Improving Statistical Sampling and Vegetation Monitoring for Open Space in Central Orange County

2007 Final Report

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EXECUTIVE SUMMARY

Monitoring to detect ecological change is an important component of many environmental and conservation programs. Developing effective monitoring programs for conservation plans is scientifically and logistically challenging. 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 conservation values through time and has identified vegetation communities as targets for long term monitoring. The Nature Conservancy holds conservation easements on properties adjacent to NROC NCCP lands, and both entities have similar monitoring requirements. The objective of this project is to evaluate the precision and accuracy of different sampling designs and field protocols for monitoring vegetation communities in the Orange County conservation lands, primarily coastal sage scrub (CSS), chaparral, and grasslands in central Orange County. This information addresses many of the fundamental questions surrounding the selection of both response designs and sampling designs and provides a foundation for long-term monitoring.

Initial sampling effort was stratified across vegetation types, including coastal sage scrub (CSS), chaparral and grasslands. Although the OC NCCP and TNC easement lands encompass many more vegetation types, CSS, chaparral and grasslands were prioritized based on previous work in the San Diego MSCP. This stratification across habitat types was coordinated with sampling in the San Diego MSCP to improve the power of the analysis and expand our understanding to the entire southern California region. This larger, combined data set will provide both sponsors a more robust set of conclusions and dramatically advance our ability to monitor southern California vegetation communities.

Methods: We set up eight plots throughout the inland portions of open space in central Orange County. A total of six plots were established on TNC easement lands with the remaining two established on NROC NCCP lands. We used plots that were 20m by50 m (0.1ha) and included ten $100m^2$ (10mx10m) subplots, two 50m point-intercept transects and the twenty $1m^2$ quadrats. All three data collection protocols were used by each team at all visited plots. Plot set-up was performed in late April, and field sampling was conducted by two teams in mid-May. Our field protocols recorded a number of response variables, including the species richness of the vegetation being sampled and the cover of individual species and functional groups (e.g. native shrubs, non-native grasses, etc.). We quantified different sources of variability using a variance components approach. This method along with our data on cost of field work is necessary to estimate statistical power and to develop an optimal monitoring plan.

Results: We found a total of 54 species throughout the plots sampled in Orange County in 2007. CSS and chaparral communities in Orange County were dominated by native shrubs. *Artemisia californica* (California sagebrush), *Malosma laurina* (laurel sumac) and *Salvia mellifera* (black sage) were the most prevalent native shrubs. The most prevalent non-native herbs were *Brassica nigra* (black mustard) and *Bromus madritensis* (red brome). All plant species were classified into functional groups including native shrubs, native forbs, native grasses, non-native forbs, non-native grasses and other species.

The presence and cover of individual plant species exhibit substantial variation among sites, among plots within a site, and at finer scales. In addition, the choice of field protocol influences the precision in our estimate. For example, the variance components analysis for species richness demonstrates that site-to-site variation is the dominant source of variation in species richness. The second largest source of

variation is team-to-team variability. This suggests that a good monitoring program would require visiting many sites as well as reducing the large team-to-team differences in estimating richness, perhaps by hiring experienced biologists and/or conducting extensive field training.

The variance attributed to each component was, itself, variable. Despite the differences among the response variables, several strong general conclusions can be reached. Variation among sites is the largest component of the variance in five of the thirteen variables. Variability among teams was small for common and easily identified species but large for some species that were easy to misidentify. Variability among teams was also seen in the estimate of species richness. Plot size was a very small component of the variance for all estimates of cover. However, plot size was a significant variance component of species richness. The variance components analysis for this single year's data collection supports the use of smaller plots and/or transects instead of the more time-consuming 0.1ha plots. The variance components analysis also justifies the decision to discontinue the visual cover protocol, which had higher team to team variability in effort and in cover estimates.

Conclusion: These results demonstrate that this approach (field sampling to estimate variance components) can be used as a framework for regional NCCP entities to design their monitoring programs. This approach will be even more useful when we can include estimates of inter-annual variation. Each subsequent year of monitoring should be looked at as not only a data collection effort, but an opportunity to refine these tools.

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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, Kinkaid et al. 2001; McDonald 2003; Legg and Nagy 2006; Sims, Wanless 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, Trenham et al. 2004; Barrows, Swartz et al. 2005; Rahn, Doremus et al. 2006; Sims, Wanless et al. 2006). Developing effective monitoring programs for conservation plans is scientifically and logistically challenging (Fuller 1999; McDonald 2003; Atkinson, Trenham et al. 2004; Legg and Nagy 2006; Sims, Wanless et al. 2006) and many monitoring programs have been criticized as naïve, inefficient, and in many cases, inadequate (NRC 1995; Legg and Nagy 2006; Rahn, Doremus et al. 2006). Recently the science and art of monitoring has improved in response to the criticism of earlier efforts (McDonald 2003; Atkinson, Trenham et al. 2004; Legg and Nagy 2006).

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 (Fuller 1999; McDonald 2003; Legg and Nagy 2006). 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 (Stevens and Urquhart 2000) distinguish two conceptually separate and distinct aspects of monitoring (see also (Larsen, Kinkaid et al. 2001)). One aspect is what they refer to as 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).

SAMPLING DESIGN:

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 heterogeneity (spatial and temporal). As a result, a key component of any monitoring design is the allocation of effort to describing status versus trend.

There is a fundamental trade-off between these two components. This can be easily illustrated with a simple example (Figure 1). Imagine a landscape with nine sites that are being monitored for nine years. Total sampling effort is limited to nine site visits which can be allocated in any way over the 9-year study. Sampling all sites in the first year provides complete information about status in year 1, but no information about trend (rate of change, Figure 1, upper left). At the other extreme, choosing a single site and sampling it each year provides complete information on trend at that site, but no information about status at any of the other sites (Figure 1, upper right). Between these two extremes lie a continuum of designs that allocate different effort to status and trend.

