrub
Helianthus gracilentus	Asteraceae	Native Shrub
Heliotropium curassavica	Boraginaceae	Native Herb
Hesperoyucca whipplei	Agavaceae	Native Shrub
Heteromeles arbutifolia	Rosaceae	Native Shrub
Hirschfeldia incana	Brassicaceae	Non-native Herb
Hordeum murinum	Poaceae	Non-native Grass
Hypochaeris glabra	Asteraceae	Non-native Herb
Isocoma acaradenia	Asteraceae	Native Shrub
Isocoma menziesii	Asteraceae	Native Shrub
Isomeris arborea	Brassicaceae	Native Shrub
Jepsonia parryi	Saxifragaceae	Native Herb
Juncus species	Juncaceae	Native Grass
Keckiella antirrhinoides	Phrymaceae	Native Shrub
Lactuca serriola	Asteraceae	Non-native Herb
Lamarchia aurea	Poaceae	Non-native Grass
Lasthenia californica	Asteraceae	Native Herb
Lasthenia coronaria	Asteraceae	Native Herb
Lasthenia gracilis	Asteraceae	Native Herb
Lasthenia species	Asteraceae	Native Herb
Lathyrus vestitus	Fabaceae	Native Herb
Layia glandulosa	Asteraceae	Native Herb
Layia platyglossa	Asteraceae	Native Herb
Lepidium species	Brassicaceae	Unknown
Leymus condensatus	Poaceae	Native Grass
Linanthus dianthiflorus	Polemoniaceae	Native Herb
Linanthus lemmonii	Polemoniaceae	Native Herb
Linanthus liniflorus	Polemoniaceae	Native Herb
Linanthus species	Polemoniaceae	Native Herb
Linaria canadensis	Plantaginaceae	Native Herb
Litter	Ground cover	Ground cover
Lolium multiflorum	Poaceae	Non-native Grass
Lomatium lucidum	Apiaceae	Native Herb
Lonicera species	Caprifoliaceae	Native Shrub

Species	Family	Functional Group
Lonicera subspicata	Caprifoliaceae	Native Shrub
Lotus scoparius	Fabaceae	Native Shrub
Lotus species	Fabaceae	Native Herb
Lupinus bicolor	Fabaceae	Native Herb
Lupinus concinnus	Fabaceae	Native Herb
Lupinus hirsutissimus	Fabaceae	Native Herb
Lupinus microcarpus	Fabaceae	Native Herb
Lupinus sparsiflorus	Fabaceae	Native Herb
Lupinus species	Fabaceae	Native Herb
Lupinus succulentus	Fabaceae	Native Herb
Lupinus truncatus	Fabaceae	Native Herb
Lycium andersonii	Solanaceae	Native Shrub
Malacothamnus fasciculatus	Malvaceae	Native Shrub
Malosma laurina	Anacardiaceae	Native Shrub
Malva parviflora	Malvaceae	Non-native Herb
Marah macrocarpus	Cucurbitaceae	Native Vine
Marchantia species	Marchantiophyta	Other
Marrubium vulgare	Lamiaceae	Non-native Herb
Medicago polymorpha	Fabaceae	Non-native Herb
Medicago sativa	Fabaceae	Non-native Herb
Melica imperfecta	Poaceae	Native Grass
Melilotus alba	Fabaceae	Non-native Herb
Melilotus indica	Fabaceae	Non-native Herb
Micropis californicus	Asteraceae	Native Herb
Microseris lindleyi	Asteraceae	Native Herb
Mimulus aurantiacus	Phrymaceae	Native Shrub
Mimulus brevipes	Phrymaceae	Native Herb
Mimulus floribundus	Phrymaceae	Native Herb
Mirabilis laevis	Nyctaginaceae	Native Herb
Muhlenbergia rigens	Poaceae	Native Grass
Muhlenbergia species	Poaceae	Native Grass
Muilla clevelandii	Themidaceae	Native Herb
Muilla maritima	Themidaceae	Native Herb
Nassella species	Poaceae	Native Grass
Navarretia species	Polemoniaceae	Native Herb
Nemacladus species	Campanulaceae	Unknown
Nemophilia menziesii	Boraginaceae	Native Herb
Nolina species	Nolinaceae	Native Shrub
Ophioglossum californicum	Ophioglossaceae	Native Herb
Opuntia basilaris	Cactaceae	Native Shrub

Species	Family	Functional Group
Opuntia littoralis	Cactaceae	Native Shrub
Osmadenia tenella	Asteraceae	Native Shrub
Oxalis pes-caprae	Oxalidaceae	Non-native Herb
Oxytheca trilobata	Polygonaceae	Native Herb
Paeonia californica	Paeoniaceae	Native Herb
Parietaria hespera	Urticaceae	Native Herb
Pectocarya linearis	Boraginaceae	Native Herb
Pectocarya linearis	Boraginaceae	Native Herb
Pectocarya recurvata	Boraginaceae	Native Herb
Pellaea andromedifolia	Pteridaceae	Native Herb
Pellaea mucronata	Pteridaceae	Native Herb
Pentagramma triangularis	Pteridaceae	Native Herb
Phacelia brachyloba	Boraginaceae	Native Herb
Phacelia campanularia	Boraginaceae	Native Herb
Phacelia cicutaria	Boraginaceae	Native Herb
Phacelia distans	Boraginaceae	Native Herb
Phacelia minor	Boraginaceae	Native Herb
Phacelia parryi	Boraginaceae	Native Herb
Phacelia ramosissima	Boraginaceae	Native Herb
Phacelia species	Boraginaceae	Native Herb
Phalaris aquatica	Poaceae	Non-native Grass
Pholistoma auritum	Boraginaceae	Native Herb
Pickeringia montana	Fabaceae	Native Shrub
Plagiobothrys species	Boraginaceae	Native Herb
Plagiobothrys species	Plantaginaceae	Native Herb
Plantago erecta	Plantaginaceae	Native Herb
Plantago lanceolata	Plantaginaceae	Native Herb
Plantago ovata	Plantaginaceae	Native Herb
Poa annua	Poaceae	Non-native Grass
Poa secunda	Poaceae	Non-native Grass
Polygonum arenastrum	Polygonaceae	Non-native Herb
Polypodium californicum	Polypodiaceae	Native Herb
Porophyllum gracile	Asteraceae	Native Herb
Prunus ilicifolia	Rosaceae	Native Shrub
Psilocarphus species	Asteraceae	Native Herb
Pterostegia drymarioides	Polygonaceae	Native Herb
Quercus agrifolia	Fagaceae	Native Tree
Quercus berberidifolia	Fagaceae	Native Shrub
Rafinesquia californica	Asteraceae	Native Herb
Raphanus sativus	Brassicaceae	Non-native Herb

Species	Family	Functional Group
Rhamnus crocea	Rhamnaceae	Native Shrub
Rhamnus ilicifolia	Rhamnaceae	Native Shrub
Rhus integrifolia	Anacardiaceae	Native Shrub
Rhus ovata	Anacardiaceae	Native Shrub
Ribes indecorum	Grossulaceae	Native Shrub
Ribes species	Grossulaceae	Native Shrub
Rock	Ground cover	Ground cover
Rumex species	Polygonaceae	Non-native Herb
Salsola tragus	Amaranthaceae	Non-native Shrub
Salvia apiana	Lamiaceae	Native Shrub
Salvia clevelandii	Lamiaceae	Native Shrub
Salvia columbariae	Lamiaceae	Native Herb
Salvia mellifera	Lamiaceae	Native Shrub
Sambucus mexicana	Caprifoliaceae	Native Shrub
Sanicula arguta	Apiaceae	Native Herb
Schismus barbatus	Poaceae	Non-native Grass
Scirpus californicus	Scrophulariaceae	Native Herb
Selaginella bigelovii	Selaginellaceae	Native Herb
Selaginella cinerascens	Selaginellaceae	Native Herb
Senecio californicus	Asteraceae	Native Herb
Senecio species	Asteraceae	Unknown
Senecio vulgaris	Asteraceae	Non-native Herb
Silene gallica	Carophyllaceae	Non-native Herb
Silene multinervia	Carophyllaceae	Native Herb
Silybum marianum	Asteraceae	Non-native Herb
Simmondsia chinensis	Simmondsiaceae	Native Shrub
Sisymbrium irio	Brassicaceae	Non-native Herb
Sisyrinchium bellum	Iridaceae	Native Grass
Solanum parishii	Solanaceae	Native Herb
Solanum species	Solanaceae	Native Herb
Solanum xanti	Solanaceae	Native Herb
Solidago californica	Asteraceae	Native Herb
Sonchus asper	Asteraceae	Non-native Herb
Sonchus oleraceus	Asteraceae	Non-native Herb
Spergularia bocconii	Carophyllaceae	Non-native Herb
Stachys bullata	Lamiaceae	Native Herb
Stem	Ground cover	Ground cover
Stephanomeria species	Asteraceae	Non-native Herb
Stephanomeria species	Asteraceae	Native Herb
Stillingia paucidentata	Euphorbiaceae	Native Shrub

Species	Family	Functional Group
Stipia speciosum	Poaceae	Native Grass
Stylocline gnaphalioides	Asteraceae	Native Herb
Swertia parryi	Gentianaceae	Native Herb
Taraxacum officinale	Asteraceae	Non-native Herb
Thalictrum fendleri	Ranunculaceae	Native Herb
Thysanocarpus curvipes	Brassicaceae	Native Herb
Thysanocarpus lacianatus	Brassicaceae	Native Herb
Thysanocarpus species	Brassicaceae	Native Herb
Toxicodendron diversilobum	Anacardiaceae	Native Shrub
Tricostema lantanum	Lamiaceae	Native Shrub
Trifolium ciliolatum	Fabaceae	Native Herb
Trifolium laciniatum	Fabaceae	Unknown
Trifolium microcephalum	Fabaceae	Native Herb
Trifolium species	Fabaceae	Non-native Herb
Trifolium species	Fabaceae	Unknown
Trifolium willdenovii	Fabaceae	Native Herb
Tropidocarpum gracile	Brassicaceae	Native Herb
Unknown	Unknown	Unknown
Urtica dioica	Urticaceae	Native Herb
Vicia ludoviciana	Fabaceae	Native Herb
Vicia villosa	Fabaceae	Non-native Herb
Viola species	Violaceae	Native Herb
Vulpia microstachys	Poaceae	Native Grass
Vulpia myuros	Poaceae	Non-native Grass
Vulpia octoflora	Poaceae	Unknown
Vulpia species	Poaceae	Unknown
Xylococcus bicolor	Ericaceae	Native Shrub
Yucca schidigera	Agavaceae	Native Shrub
Zigadenus fremontii	Melanthiaceae	Native Herb

APPENDIX 5: DATA SHEETS AND DESCRIPTION

Point Intercept Transect Data Sheets:

Point intercept transects were read starting at 0 at the origin, and were spaced (and numbered) every 1m to 49

Point intercept transect data sheets are located on the following two pages.

Transect 1

Site	Date
Plot	**Start Time**
Field Crew	**End Time**

	Ground Cover	
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

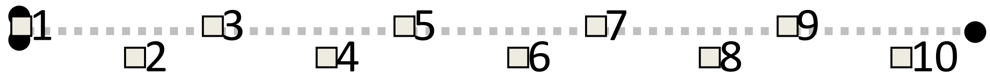
Transect 1

Site		Date	
Plot		**Start Time**	
Field Crew		**End Time**	

	Ground Cover	
25		
26		
27		
28		
29		
30		
31		
32		
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
46		
47		
48		
49		

Quadrat Data Sheets:

Ten quadrats per transect were read on alternating sides of the transect Quadrats were 1m2We always positioned quadrats so they rested from 0m to 1m, 5m to 6m, 10m to 11m, and so on. We began reading quadrats at 0m on the left, and ended at 45m on the right.



Quadrat data sheets can be found on the following two pages.

Quadrats

1-10 (all plots)

Site		Date	
Plot		**Start Time**	
Field Crew		**End Time**	

Species/Cover Type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Litter (L)										
Bare (B)										
Rock (R)										
Crypto Crust (C)										
Moss (M)										

Species/Cover Type	1	2	3	4	5	6	7	8	9	10

Back of Sheet

NOTES

Appendix 6: Burned Vegetation Characterization

This report will focus on characterizing the CSS and grassland plots that burned during the Santiago fire in October 2007. It will follow the same general format as the vegetation characterization in the main report, but will go into less detail since we are describing changes caused by the compound effect of a point event (fire) and dramatic changes in yearly conditions.

Species Richness

We will focus on the change in species richness and composition after fire by evaluating plots sampled in both 2007 and 2008. Species richness values for all of the unburned sites and plots are given in table 4 of the main report.

Overall there was a dramatic increase in species richness from 2007 to 2008. In 2007 we identified 35 species in the plots that would later burn. In 2008 we found 67 species. Some of the species identified previously were not present, and a number of new species appeared in these plots. At some sites the turnover of species was somewhat remarkable. In the case of some species we can assume they benefited from the effect of fire and others increased rainfall. A handful of species not identified in each year could be due to observer error or an interaction of fire, rain and other annual factors we are unable to appraise at this time.

As noted in the main report, the native and non-native forb functional groups increased the most in terms of richness. The richness of other functional groups changed less so. Richness is only one aspect of ecosystem function. If the loss of a non-native species at a site has enabled a larger monoculture of another non-native species, this is actually net degradation of habitat. The cover of native and non-native species will be considered in the next section of this report.

			Native						Non-native			
	All Species		Shrubs		Forbs		Grasses		Forbs		Grasses	
	07	**08**	07	**08**	07	**08**	07	**08**	07	**08**	07	**08**
Both Plots	35	**67**	7	**10**	12	**36**	4	**3**	5	**13**	7	**5**
CSS 3	22	**50**	6	**8**	7	**29**	2	**2**	3	**8**	4	**3**
Grassland 2	22	**53**	2	**3**	8	**31**	3	**3**	4	**12**	5	**4**

Table A-1*: Species richness in burned plots, comparison across years*

Prior to fire the CSS plot and the grassland plot had the same number of species (22). After fire both plots had very similar increases in richness; richness in the CSS plot increased by 28 species, and richness in the grassland plot increased by 31 species. Changes in the richness of different functional groups was similar in both burned plots, for example both plots saw nor or very minor changes in the richness of native and non-native grasses Despite the similarity of the changes in richness and species turnover, the composition of the two plots was dramatically different in terms of species composition (as is expected when comparing CSS to grasslands) and their relative cover of those species (which will be discussed in the next section).

Dominant Species

We define dominant species as species with high average absolute cover, relative to other species. Absolute cover was calculated by plot, averaging the cover result for transects and quadrats. For point intercept transects the total number of times a species is encountered is divided by the total number of points on the transect (100 at sentinel plots, 50 at new plots). Absolute cover is calculated for quadrats by averaging the estimated cover of a species in each quadrat across the entire plot.

Dominant Coastal Sage Scrub

Prior to fire CSS plot 3 was of mixed composition, and included *Artemisia californica*, *Salvia mellifera* and *Eriogonum fasciculatum* as dominant shrub species. It was also invaded by a significant amount of *Bromus madritensis* and *Erodium* species.

Following the fire the cover of *Artemisia californica* and *Salvia mellifera* went down dramatically (those plants burned), but the cover of *Eriogonum fasciculatum* went up slightly. This is an interesting result, but is likely an artifact of only having one CSS plot to make a post fire comparison with. At this particular plot the Eriogonum either didn't burn completely (the fire was especially patchy, as well as Eriogonum, and just happened to miss that area), is re-sprouting from root systems (the fire was not especially intense) or a large number of seedlings was germinating. Of these three explanations the most likely one is stump sprouting. Photographs taken from a nearby ridgeline show small green patches in the vicinity of the plot, which could be shrub re-growth. In addition, if the location of the shrubs had changed we would likely not have come so close to the pre-fire cover value. It makes sense that the fire would be less intense at this plot as the pre-fire shrub cover was patchy with lots of open space between shrubs meaning that the shrubs probably burned as individuals as opposed to a single mass of fuel. In addition Salvia mellifera and Artemisia californica both have volatile oils that make them burn more readily and intensely than Eriogonum, which could explain why they behaved differently. If there had been other burned plots to average into the "burned CSS" figure we would likely have seen a decline in cover.

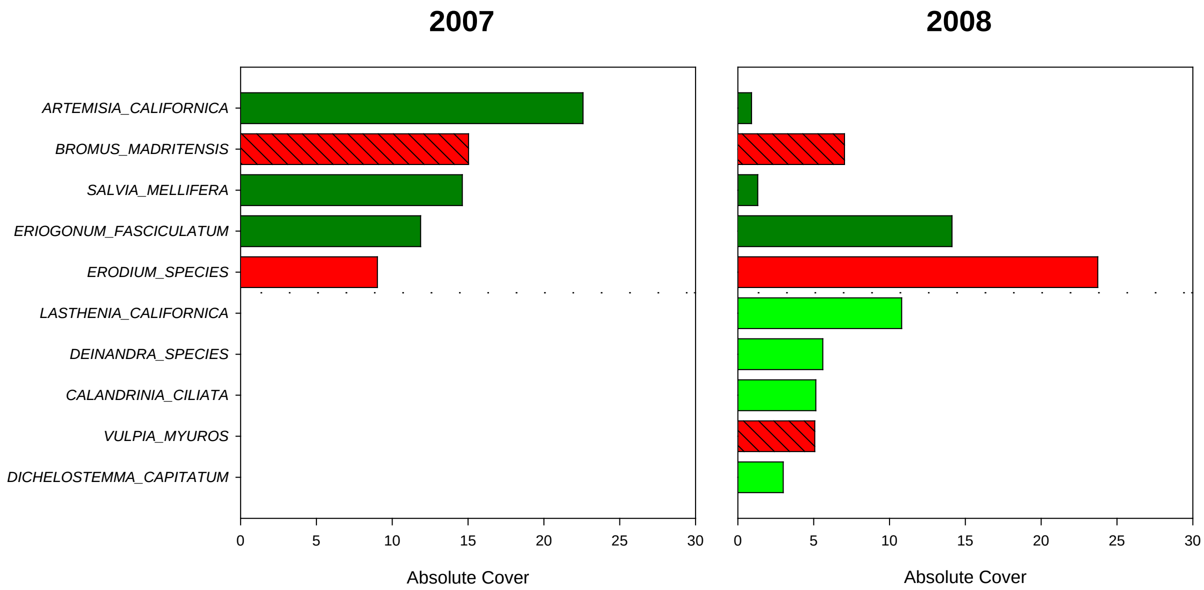


Figure A-1: *Absolute cover of dominant CSS species after fire. Shrub cover fell close to 0 as a result of fire. The increase in native and non-native forbs was likely an interaction of increased rainfall and fire disturbance.*

Erodium seemed to benefit this year, but the cover of *Bromus madritensis* actually contracted this year. Like other, unburned plots, we saw dramatic increases in the cover of native forbs, including *Lasthenia californica, Deinandra* species, *Calandrinia ciliata* and *Dichelostemma capitatum,* all of which had not been encountered at this plot in 2007.