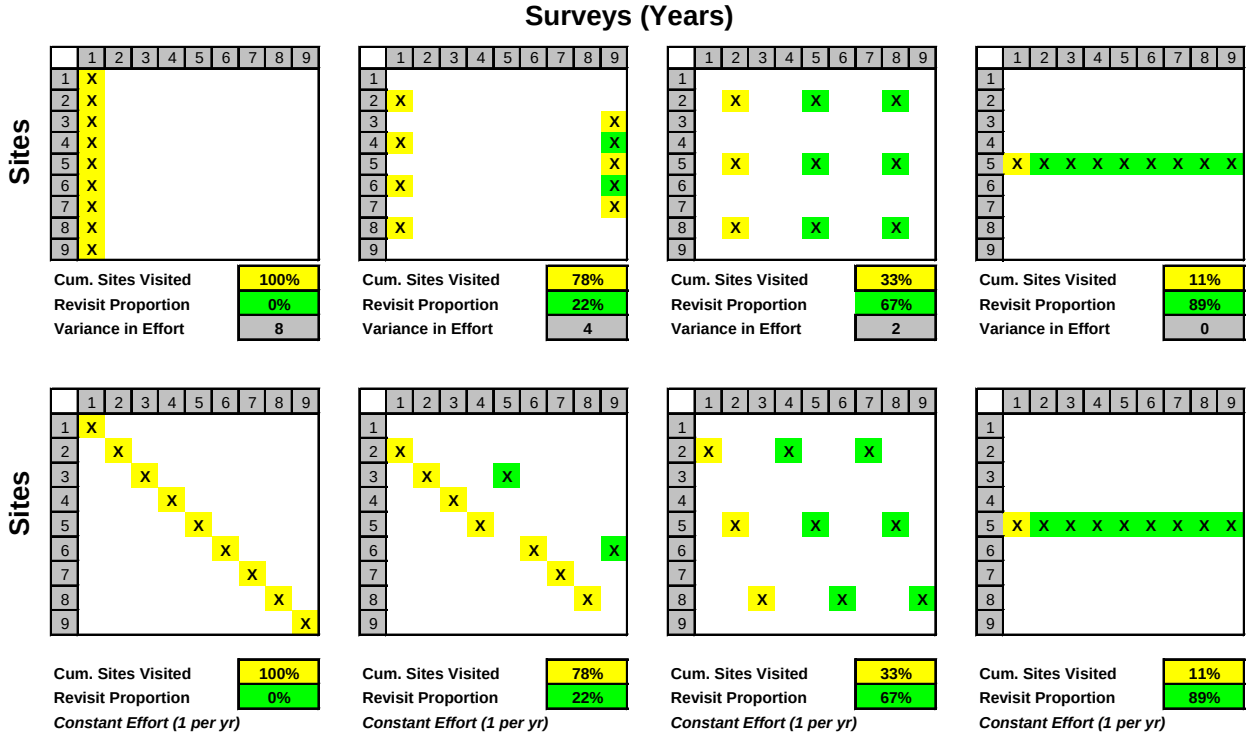

Figure 1: Trade-off between effort for status and trend. Simple representation of alternative monitoring strategies. The system consists of 9 sites that are monitoring through 9 surveys (or years). The total cost of the monitoring program is limited so that only 9 samples can be taken (of a possible 81). The designs are arrayed on a continuum from describing status (left) to trend (right). Initial visits are colored yellow, while revisits are colored green. The variance in effort (across time) is also displayed. The bottom row of designs are further constrained to have constant effort through time.

Developing an efficient monitoring program requires the matching of sampling effort to variability encountered. In a sense, this is analogous to the Neyman (Barnett 1974) allocation of sampling effort in stratified random sampling. In stratified sampling, 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, Kinkaid et al. 2001; Sims, Wanless et al. 2006). The optimal monitoring strategy will depend critically on the magnitude of temporal variation relative to spatial variation and the relative costs of alternative designs.

Common designs range from revisiting selected sites in each sampling period (Figure 2; "Repeated Visits") to visiting new sites each period (Figure 2; "New Sites"). Many monitoring designs balance the relative effort allocated to estimating status and trend. One common design calls for sampling several alternative sets of sites ("Serial Alternating" or "Rotating Panel"). Typically sites are divided into a few groups (say 3) and then each group is visited in a sequence like 1 – 2 – 3 – 1 – 2 – 3. In this design, all selected sites are revisited, but not during every sampling period