DOMINANT GRASSLAND SPECIES

Prior to fire grassland plot 2 was already heavily invaded. Erodium species and Bromus diandrus were co-dominant. Eriogonum fasciculatum cover was actually higher than Nassella cover, but unlike the CSS plot discussed above, disappeared completely after the fire. In 2008 both Bromus species saw dramatic declines, but other non-native forbs and grasses that had not been detected before became highly dominant.

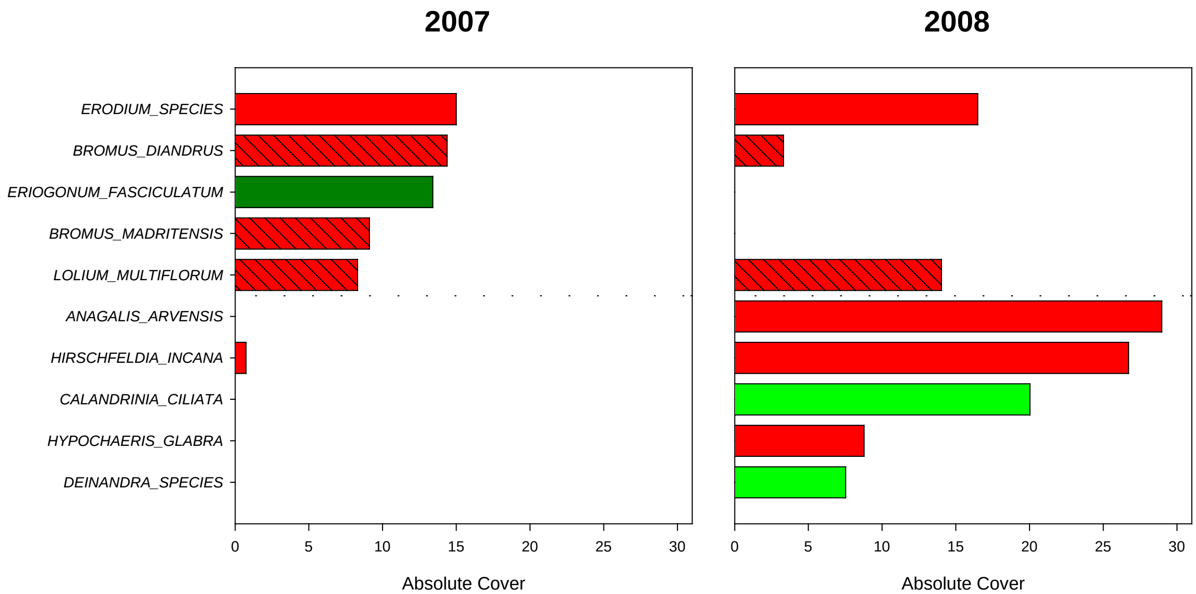


Figure A-2: *Absolute cover of major species in grassland plot 2 in lime stone canyon*

APPENDIX 7: 2008 FIELD REPORT

Vegetation Monitoring for the Central Orange County Conservation Lands

Field Report, 2008

July, 2008

Prepared for: The Nature Conservancy
Contracts Manager: Zachary Principe

Prepared by: Department of Biology, San Diego State University
Dr. Douglas Deutschman, PI, Spring Strahm, David Bailey,
Dr. Janet Franklin, Dr. Rebecca Lewison

SAN DIEGO STATE UNIVERSITY

Table of Contents

TABLE OF FIGURES:

LIST OF TABLES

INTRODUCTION

Monitoring to detect ecological change is an important component of many environmental and conservation programs. The Nature Conservancy holds conservation easements on over 11,500 acres on the Irvine Ranch land in central Orange County. The Nature Conservancy is obligated to monitor the condition of conservation values through time and has identified vegetation communities as targets for long term monitoring. Similarly, the Nature Reserve of Orange County has identified vegetation communities as a target for long-term monitoring. The objective of this project, which is being implemented collaboratively on both on TNC easement lands and NROC lands, is to evaluate the precision and accuracy of different sampling designs and field protocols for monitoring vegetation communities, primarily coastal sage scrub (CSS), chaparral, and grasslands in central Orange County. Unfortunately, it is difficult to design and implement a monitoring plan.

This project is designed to detect sources of variability in vegetation community monitoring data and make recommendations to scientists and land managers for the reduction and control of variability in their long-term data. In addition, the results will provide a foundation for long-term monitoring by collecting baseline data that is scientifically credible and cost-effective. In 2007 we focused on methodological factors, such as repeatability between teams and comparison of methods. In 2008 we shifted our emphasis to spatial coverage. This interim report summarizes the preliminary results for the second field season of the project (field data collected in April 2008).

PLOT SELECTION AND FIELD METHODS

Our effort was stratified across vegetation types, including coastal sage scrub, chaparral and grasslands. Although central Orange County has many more vegetation types, CSS, chaparral and grasslands were prioritized based on Franklin et al. (Franklin 2006) work in the San Diego MSCP. This year we increased both the number of plots we sampled and the spatial coverage of that sampling. We prioritized the number of plots, and therefore the amount of effort for each vegetation type based on the expense of sampling each one (high for chaparral and low for grasslands) and the amount of new information we expected to glean from each type this year (chaparral low, CSS high). In addition to the 3 original CSS plots set up last year, we added 6 more plots to the interior section and 5 more plots in the coastal region for a total of 14 CSS plots. We added 4 new grassland plots in the interior section of open space and two in the coastal area for a total of 8 grassland plots. Finally we added two chaparral plots in the interior section, for a total of 5 chaparral plots. A total of 16 plots are now established on TNC easement lands, while the remaining 11 plots are on NROC lands (Figure 1).

Our primary goal this year was to get better spatial coverage across the study area. Plots were selected using a stratified random design. The vegetation maps were not publicly available, so random points were selected by County of Orange GIS analysts. These points were stratified across chaparral, CSS and grassland vegetation types. Points were buffered to be located between 30m and 300m of an accessible road, and under a 35 percent slope. A great number more points were generated in order to provide back-up locations if any given point was deemed unsafe or inappropriate for work (re: wrong vegetation type) and for future monitoring. This year teams did not double sample plots in Orange County in order to maximize our spatial coverage.

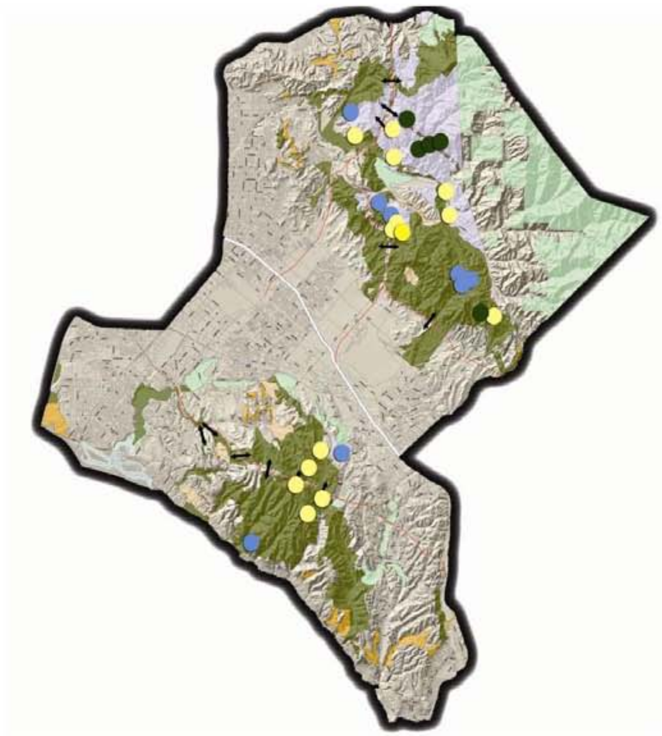


Figure 1: Plots and sites in Orange County. Plots were stratified across CSS, chaparral, and grasslands in central Orange County. Circles mark each plot and circle color depicts vegetation type for chaparral (green), CSS (yellow), and grassland (blue).

Our field protocols were selected to capture a number of response variables, including the richness of the vegetation being sampled and the cover of different species and functional groups. In 2007 we used a modified 0.1ha Keeley plot (Keeley and Fotheringham 2005) which included sub-plots for visual cover estimates. This year we eliminated visual cover sub-plots because they were of limited value. We also reduced the length of the transect (from 100m to 50m) and the number of quadrats (from 20 to 10). The 50m length was used as a point intercept transect, with observations made every 1m starting at zero. Quadrats were read every five meters on alternating sides, starting on the left (Figure 2). This allowed us to test two different protocols at the same exact location.

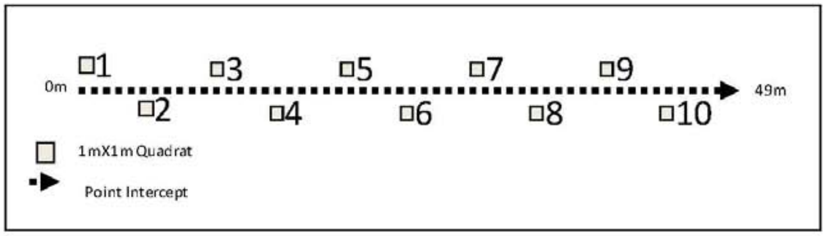


Figure 2: Transect plot design. Each plot measured 50m in length. A single 50m point intercept transect took measurements every 1m, starting at 0m. Quadrats were read for percent cover every 5m starting at 0m.

Figure 2 depicts our response design for 2008, refined from a much larger and time consuming design used in 2007. Since 2007 and 2008 were very different years in terms of rainfall and fire, we needed to evaluate our methods very carefully before arriving at a final response design. We anticipate endorsing this response design as a long-term protocol, however have not yet finalized a complete evaluation of the data. In addition we have yet to quantify an above average rainfall year which could also affect our results.

Both data collection protocols were used at every plot. In order to reduce learning bias, teams collected their data in a strict sequence. First, teams used point intercept transects. During transects, teams did not spend time looking for hidden or cryptic species except for those touching the pole. Second, teams placed the ten $1m^2$ quadrats on alternating sides of the transect, and tried to capture every species inside the quadrat frame.

Figure 3 Implementation of the two protocols, point-intercept, and quadrats.

We calculated cover for all species found on the plots. We analyzed species richness, the cover of different plant functional groups (such as native shrubs and exotic forbs), the cover of individual diagnostic species and the cost (as estimated by hours worked). We quantified different sources of variability in these response variables by estimating the different components of variance (Urquhart, Paulsen et al. 1998; Larsen, Kinkaid et al. 2001; Sims, Wanless et al. 2006). This variance decomposition along with the cost estimates are necessary to develop an optimal (or at least near optimal) monitoring plan and to estimate statistical power. Last year we did not perform a formal power analysis because temporal data was not available. This year the power analysis will be restricted by the effects of the 2007 Santiago fire, which burned two of eight plots established in 2007.

FIELD WORK PERFORMED

Preparation for the field work started several months before data was collected. Prior to making site visits, emergency backpacks and directions were assembled, field equipment was purchased, data sheets were created and field teams were trained on how to implement the three protocols. Field teams were always required to check out and back in with the PI or a senior field crew member.

TRAINING

In 2007 we identified inter-observer bias as a major source of variability, especially for species richness, and the cover of less common and less well known species. We therefore implemented an expanded, three stage training program in 2008. The first part of the training program was a lecture and question/answer session given by one of the senior project biologists. The project was introduced, goals were explained, and methods were discussed. Field teams also took time to experiment and practice with GPS units.

The second stage of training involved a field exercise. Field teams were driven to Mission Trails Regional Park (San Diego, CA), and given a random location (GIS coordinates). They navigated to their assigned point, set up a transect, and collected data using both methods. Once they returned from the field the teams practiced entering data. A senior project biologist worked with each team to ensure that methodological and taxonomic questions were addressed.

The third stage of the training was also the first day of field work for the trainees. On their first day in the field, each team was accompanied by a senior project biologist, who provided taxonomic and methodological assistance.

In addition to an improved training program, we also made an effort to re-hire the 2007 field crew where they were available. Ultimately we had three field teams, one with two senior project biologists, and two with one new and one returning crew each. Although we had fewer crews than last year's five, these three teams had, on average, more field experience and worked the entire field season (last year 2 teams worked only part of the season).

Plot Visits

This year we set up 19 new plots and returned to all 8 2007 plots. Of the 27 plots, 10 plots are on Irvine Ranch conservation easement lands north of Santiago Canyon Road. An additional 10 plots are in the open space south of Santiago Canyon Road: five plots are within Limestone-Whiting Wilderness Park, and the remaining five are within the TNC Orange Conservation Easement on the Irvine Ranch. In the coastal area, 1 plot was established on the Laguna Laurel conservation easement, 5 were established within Laguna Coast Wilderness Park, and one was estab,lished at Crystal Cove State Park (please see Appendix 1 for plot locations). New plots were set up when field sampling was conducted by two teams in mid-April, at the climax of the growing season. This year Orange County received about average rainfall, and germination rate of herbaceous species was much higher than in 2007.

In addition to quantifying spatial and inter-observer variability, we also wanted to understand the tradeoff between effort, cost, and accuracy. In this project, we used time as an overall surrogate for effort and cost. Effort for each protocol was recorded in two phases this year: data collection time, and data entry time. Travel time was not recorded, as those data were not likely to change from 2007 to 2008. Set-up time for transects is very minimal. Note that set-up time and data entry time are often more flexible in terms of scheduling than travel time and data collection time, as these must occur during the growing season and be optimized for the maximum possible number of plots sampled.

Effort

Time spent in the field is an important constraint to consider when designing a vegetation monitoring program which must be completed in a modest amount of time (e.g. within the growing season) and with a restricted budget. Set-up time (plot selection, navigation to plot, permanent marking) is significant, but can be completed prior to the start of the field season given enough forward planning. While data entry time is also important to a monitoring effort, time spent entering data is more flexible in terms of scheduling and staff. In our time budgets, we assumed that the field day began when a field team left a meeting site or hotel in Orange County and traveled to the field site (travel to and from San Diego was not considered). Effort was recorded as data collection time, and data entry time, with values for travel and set-up time carried over from 2007 (Figure 4).

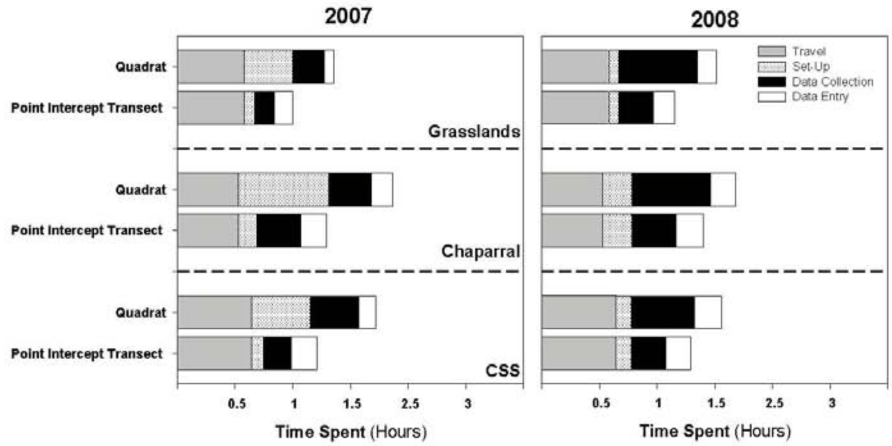


Figure 4. Average time (hours) in unburned plots spent on two protocols (transects, and quadrats). Quadrats were more time consuming in the field than point intercept transects. Data entry times were about the same for both methods. Despite this, point intercept transects had the lowest total time. 2007 values are cut in half to reflect the difference in plot design.

Last year we observed that point intercept transects were much faster than quadrats. This year that trend continued, although the difference between the two methods was less pronounced (Figure 4). Unexpectedly it took us much longer to cover 50m and 10 quadrats than it did to cover 100m and 20 quadrats last year. This is due to the tremendous increase in cover and diversity associated with this year's increased rainfall.

Data entry time was expected to be cut roughly in half, and in general our expectations were met, although increased diversity added some time. Unlike last year, when it took significantly more time to enter transect data than quadrat data, this year the two methods took about the same time to enter.

VEGETATION COMMUNITIES IN ORANGE COUNTY

Coastal sage scrub, chaparral and grassland vegetation communities were sampled separately. In this section we will first discuss species richness in the three selected vegetation communities. We then discuss common species and the cover of functional groups (e.g. native shrubs, non-native grasses, etc). Finally, we discuss the variability in cover of some species.