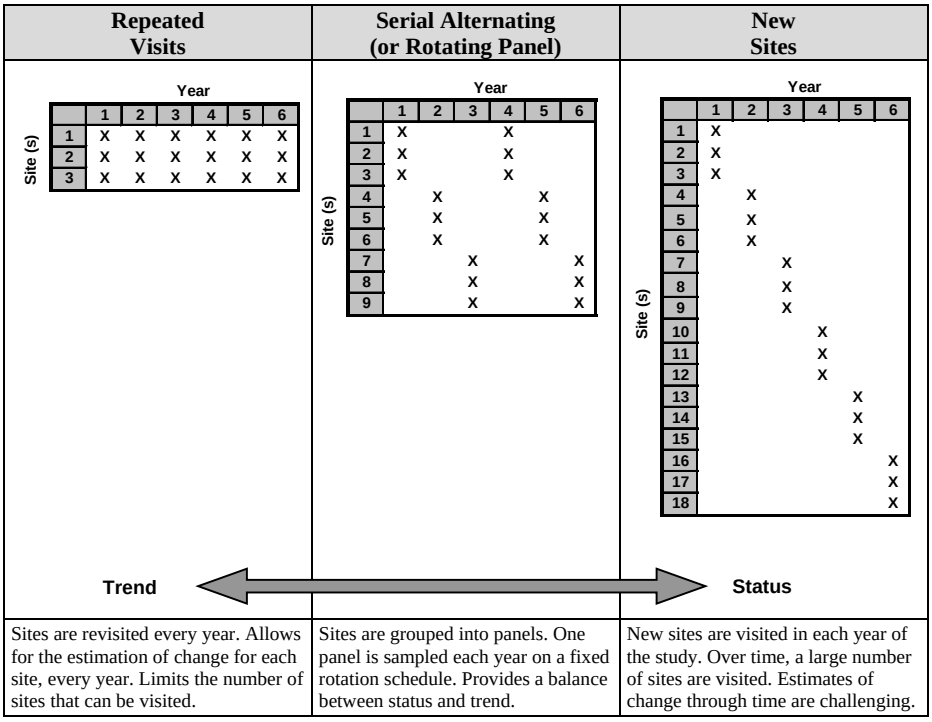

Figure 2: Common designs for monitoring status and trend. Representation of several monitoring designs. These ideas are presented as icons and described in more detail. In all three examples, total effort is equivalent (18 sites visited over a 6 year period). The designs differ radically in their allocation of effort to describing status and trend.

RESPONSE DESIGN

The response design is defined by (Stevens and Urquhart 2000) as determining what to measure, count or observe. The response design is often more closely linked to the specific questions being asked (Larsen, Kinkaid et al. 2001). Common response designs for vegetation sampling include visual estimation (Sykes, Horrill et al. 1983; Mitchell, Bartling et al. 1988; Sawyer and Keeler-Wolf

1995);(Carlsson, Bergfur et al. 2005) (but see (Klimes 2003; Podani 2006; Podani and Csonotos 2006)), quadrats (Stohlgren, Bull et al. 1998; Keeley and Fotheringham 2005; Ringvall, Petersson et al. 2005; Archaux, Gosselin et al. 2006), transect or belt transect (Grant, Madden et al. 2004), or line-intersect (Floyd and Anderson 1987; Stevens and Urquhart 2000; Kercher, Frieswyk et al. 2003) (Figure 3). 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 …" (Page 1070). However, the choice of what to measure and how to measure it can have enormous impact on the sampling design.

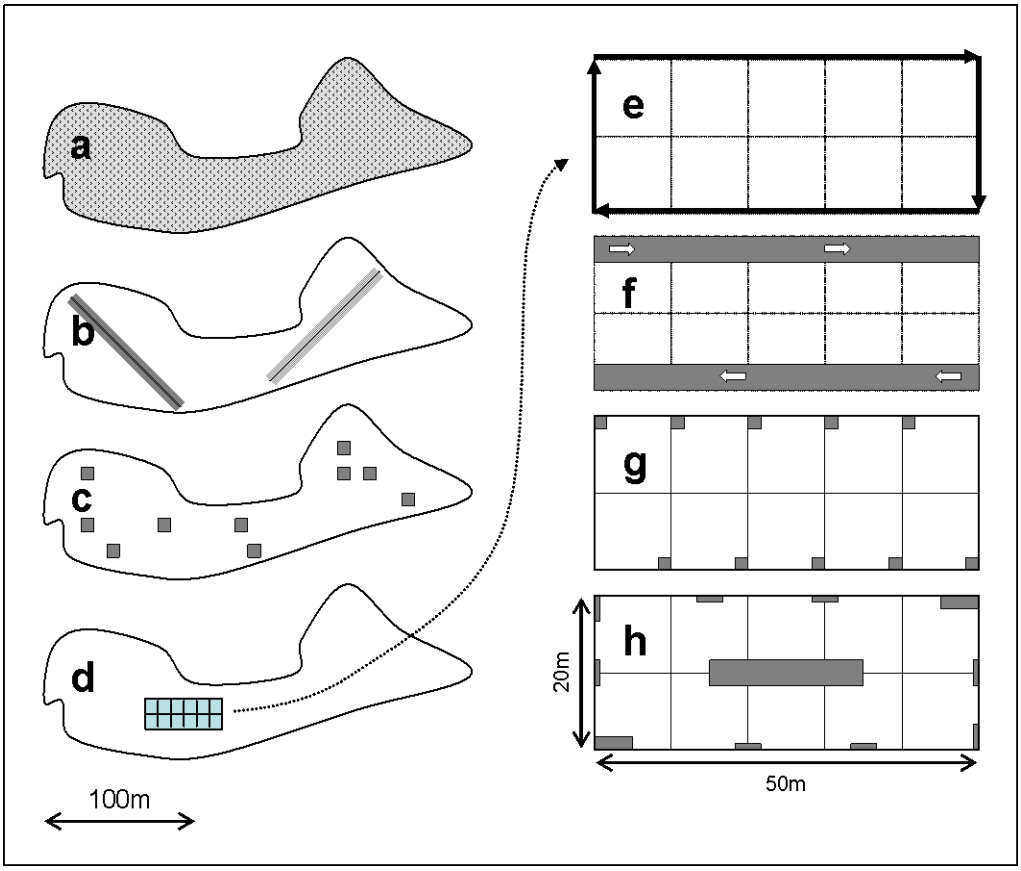

Figure 3: Common protocols for monitoring vegetation. Representation of several monitoring protocols. These ideas are presented as icons and described in more detail.