SPECIES RICHNESS (ALL PLOTS REGARDLESS OF BURN HISTORY)

We found a total of 146 species throughout the Orange County study area in 2008 based on species detections by all teams combined (Table 1), over 200 percent more species than in 2007 (full species list in Appendix 2). Of those species, 100 were native species, including: 31 native shrubs, 64 native forbs, 6 native grasses, and 4 other native species. We identified a total of 40 non-native species, including 25 forbs, 12 grasses and 3 other native species. Forbs, both native and non-native were the largest contributors to the increased richness this year. *Artemisia californica*

(California sagebrush), and *Salvia mellifera* (black sage) were the most prevalent native shrubs. *Nassella* sp. (needle grasses) was the most prevalent native grass. *Dichelostemma capitatum* (blue dicks) was the most prevalent native forb. The most prevalent non-native species were *Erodium* species (stork's bill) and *Bromus madritensis* (red brome, grass).

Species	All		Native						Non-native				Other	
Richness	Species		Shrub		Forb		Grass		Forb		Grass		Species	
All Plots	146	66	31	30	64	10	6	5	25	6	12	7	7	8
CSS	99	34	21	17	44	1	5	4	13	5	9	3	7	4
Chaparral	74	38	19	23	30	9	1	1	14	1	5	2	5	2
Grasslands	86	24	10	11	39	2	3	3	22	4	9	2	3	2

Table 1: Species richness in Orange County based on species detections by all teams combined. Species are grouped by habit (shrub, forb, grass) and origin (native, non-Native). Other species included a tree and several vines. 2007 values are in gray.

We found a total of 99 species across the 11 unburned CSS sites (Table 1). Of these, 21 were native shrubs and 22 were non-native forbs and grasses. The most widespread native shrub was *Artemisia californica*, appearing in 8 of 10 unburned CSS plots. *Salvia mellifera* and *Lotus scoparius* (deerweed) were also prevalent, being found in 7 of 10 unburned CSS plots. The most widespread non-natives included *Bromus madritensis* (grass) found in all 10 unburned CSS plots, and *Erodium* species (forb) found in 8 unburned CSS plots.

In chaparral, we found a total of 74 species, including 19 native shrubs, 30 native forbs, one native grass and 19 non-native forbs and grasses. *Adenostoma fasciculatum* (Chamise) and *Salvia mellifera* were the most prevalent species, occurring in all 4 unburned chaparral plots. *Ceanothus tomentosus* (California lilac), *Hesperoyucca whipplei* (our lord's candle) and *Malosma laurina* (laural sumac) were found in three chaparral plots sampled. *Antirrhinum kelloggii* (twining snapdragon) and *Dichelostemma capitatum* were the most prevalent native forbs occurring in all four unburned plots. *Bromus madritensis* was the most widely distributed non-native grass, occurring in all four unburned chaparral plots sampled. *Anagalis arvensis* (scarlet pimpernel) was the most widespread non-native forb, occurring in all 3 of 4 unburned chaparral plots.

We found a total of 86 species in the eight grassland plots sampled in 2008. There were at least 3 species of native grasses. It is likely that there are at least two species of *Nassella*, however the entire genus was grouped for analysis since some individuals were not fruiting yet and could not be positively identified. *Nassella* occurred in 3 of 4 unburned grassland plots. *Daucus pusillus* (rattlesnake weed) was the most common native forb, again occurring at 3 of 4 unburned grassland plots. A combination of *Bromus hordeaceus* (soft chess brome), *Avena* sp. (wild oat) and *Erodium* species were found at 3 of 4 grassland plots. Grassland diversity results were the most dramatically affected by rainfall as many diagnostic species are annual, and did not germinate last year.

FUNCTIONAL GROUP COVER (USING UNBURNED PLOTS ONLY)

All plant species were divided into six functional groups: native shrubs, native forbs, native grasses, non-native forbs, non-native grasses and other species (including all vines and unidentified samples). Functional group cover was averaged for each vegetation type of interest. Plots that burned in the October 2007 Santiago Fire were not included in these analyses.

We found that the shrub communities in Orange County (CSS and chaparral) have high absolute percent cover of native shrubs (Table 2). In chaparral, native shrubs occupy 57 percent absolute cover, well over the next most dominant category, native forbs, at 28 percent absolute cover. In CSS, native shrubs occupy 67 percent absolute cover, well above the next most dominant group, non-native forbs at 42 percent absolute cover. Native grasslands, on the other hand, are not dominated by their target functional group. Non-native forbs cover 97 percent of grass land plots on average, and forbs cover about 77 percent, with native grass following behind at 27 percent cover (Table 2).

Functional Group	Absolute	Relative
CHAP	**Total=123%**	**100%**
Native Grass	5%	4%
Native Forb	28%	23%
Native Shrub	57%	47%
Native Vine	3%	2%
Non-native Grass	16%	13%
Non-native Forb	14%	11%
CSS	**Total=164%**	**100%**
Native Grass	11%	6%
Native Forb	20%	12%
Native Shrub	65%	40%
Native Vine	2%	1%
Non-native Grass	24%	15%
Non-native Forb	42%	26%
GL	**Total=236%**	**100%**
Native Grass	27%	11%
Native Forb	21%	9%
Native Shrub	14%	6%
Non-native Grass	77%	33%
Non-native Forb	97%	41%

Table 2: Absolute and relative cover of different functional groups in Orange County conservation lands. Absolute cover is calculated by dividing the total number of hits, by the total number of possible points. Absolute cover indicates total canopy cover of a functional group. Relative cover is calculated by dividing the number of hits for a single functional group by the total number of hits of all functional groups. Relative cover gives the ratio of one functional group to all others, and is a good metric for looking at dominance, especially when absolute cover values are so high.

Spatial Variability of Functional Groups in 2008

This year we selected plots in a semi random fashion, in addition to increasing our sample size to avoid bias. Last year we selected plot locations to capture the largest range of natural variability throughout the region, and included those plots in this year's data. Both years, we found that plot to plot variability was quite large in terms of functional group cover. Most plots conformed to our general expectations about the relative cover of different functional groups (e.g. chaparral plots had more native shrub cover than exotic grasses or forbs), but the absolute cover values varied dramatically between plots (Figure 5)..

This year we sampled a much larger number of CSS plots than we did last year, with a total of 10 unburned plots (Figure 5). These plots ranged from 15 percent shrub cover to over 100 percent shrub cover. These functional groups often had an inverse relationship, so where native shrub cover was high, non-native forb and grass cover tended to be low. CSS was much more highly invaded than chaparral stands, which is expected given larger plant interspaces typical of CSS. Absolute cover of native shrubs also appears to be higher in CSS than chaparral, which is slightly misleading. CSS typically had a more mixed set of shrubs, as opposed to chaparral which tended to grow in monocultures dominated by one shrub species. The result is that CSS has a more layered canopy and higher absolute cover.

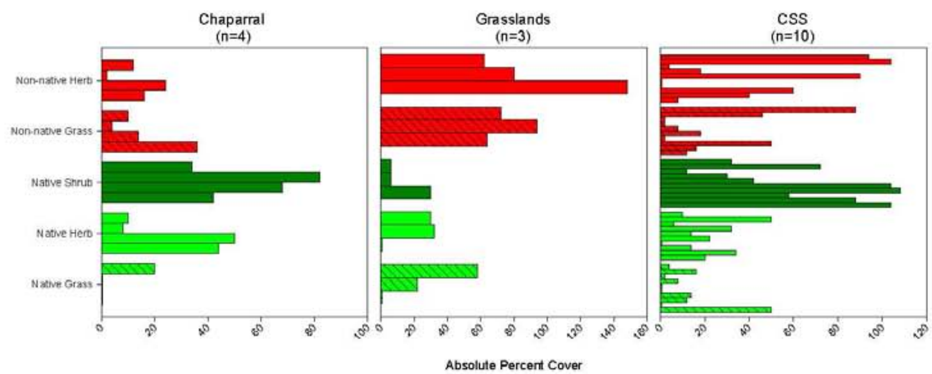


Figure 5. Inter-plot variability of functional group cover. Bars are clustered by functional group, and represent different plots in each vegetation type. Green shading indicates native species, with the darker green denoting shrubs. Red indicates non-native species. Diagonal lines indicate grass species (as opposed to the forbs).

Plots in grasslands showed a great deal more cover this year than last. In all three unburned grassland plots we observed a great deal more exotic cover than native cover this year (Figure 5). This is not a typical for native grasslands in southern California. One of the new grassland plots, in

Crystal Cove State Park, actually had no native grass or forb cover and was highly invaded by non-native forbs (e.g. *Brassica nigra*, black mustard) and grasses.

DOMINANT SPECIES

Absolute cover was high in 2008. Despite this, the vast majority of individual species averaged one percent cover or less. In the following descriptions, we present the 10 species with highest absolute cover.

Dominant native species in the chaparral include *Adenostoma fasciculatum, Salvia mellifera, Nassella* species, *Malosma laurina*, *Ceanothus tomentosus* and the annual forbs *Cryptantha* and *Phacelia parryi* (Parry's phacelia) (Figure 6). Non-native species playing a dominant role in the chaparral included *Bromus madritensis, Hirschfeldia incana* (Mediterranean mustard), and *Brassica nigra*. In general we expect to see far less non-native cover in chaparral than CSS, given the more closed nature of the vegetation type. In this case we set up plots on stands recovering from fire, as well as stands in their climax state, so while there are fewer non-native species at lower cover, we are still see some invasion in chaparral, particularly younger stands with more open canopies.

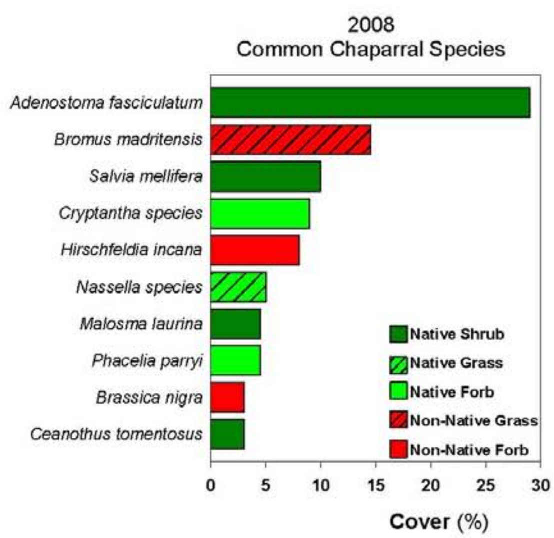


Figure 6. Dominant species in 2008 unburned chaparral plots.

Dominant native species of the CSS included *Eriogonum fasciculatum* (flat-top buckwheat), *Salvia mellifera*, *Artemisia californica*, *Malosma laurina*, *Nassella* species (needle grass), and the annual forb *Daucus pusillus* (Figure 7). Non-native plants with significant cover in CSS plots included *Bromus madritensis*, *Erodium* species, *Hirschfeldia incana* and *Anagalis arvensis*. In CSS native shrubs were competing with exotic species, and occupied just a little more cover than the other non-native dominant species. This result is linked to large plant interspaces in CSS which leave open spaces for recruitment of annual species, including non-natives.

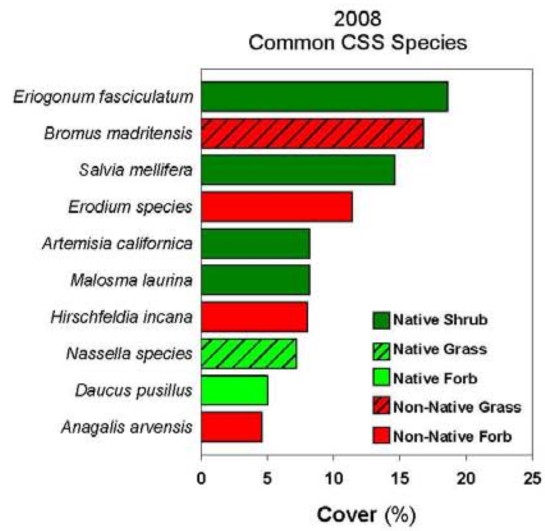


Figure 7. Dominant species in 2008 unburned CSS plots.

Grasslands were primarily dominated by non-native species (Figure 8), including *Erodium* species, *Brachypodium distachyon* (purple false-brome), *Brassica nigra, Bromus diandrus* (ripgut brome), *Bromus madritensis, Melilotus indica* (Indian sweetclover), and *Avena* species (wild oat). Following only *Erodium* species, *Nassella* species had higher cover than other key species, a positive result in southern California where most of the native grasslands are highly invaded. It should be noted that we grouped all three key *Erodium* species (E. *botrys, E. cicutaria and E. moschatum)* together for this analysis, as we did all *Nassella* species. This grouping was made to be consistent with 2007 data, where some teams could not distinguish among the species in these genera. While this results in increased cover estimates we believe that in these cases the grouping accurately reflects the function and behavior of the species.

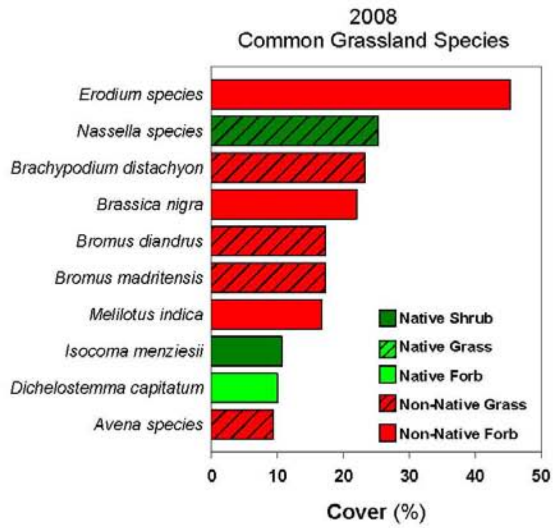


Figure 8. Dominant species in 2008 unburned grassland plots.

DOMINANT SPECIES ACROSS YEARS

Last year we had a small sample size, concentrated in the interior section of the conserved/easement lands. This year we had a much larger sample for CSS and grassland vegetation types, however, due to the limited nature of our 2007 data, and the further limitation imposed by the Santiago Canyon Fire, it is difficult to compare years. To construct an unbiased comparison it was necessary to remove all new plots and the plots that burned in 2007. As a result this comparison is valid at the three chaparral plots from last year, and the two remaining CSS plots. Grasslands were excluded because there was only one grassland plot that did not burn last year.

In general, the cover of dominant native shrubs and grasses stayed about the same from 2007 to 2008 (Figure 9). This is to be expected since shrubs are perennial, grow more slowly, and are drought resistant when they are already established. Annuals, however, went up dramatically in both CSS and chaparral. *Brassica nigra* was not observed in the three original chaparral plots this year where it was present in small amounts last year. This suggests that it is present, but that we may have missed it this year because we conducted our field sampling earlier in the year. We also saw an increased number of native annuals occupying significant area in plots this year, including *Cryptantha* species, *Calandrinia ciliata* (red maids), and *Camissiona hirtella* (field suncup).

In CSS, several species were recorded that had not been recorded in 2007, including *Plantago erecta* (California plantain), the host plant for *Euphydryas editha quino* (Quino checkerspot butterfly) (Figure 9). In addition a number of exotic forbs appeared including *Hirschfeldia incana* and *Erodium* species, which is surprising given their prevalence in 2008. Last year we likely missed *Hirschfeldia incana* because it had either not germinated, or had already senesced by the time we sampled. It is also possible that *Hirschfeldia* was mistaken for *Brassica nigra*, which is more widely publicized and matures later in the season

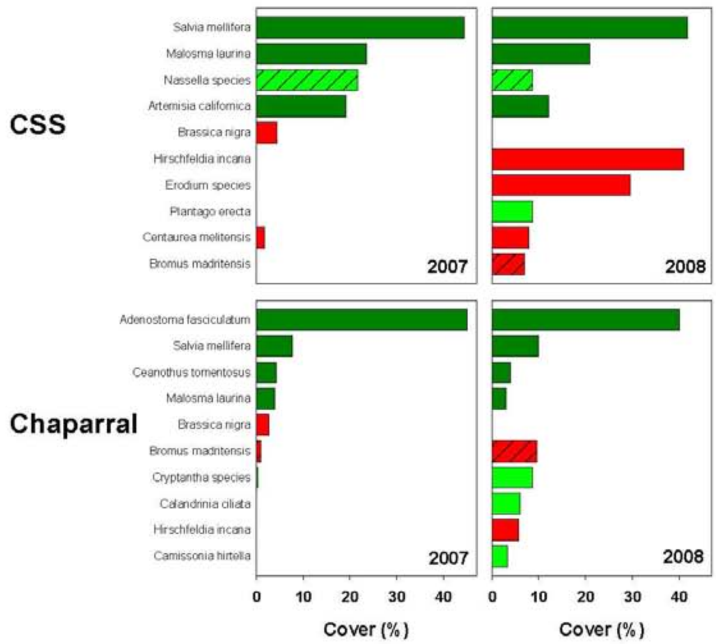


Figure 9. Dominant species compared from 2007 to 2008.

SPATIAL VARIABILITY OF DOMINANT SPECIES

In addition to community wide differences in the distribution of species, there were also significant plot to plot differences. In some cases the prevalence of a species in a single plot was high enough to put it in the top 10 species for the vegetation type as a whole.

For example, *Adenostoma fasciculatum* was in every chaparral plot, however plots 1 and 4 (both of which burned in the 2006 Sierra Fire) had significantly below average chamise cover, while plots 2 and 3 had above average chamise cover (Figure10). *Salvia mellifera* was also found throughout the chaparral sites at low cover, except for plot 2 where it was almost as prevalent as *Adenostoma fasciculatum*. The most prevalent non-native species in chaparral, *Bromus madritensis*, was variable from plot to plot, but generally inversely correlated with shrub cover (Figure 10).