The linkage between the response design and sample design is evident when you compare two recently proposed monitoring protocols. One approach to monitoring plant communities is the relevé method (Sawyer and Keeler-Wolf 1995, CNPS 2004, Podani 2006). Investigators identify and delimit typical vegetation stands and then visually estimate cover within these stands. This technique is very fast and allows the investigator to map large areas in a limited amount of time (CNPS 2004). The method has been criticized because it relies heavily on the investigators

judgment (Chytry and Otypkova 2003; Podani 2006). As a result, the method is only semi-quantitative and may vary dramatically among observers. An alternative strategy, proposed by (Keeley and Fotheringham 2005) is based on a 0.1 ha rectangular plot with 20 1m^2 quadrats dispersed systematically across the plot. This method is much more time consuming but is expected to be much more precise. These two methods reflect different decisions about the trade-off between cost (effort) and precision. Since landscapes are heterogeneous, it is important to evaluate which combination of a sampling design (e.g. revisit, rotating panel, etc) and monitoring protocol (e.g. releve, quadrat, etc.) will be most effective in a particular application.

PROJECT OBJECTIVES

The Nature Reserves of Orange County (NROC) hold 38,000 acres of 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 the NCCP lands lie directly adjacent to 11,500 acres of conservation easement lands 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 MSCP, which was structured based on the Atkinson et al 2004 (Atkinson, Trenham et al. 2004) technical report for monitoring multiple species reserves..

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, including person-to-person variability. 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 through a CA Department of Fish and Game Local Assistance Grant to Deutschman, Franklin and others. Since this project is running concurrently with a similar effort in San Diego County, this report will use data from both counties to maximize the number of samples presented in the effort analysis and variance components analysis. This report will summarize the results for year 1 of the project (field data collected in April, 2007).

FIELD WORK

Our data collection plan was based on optimizing data collection this year, with the expectation that it will be modified as our understanding of the system improves. Our chief concerns this year were to address inter-observer variability and to compare field protocols in terms of efficiency, variability, observed species richness and functional group cover results.

Sampling Design

Our effort was stratified across vegetation types, including coastal sage scrub (CSS, 3 plots), chaparral (3 plots) and grasslands (2 plots, Figure 4a). Although the NROC NCCP and TNC easement lands encompass many more vegetation types, CSS, chaparral and grasslands were prioritized based on Franklin et al.'s (Franklin 2006) work in the San Diego MSCP. The three chaparral plots were near the burn perimeter of a major wildfire and were placed in stands that were 1 year old, 10 years old and forty years old. Field teams kept plots inside the same vegetation type as spatially separated as possible. In addition, our stratification across habitat types (minus grasslands) was the same for work in San Diego, which allowed us to combine field sets later on and improve the power of the analysis and expand our understanding to the entire southern California region (Figure 4b). This larger, combined data set will provide both sponsors a more robust set of conclusions and dramatically advance our ability to monitor southern California vegetation communities.

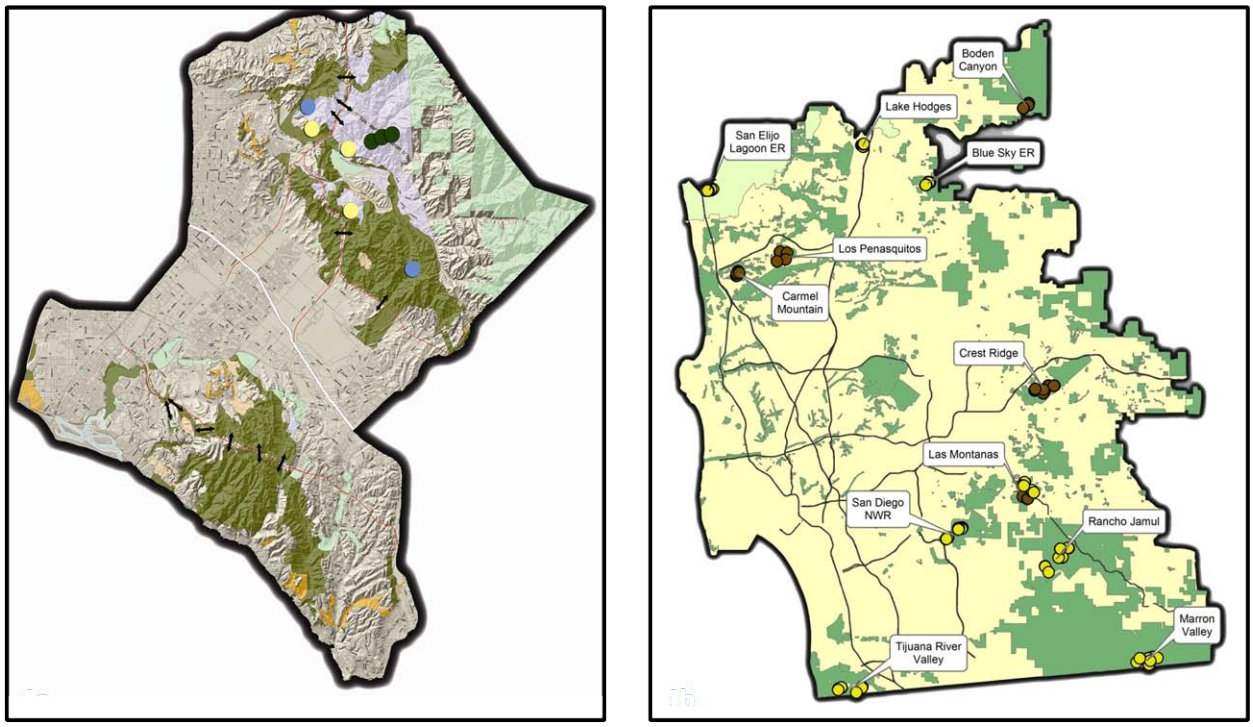

Figure 4: Plots and sites in central Orange County (a) and San Diego (b). Plots were stratified across CSS and chaparral in Orange County and San Diego. Grasslands were also monitored in Orange County only. Circles mark each plot and circle color depicts vegetation type for chaparral (green), CSS (yellow), and grassland (blue).