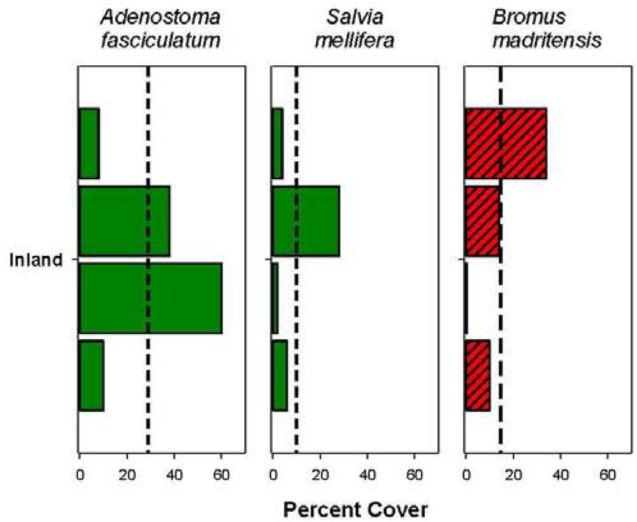


Figure 10. Plot to plot variability of individual species in chaparral. Dashed lines indicate the mean for the vegetation type.

In CSS the distribution of the dominant shrubs was also extremely variable from plot to plot, and differed significantly between interior and coastal sites. For example, most interior plots have very little or no *Eriogonum fasciculatum* (save for plot 7, where it was dominant) whereas coastal sites usually have high, albeit variable cover of this species (Figure 11). *Salvia mellifera* was present in most CSS plots at moderate levels (around 15 percent). However one plot had very high cover and four plots had no *Salvia mellifera* at all. Again the distribution of *Bromus madritensis*, was variable from plot to plot, and was loosely negatively correlated with shrub cover.

We only had three unburned non-native grassland plots, however, we still noted a high degree of plot to plot variability especially for some species. *Erodium* species were distributed throughout all three grasslands, sometimes at very high cover (Figure 12). *Nassella* species, one of the key native grasses, was present in significant amounts in two out of three grassland plots. At the unburned inland plot *Nassella* cover was close to sixty percent, an extremely strong result, however the grassland near Crystal Cove State Park had no native grasses. *Brachypodium distachyon* was the second most prevalent non-native in the grasslands, behind *Erodium*. However, the average cover of this species is inflated significantly by its high cover in the grassland plot on the Laguna Laurel conservation easement. In the other two unburned grassland plots this species is completely absent.

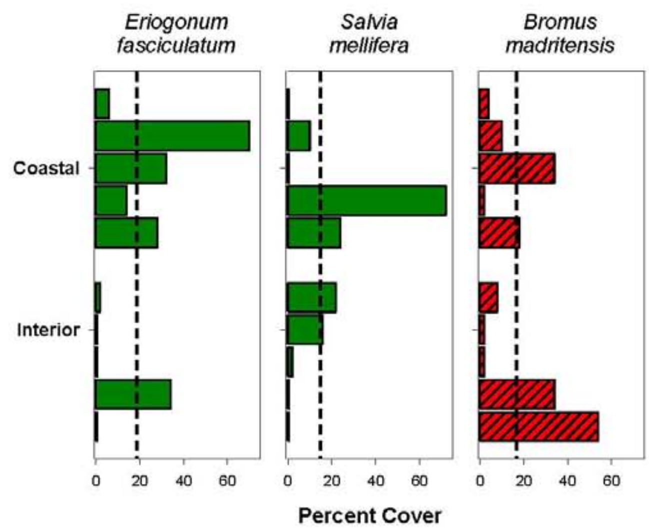


Figure 11. Plot to plot variability of individual species in CSS.
Dashed lines indicate the mean for the vegetation type.

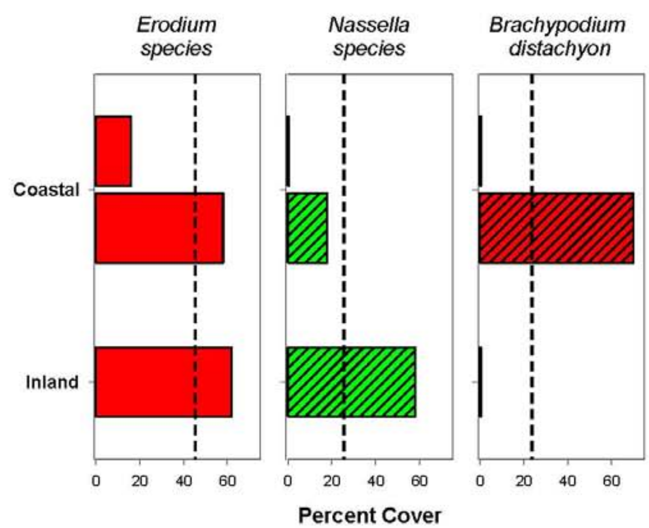


Figure 12. Plot to plot variability of individual species in grasslands.
Dashed lines indicate the mean for the vegetation type.

Given these results, it is important to quantify the spatial variability of each vegetation community in order to design a robust monitoring strategy. In order to achieve a robust vegetation monitoring strategy, it will be important to monitor the smallest number of plots possible, while still capturing the full range of variability.

Conclusions and Next Steps

This year we came closer to understanding just how important it is to understand variability in time and space when monitoring shrub and grasslands in Southern California. Our results showed a staggering increase in both the richness and the cover in all three surveyed vegetation types.

This year we observed 146 species, up from 66 in 2007. Despite the increased time it took to sample each plot, we completed 27 plots in Orange County. Overall native herbaceous cover and richness was up, although native shrub cover stayed about the same. Next year we will likely see shrub cover increase marginally at unburned sites, since we sampled prior to their growing season in 2008.

CSS in Orange County is currently invaded by non-native forbs and grasses, however shrub cover of target species remains high. The risk of further invasion hinges on two different factors, recruitment success and fire. It is likely that the exotic annual cover in plant interspaces is interfering with native shrub recruitment, so as mature shrubs experience regular mortality they may be unable to replace themselves. As in many other open spaces in California a shorter fire return interval is an even more pressing threat. The conserved lands now have an adequate non-native seed bank to allow faster growing non-native annuals to reestablish after fire, and immediately begin producing seed. Native shrubs that stump sprout or recruit from adjacent areas will need several years to reach their previous cover and begin producing seed. If exotic species reduce the chances for recruitment after fire, then decrease native shrub cover is to be expected, and type conversion may occur if fires occur reasonably quickly in the same areas.

This year we captured several problematic non-natives that are particularly invasive, and could contribute significantly to type conversion events including *Chrysanthemum coronarium*(crown daisy), *Cynara cardunculus* (artichoke thistle), and *Hedypnois cretica* (crete weed). We found one such species, *Brassica tournefortii* (Sahara mustard), that was previously unidentified in these lands at low cover, indicating a potential emergent invasion. Although we suggest target surveys for these specific species prior to management action, it is important to note that vegetation community level surveys were able to detect and bring in primary data on these species.

Although we only sampled three unburned grasslands this year we captured what appear to be good examples of variability in grassland communities. We visited one grassland that had about 60 percent native grass cover, one that had no native grass cover, and one with intermediate cover. These results are somewhat encouraging because native grass is persisting in many of the areas currently mapped as grasslands (although we do not know their pre-European conditions). It should be noted however that at every grassland plot there was at least one annual non-native species with higher cover than the native grasses. Last year we did not observe the full magnitude of the invasion in grasslands because germination of annual species was suppressed by low rainfall.

This seasonal and annual signal in grasslands could have implications for management, but this needs further research prior to making recommendations.

At this time (about 50% through this year's grant cycle) we are still in the process of data analysis. Due to the fire, which burned two of eight plots from last year, our data analysis will be challenging in terms of quantifying temporal changes and balance across vegetation communities. We will therefore perform three semi-independent analyses to answer as many questions as possible.

We will perform a reanalysis of spatial and methodological variance on 2008 data from all non-burned plots, using the same approach as 2007. This year's increased plant species diversity and cover may show some changes in the magnitude of both spatial and methodological sources of variation. It is important to exclude recently burned sites as their cover diversity and composition have been radically altered and would convolute the variables we identified in 2007.

We will add time to the variance components analysis by comparing 2007 and 2008 data. This analysis will be run only on sites that did not burn in 2007, and will therefore be biased toward chaparral as fewer of our chaparral sites burned. This is unfortunate since chaparral likely changes less year to year than CSS as the vast majority of cover in that vegetation type is long lived, slow growing, native shrubs. Again, the radical changes caused by fire would bias the results from year to year and lead to potentially misleading results.

It is important to recognize that the fire allows us other opportunities for data analysis which are important to monitoring programs in southern California. We will therefore explore our post-fire data using variance component analysis and other statistical techniques, to assess the efficacy of our field methods in post-fire environments. If it appears that post fire systems require more or different monitoring we will aim to make recommendations, and to implement and test them next year.

Overall we anticipate that functional groups (native shrubs, non-native forbs, etc.) will continue to be easy to estimate, while diversity and individual uncommon species will pose more of a challenge. How those species affect data collection and analysis in an average rainfall year may help us look toward upper limits on several factors, including team-to-team variability, method field time, and other factors, which will help us transition into a stable, scientifically credible and fiscally responsible long-term monitoring program.