This year our primary goal was to quantify the benefits and drawbacks of different protocols (see the response design section). We also wanted to quantify inter-observer variability. Specific plot locations were therefore chosen based on expert opinion, in an attempt o visit the full range of variability inside each habitat type and for relatively easy access, in order to allow a number of different teams to visit the plots. In this first year, we can't address temporal variability. Our expectation is to continue this work for several years and be able to address the temporal aspect of sampling design in subsequent years.

RESPONSE DESIGN AND FIELD PROTOCOLS

Our field protocols were selected to capture a number of response variables, including the richness of the vegetation be sampled and the cover of different species and functional groups. We based our plot set up on the (Keeley and Fotheringham 2005) paper which tested plot "shape effects on plant species diversity measurements".

Keeley plots measure 20m X50 m (0.1ha) and were originally used to estimate species richness results at the $1m^2$, $100m^2$ and 0.1ha scales. We retained the overall 0.1ha rectangle, the ten $100m^2$ (10mx10m) subplots and the twenty $1m^2$ quadrats. We added two 50m point intercept transects to the long sides of the plot. This allowed us to test three different protocols at the same exact location.

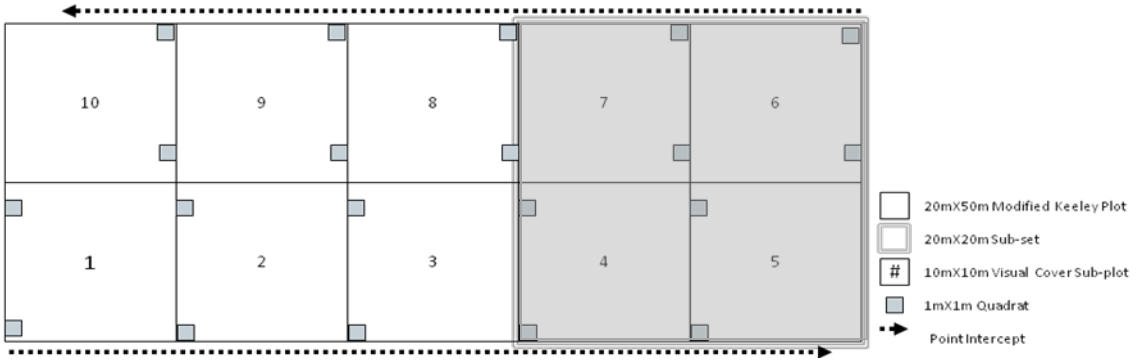

Figure 5 Modified Keeley plot. Each plot measured 20m X 50m (0.1 ha). This plot was divided into ten 10x10m subplots, each with two 1x1m quadrats located on the starting end in the exterior and interior corners. Two 50m long point intercept transects were added to the Keeley plot in order to offer three different methods and scales to compare for this study.

The final design of the plots allowed for ten $10m^2$ subplots, two 50m long transects and twenty $1m^2$ quadrats, arranged in a 20mX 50m (0.1 ha) area. In addition, the larger plot was sub-sampled (*a posteriori*) to 0.04 ha (20m x 20m) in order to compare the effects of plot size. Our analyses were made at the plot level for each method, averaging all the observations of a single method across a single plot.

All three data collection protocols were used by each team at all visited plots. In order to reduce learning bias, teams collected their data in a strict sequence. First, **visual cover was estimated.** During the visual cover, teams did not have an opportunity to search for uncommon or cryptic species. Second, **teams used point intercept transects.** During transects, teams did not enter

the center of the plot. Third, **teams placed the twenty 1m²** quadrats along the sides and in the center of the plot.

Field teams consisted of two members at a similar experience level. Once paired, team composition was not changed during the field season. This consistency facilitated the interpretation of "team" as a factor in the subsequent statistical analyses. Experience was rated, albeit somewhat qualitatively, on previous field experience and university courses completed in the areas of botany and field ecology.

Figure 6 Implementation of the three protocols. Left to right: visual cover, point-intercept, and quadrats.

Visual Cover (ten 0.01ha visual cover estimates)

Each 20x50m plot was subdivided into ten 100m² (10m by 10m) subplots. We utilized a cover estimation technique similar to those described in the California Native Plant Society's Releve and Rapid Assessment techniques. The main goal of these methods is to estimate plant cover, not measure it precisely, and to do so quickly (CNPS 2004). We therefore anticipated that visual cover estimates would be the most efficient, the least precise and have the most inter-observer bias.

During visual cover estimation, teams were instructed stand at some distance from the area to be assessed, and make a careful guess at what the percent cover of each species visible from there vantage point. We used absolute cover, to allow for overlap of species and functional groups among different canopy classes (therefore teams were allowed to record over 100% cover if they spotted multiple species over lapping in space). Our analysis was based on the average cover of a species or functional group in the 10 sub-plots .

The main differences between our protocol and the Releve protocol were: (1) our sub-plots had a predetermined shape and dimension (10m x 10m); (2) we generally stood just inside the sub-plots to make our estimations (instead of from a distance); and (3)we did not utilize cover categories, but

arrived at a team consensus for the percent absolute cover of each species. The option of splitting observations into cover classes is available post hoc.

We offered our field crew the same general suite of guidelines provided in the Releve protocol to help them make estimations. For example, we suggested visually dividing sub-plots into quadrants then estimating cover based inside each quadrant, or "squashing" species of the same type together in their mind's eye and using an imaginary 1m^2 quadrat as a benchmark for 1% cover. We also suggested thinking in terms of canopy, and rounding the general shape of shrubs to facilitate estimation. Field crews were directed to stand directly across or cattycorner to one another in the sub plots, and to discuss (sometimes via handheld radios), the percent cover of the species they were seeing, and come to a consensus. Teams were instructed not to search the area for less common or hidden species, as this would better reflect an "area search" method.

TRANSECTS (TWO 50m POINT INTERCEPTS)

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, Salzer et al. 2001). Of the many transect techniques available, we decided on point intercept because it minimizes decision making by the field teams. During a point intercept transect the observer drops a dowel perpendicular to the meter tape at a predetermined distance (in our case every 1 meter). 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 foe this method by dividing the total number of hits for each species, by the total number of points on the transect. This was the only technique we used that routinely records ground cover, even when overgrown by canopy plants.

QUADRATS (20 1m^2 QUADRATS)

Quadrats were located on the leading edge of each 10m^2 subplot, one on the exterior corner, and one 1m in from the interior corner (Figure 5). The interior quadrats on the origin side of the plots (sub plots 1-5, Figure 5) were permanently marked with two aluminum landscape spikes to allow for precise relocation of the quadrats between teams.

We offered 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 often not useful, as species cover estimations were allowed to total over 100. This technique did not require an estimation of groundcover.

The primary difference between visual cover and quadrat was that a more 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 et al. (Franklin 2006)and Deutschman et al. (Deutschman 2007), we selected three key response variables to perform our data analysis on: species richness, the cover of different plant functional groups (such as native shrubs and exotic forbs) and the cost (as estimated by hours worked). Species richness was a simple count of the number of species detected in each plot. Cover estimates for functional groups and individual species was calculated by averaging the cover in each sub-plot (visual cover) or quadrat for the entire plot, and evaluated at the plot level. Absolute cover for transects was calculated by dividing the number of hits each functional group or species had on the transect by the total number of possible hits (e.g. by 100 for 100m transects). Relative cover, which is calculated and interpreted slightly differently, was not used for this study, but can easily be calculated from our baseline data set.

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. A formal power analysis will not be conducted until the second year of this study, because it requires information about temporal (inter-annual) variability. This information will not be available until we can revisit the plots in year two.

Multiple Observer, Multiple Protocol Sampling Design

This year, one of our key goals was to characterize inter-observer variability and the dependence of this variability on the protocol used. In order to do this we used a partial factorial design with multiple teams collecting data at most plots at each site, and using all three field protocols.

Our original plan was to use a full factorial design, with all teams visiting all plots in every site. This was impossible to fully implement due to time constraints as well as concern about disturbance associated with repeated visits. Only one team (later referred to as the “expert” team) was able to visit every plot in every site. As a result, all other teams were assigned plots to maximize double sampling while the expert team focused on spatial coverage.

Field Work Performed

Preparation for field work started several months before data was collected. Prior to making site visits, emergency backpacks and directions assembled, field equipment was purchased, data sheets were created and field teams were trained on how to implement the three protocols.

Training

All field crews were trained by an “expert team” whose members had used each of the field protocols professionally. The training period was brief due to the late start of the field season, and the lack of rain, which truncated the growing season. During training, three hours were spent introducing the goals of the project, discussing safety procedures, and describing the sites. Teams were instructed how to navigate to and around plots, how to record species with 6-letter codes,

how to collect unidentified species, how to perform all three protocols, and basic safety and preparation. An additional three hours were spent together at an example plot established at Mission Trails Regional Park (San Diego).

Teams practiced navigating with the GPS units, performing all three protocols and recording data, as well as collecting and numbering unknown species. All team members were given a review of the most common CSS and chaparral plants as they were discovered in the field. At this time the principal investigator (Douglas Deutschman) and the expert team were available for questions and clarification. In addition to this training day, field crews were encouraged to call one of the expert team members with procedural questions (or emergencies) as they arose in the field. In order to assure reasonable adherence to the protocols, as well as proper orientation around sites and in plots, teams also carried a quick-reference guide to the plot set-up, the three protocols, and a GPS unit. They were also required to check out (as they headed out to a site) and in (when they returned) with either the PI or one of the two senior team members for safety.

PLOT VISITS

This year we set up eight modified Keeley plots throughout the inland portions of open space in Orange County. A total of six plots were established on TNC easement lands with the remaining two established on NROC NCCP lands. We set up 5 plots in the large inland section of open space to the north of Santiago Canyon Road, and just west of Black Star Canyon Road (the MWD pipeline road and a number of other unmarked dirt roads were used to access the plots). We set up an additional two plots south of Santiago Canyon Road: one in the Limestone –Whiting Wilderness Park /NCCP lands and one on TNC conservation easement lands (please see Appendix 1 for field maps). Plot set-up was performed in late April, and field sampling was conducted by two teams in mid-May. It should be noted that while field sampling occurred late in the season that there was adequate standing material to identify most annual species. In addition, this year Orange County received below average rainfall, and germination rates were likely extremely low, limiting the number of species present this year and therefore the possibility that we erroneously missed herbaceous species.

Habitat	Plot	Designation	N	W	Elevation	Double Sampled?
CHAP	1	TNC Easement	33.79392	117.6845	2047 ft	Yes
CHAP	2	TNC Easement	33.79128	117.69066	1834 ft	Yes
CHAP	3	TNC Easement	33.79531	117.67872	2013 ft	Yes
CSS	1	TNC Easement	33.78647	117.71211	1174 ft	Yes
CSS	2	NROC	33.79931	117.74178	710 ft	No
CSS	3	TNC Easement	33.75008	117.71372	1297 ft	No
GL	1	TNC Easement	33.81196	117.74771	885 ft	Yes
GL	2	NROC	33.71782	117.65993	1388 ft	No

Figure 7. Plot location, protection designation and double sampling for central Orange County vegetation monitoring.

In addition to quantifying 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 four phases: travel time, set-up time, data collection time, and data entry time. 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 is not considered). Effort for each protocol was recorded in four phases: travel time, set-up time, data collection time, and data entry time (Figure 8).

Set up time, data collection time, and data entry time all vary based on the method. Travel time refers to the time it took to get to each plot from a central meeting location, and is estimated. Travel time between plots was not recorded; however it always took a significant amount of time (Figure-8).