It is important to continue scrutinizing our methods for the next one to two years prior to finalizing our recommended sampling design. The conditions in 2007 and 2008 were radically different, demonstrating extreme environmental variability inherent in southern California. With the addition of the fires, we need to continue our efforts to gain a consistent and reliable understanding of the system, and to complete a tool box of techniques for regional monitors and managers. This methodological research will be continued as one key aspect of a long term monitoring program.

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APPENDIX 1: PLOT LOCATIONS

Site	Veg Type	TX #	Origin N	Origin W	Designation	Started	Region
OCC	CSS	1	33.59778	117.78794	NROC/LCWP	2008	Coastal
OCC	CSS	2	33.58045	117.77473	NROC/LCWP	2008	Coastal
OCC	CSS	3	33.58476	117.76566	NROC/LCWP	2008	Coastal
OCC	CSS	4	33 36.421	117 46.469	NROC/LCWP	2008	Coastal
OCC	CSS	5	33 36.600	117 45.815	NROC/LCWP	2008	Coastal
OCC	GL	1	33.56576	117.82040	NROC/CCSP	2008	Coastal
OCC	GL	2	33.61654	117.75225	TNC Easement	2008	Coastal
OCI	Chap	1	33.79392	117.68450	TNC Easement	2007	Inland
OCI	Chap	2	33.79082	117.69073	TNC Easement	2007	Inland
OCI	Chap	3	33.79531	117.67872	TNC Easement	2007	Inland
OCI	Chap	4	33 48.284	117 42.525	TNC Easement	2008	inland
OCI	Chap	5	33.69873	117.64547	NROC/LWWP	2008	Inland
OCI	CSS	1	33.78647	117.71211	TNC Easement	2007	Inland
OCI	CSS	2	33.79931	117.74178	TNC Easement	2007	Inland
OCI	CSS	3	33.75008	117.71371	TNC Easement	2007	Inland
OCI	CSS	4	33.74987	117.7137	TNC Easement	2008	Inland
OCI	CSS	5	33.75077	117.71265	TNC Easement	2008	Inland
OCI	CSS	6	33 48.099	117 42.846	TNC Easement	2008	inland
OCI	CSS	7	33.75453	117.67253	TNC Easement	2008	inland
OCI	CSS	8	33.76519	117.67321	TNC Easement	2008	inland
OCI	CSS	9	33.69582	117.64039	NROC/LWWP	2008	Inland
OCI	GL	1	33.81195	117.74771	TNC Easement	2007	Inland
OCI	GL	2	33.71782	117.65993	NROC/LWWP	2007	Inland
OCI	GL	3	33.72087	117.65689	NROC/LWWP	2008	Inland
OCI	GL	4	33.72195	117.66164	NROC/LWWP	2008	Inland
OCI	GL	7	33.75878	117.71523	TNC Easement	2008	Inland
OCI	GL	8	33.76317	117.71899	TNC Easement	2008	Inland

Appendix 2: Species List

Species	Functional Group
Agavaceae	
Hesperoyucca whipplei	Native Shrub
Anacardiaceae	
Malosma laurina	Native Shrub
Rhus integrifolia	Native Shrub
Toxicodendron diversilobum	Native Shrub
Apiaceae	
Apiastrum angustifolium	Native Forb
Daucus pusillus	Native Forb
Sanicula arguta	Native Forb
Asteraceae	
Acourtia microcephala	Native Forb
Ambrosia psilostachya	Native Forb
Artemisia californica	Native Shrub
Artemisia palmeri	Native Forb
Baccharis pilularis	Native Shrub
Baccharis sarothroides	Native Shrub
Centaurea melitensis	Non-native Forb
Chaenactis glabriuscula	Native Forb
Chrysanthemum coronarium	Non-native Forb
Cirsium species	Non-native Forb
Corethrogyne filaginifolia	Native Forb
Cynara cardunculus	Non-native Forb
Deinandra species	Native Forb
Encelia californica	Native Shrub
Ericameria palmeri	Native Shrub
Eriophyllum confertiflorum	Native Forb
Filago californica	Native Forb
Filago gallica	Non-native Forb
Filago species	Non-native Forb
Gnaphalium bicolor	Native Forb
Gnaphalium species	Native Forb
Gutierrezia species	Native Shrub
Hazardia squarrosa	Native Shrub
Hedypnois cretica	Non-native Forb
Helianthus gracilentus	Native Shrub
Hypochaeris glabra	Non-native Forb
Isocoma menziesii	Native Shrub
Lasthenia californica	Native Forb

Species	Functional Group
Psilocarphus species	Native Forb
Senecio californicus	Native Forb
Silybum marianum	Non-native Forb
Solidago californica	Native Forb
Sonchus asper	Non-native Forb
Sonchus oleraceus	Non-native Forb
Stephanomeria species	Native Forb
Boraginaceae	
Amsinckia menziesii	Native Forb
Cryptantha species	Native Forb
Emmenanthe penduliflora	Native Forb
Eucrypta chrysanthemifolia	Native Forb
Phacelia cicutaria	Native Forb
Phacelia parryi	Native Forb
Plagiobothrys species	Native Forb
Brassicaceae	
Arabis sparsiflora	Native Forb
Brassica nigra	Non-native Forb
Brassica tournefortii	Non-native Forb
Hirschfeldia incana	Non-native Forb
Lepidium species	Unknown
Cactaceae	
Opuntia littoralis	Native Shrub
Caprifoliaceae	
Lonicera subspicata	Native Shrub
Carophyllaceae	
Cerastium glomeratum	Non-native Forb
Silene gallica	Non-native Forb
Cistaceae	
Helianthemum scoparium	Native Shrub
Convolvulaceae	
Calystegia macrostegia	Native Vine
Convolvulus arvensis	Non-native Vine
Cuscuta species	Native Vine
Crassulaceae	
Crassula connata	Native Forb
Cucurbitaceae	
Marah macrocarpus	Native Vine
Euphorbiaceae	
Eremocarpus setigerus	Native Forb

Fabaceae	
Lotus scoparius	Native Shrub
Lotus species	Native Forb
Lupinus bicolor	Native Forb
Lupinus concinnus	Native Forb
Lupinus hirsutissimus	Native Forb
Lupinus microcarpus	Native Forb
Lupinus species	Native Forb
Lupinus succulentus	Native Forb
Lupinus truncatus	Native Forb
Medicago polymorpha	Non-native Forb
Melilotus indica	Non-native Forb
Trifolium species	Unknown
Fagaceae	
Quercus agrifolia	Native Tree
Quercus berberidifolia	Native Shrub
Geraniaceae	
Erodium species	Non-native Forb
Geranium dissectum	Non-native Forb
Hyacinthaceae	
Chlorogalum parviflorum	Native Forb
Hydrophyllaceae	
Eriodictyon crassifolium	Native Shrub
Iridaceae	
Sisyrinchium bellum	Native Grass
Juncaceae	
Juncus species	Native Grass
Lamiaceae	
Salvia apiana	Native Shrub
Salvia mellifera	Native Shrub
Stachys bullata	Native Forb
Trichostema lanatum	Native Shrub
Liliaceae	
Calochortus catalinae	Native Forb
Calochortus species	Native Forb
Calochortus splendens	Native Forb
Malvaceae	
Malacothamnus fasciculatus	Native Shrub
Malva parviflora	Non-native Forb
Nolinaceae	
Nolina species	Native Shrub

Nyctaginaceae	
Mirabilis laevis	Native Forb
Onagraceae	
Camissonia bisorta	Native Forb
Camissonia hirtella	Native Forb
Camissonia species	Native Forb
Epilobium canum	Native Forb
Orobanchaceae	
Castilleja exserta	Native Forb
Oxalidaceae	
Oxalis pes-caprae	Non-native Forb
Papaveraceae	
Dicentra chrysantha	Native Forb
Phrymaceae	
Mimulus aurantiacus	Native Shrub
Plantaginaceae	
Antirrhinum kelloggii	Native Forb
Linaria canadensis	Native Forb
Plantago erecta	Native Forb
Plantago ovata	Native Forb
Poaceae	
Agrostis viridis	Non-native Grass
Avena species	Non-native Grass
Brachypodium distachyon	Non-native Grass
Bromus diandrus	Non-native Grass
Bromus hordeaceus	Non-native Grass
Bromus madritensis	Non-native Grass
Bromus species	Non-native Grass
Cynodon dactylon	Non-native Grass
Gastridium ventricosum	Non-native Grass
Hordeum murinum	Non-native Grass
Leymus condensatus	Native Grass
Lolium multiflorum	Non-native Grass
Melica imperfecta	Native Grass
Nassella species	Native Grass
Stipa speciosum	Native Grass
Vulpia myuros	Non-native Grass
Polemoniaceae	
Gilia species	Native Forb
Linanthus dianthiflorus	Native Forb
Linanthus species	Native Forb