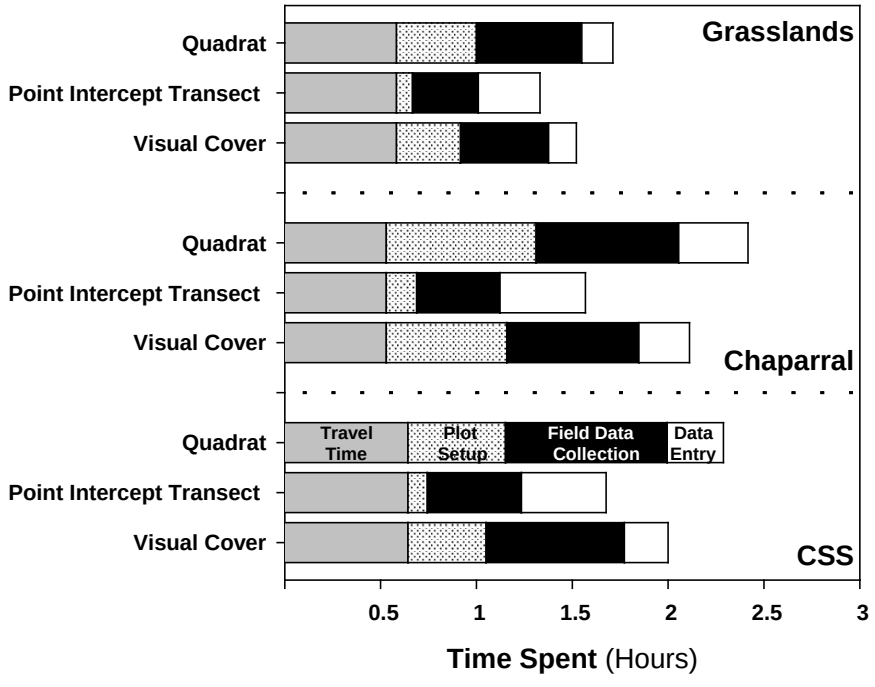

Figure 8. Average time (hours) spent on three protocols (Visual Cover, Point Intercept Transects, and Quadrats) for each team. Visual cover and quadrats were more time

consuming in the field than point intercept transects. Point intercept transects were more time consuming to enter and validate. Despite this, point intercept transects had the lowest total time.

We also wanted to consider what the field effort may have looked like if we had only sampled our 20 x 20m (0.04ha) subset. Based on our estimation most teams could have completed four 0.4 ha plots in a slightly longer day (only one more plot a day than the 50 x 20m plots). This seems an unusual result, since a 0.04 ha plot is actually less than half the size of our original 0.1ha. This is a direct result of the travel time between plots. Since travel time is unaffected by choice of protocol, it imposes an upper limit to the number of plots that can be surveyed in a given day.

COMPARISON OF EFFORT

Counter to our initial assumptions, point intercept transects were the fastest protocol; rather than visual cover which is specifically designed for speed Figures 8 and 9). We found that crews took slightly less time to complete visual cover than quadrats. Some teams completed the quadrat sampling in less time than estimating cover visually. For each 0.1ha plot, data collection varied between 27 minutes (average for point intercept) and three quarters of an hour (quadrats, Figure 9).

Interestingly, volunteer teams from San Diego, whose members were experienced biologists, but who had not received the same level of protocol specific training as the SDSU teams, consistently performed quadrats much faster (31 minutes vs. 46 minutes) and visual cover much slower (65 minutes vs. 41 minutes) than SDSU teams. One possibility for this difference is that volunteer teams performed the visual cover protocol as an area search, moving through the entire $100m^2$ sub-plot looking for species instead of standing off at the edges. Their faster performance on quadrats may speak to their experience with local flora, or to lower diversity at the sites hey visited. This difference emphasizes the important of training and communication.

Strikingly, the point intercept method took both SDSU trained teams and volunteer teams an average of 27 minutes, which indicates that this methodology is fairly predictable (consistent) in terms of effort. It is hard to draw firm conclusions based on volunteer team data since those teams made many fewer site visits than the four project teams, and their timing data may be biased on certain site conditions (for example low cover or high diversity). For this reason we will base the rest of our analysis of effort on the regular SDSU teams only.

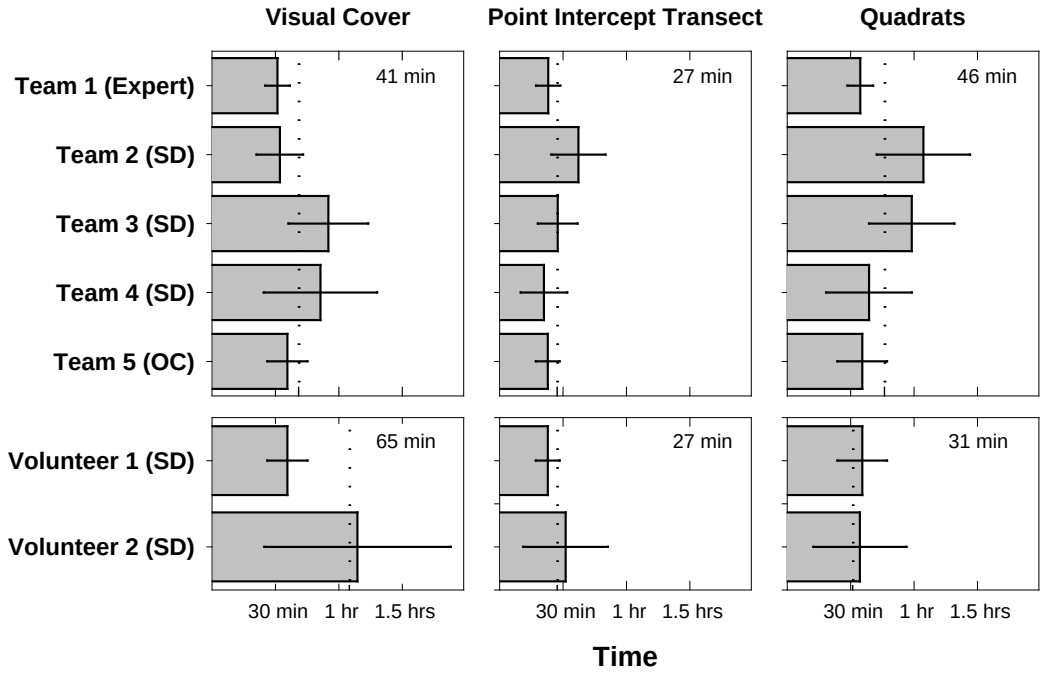

Figure 9. Average time spent collecting data in the field for three protocols (visual cover, point intercept transects, and quadrats) for each field team. Point intercept transects were quickest and time spent was the least variable among teams.

Visual cover was, on average, only slightly faster than quadrats (41 minutes vs. 46 minutes, Figure 9), and much slower than point-intercept transects (27 minutes). The unexpected slowness of the visual cover protocol is due to two factors, setup time (Figure 8) and data collection time (Figure 9). Setup for visual cover took a significant amount of time, particularly in the chaparral, because the corners of the plots needed to be squared off (Figure 4). This is especially difficult in dense, tall shrub vegetation, such as chaparral. During a relevé rapid assessment protocol, squaring and locating plots would not be an issue since you are instructed to stand at some distance from the plot (CNPS, 2004). In addition, data collection was often slow because of the decision making process that teams went through before recording percent cover. Confidence in species identification and cover estimation may have played a significant role here.

As expected, quadrats were the slowest (46 minutes, Figure 9) protocol tested. Reading quadrats took longer because there were twice as many quadrats per-plot than visual cover sub-plots. In addition, although the quadrats are small ($1m^2$) the protocol requires that teams search for hidden, cryptic and uncommon species, potentially obscured by larger plants. This process requires some time, and making additional judgment calls about species with low percent cover also takes additional time.

Point intercept transects were the fastest method. This was due to rapid set-up time and quick reading time. Set-up time for point intercept transects is fast because it only requires the team to

find the originating point, and run a meter tape in a straight line. While this can be challenging, especially in chaparral, it is much easier to pull one perfectly straight line than five perfectly squared lines for visual cover or quadrats. Despite the fact that teams had to make one hundred observations during point intercept transects (instead of ten for visual cover or twenty for quadrats), data collection time was still much faster than the other two protocols. This protocol was also the least variable among field teams and volunteer teams. The method benefits from a very simple and precise method —if the dowel is touching a plant, it gets counted. This process eliminates many of the judgment calls that may make visual cover and quadrats challenging. Baring species misidentifications, his method should derive most of its variance between teams from relocation error.

VEGETATION COMMUNITIES IN ORANGE COUNTY

Coastal sage scrub, chaparral and grassland vegetation communities were sampled separately. In this section we will first address 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 individual species. The data presented in this section are from Orange County lands only.

SPECIES RICHNESS

We found a total of 54 species throughout the plots sampled in Orange County in 2007 based on species detections by all teams combined (Table 1). Of those species, 42 were native species, including: 25 native shrubs, 10 native forbs, 5 native grasses, and 2 other native species. We identified a total of 12 non-native species, including 5 forbs, 6 grasses and 1 other species. *Artemisia californica* (California sagebrush), *Malosma laurina* (laurel sumac) and *Salvia mellifera* (black sage) were the most prevalent native shrubs, each occurring in six of the eight plots throughout the county. *Nassella* sp. (needle grasses) was the most prevalent native grasses, occurring in five of eight plots. *Gnaphalium californica* (California everlasting) was the most prevalent native forb, but appeared in only two of the eight plots (another indication of the dry year). The most prevalent non-native forb was *Brassica nigra*. (black mustard) which was encountered in six of eight plots. *Bromus madritensis* (red brome) was the most prevalent non-native grass, found in five of eight plots.

In San Diego County we found 60% more native forbs than shrub species, and as a rule of thumb expected to get similar results (slightly lower because the county is smaller) in Orange County. The relatively low number of forbs suggests that there was significantly below-average germination this year, linked to below-average rainfall and a short growing season. This result illustrates the importance of multi-year studies, especially in environments like southern California, where stochastic abiotic processes can significantly influence biology. In addition, because we were only able to visit eight plots, and were not able to get to the coastal region of the county's open space this year, we likely missed some common species that occur in patchy distributions in sections of the lands we did not visit.

Species Richness	All Species	Native Shrub	Native Forbs		Non-Native Forbs		Other Species
			Forb	Grass	Forb	Grass	
All Plots	54	25	10	5	5	6	3
CSS	28	15	1	4	4	2	2
Chaparral	32	18	8	1	1	2	2
Grasslands	25	9	4	2	4	6	0

Table 1: Species richness across the Orange County lands, within vegetation communities, and at each site, based on species detections by all teams combined. Species are grouped by habit (shrub, forb, grass) and origin (native, non-native). Other species were native and non-native species including a tree and several vines.

We found a total of 28 species across the three CSS sites. Of these, 15 were native shrubs and 6 were non-native forbs and grasses. The most widespread native shrubs were *Artemisia californica*, *Malosma laurina*, *Salvia mellifera* and *Lotus scoparius* (deerweed) at all three CSS plots. The most widespread non-natives included *Brassica nigra*. (forb) found at all three CSS plot, and *Bromus madritensis* (grass) found in two of three CSS plots.

In chaparral, we found a total of 32 species, including 18 native shrubs and only 3 non-native forbs and grasses. *Ceanothus tomentosus* (California lilac), *Adenostoma fasciculatum, Salvia mellifera* and *Malosma laurina* were found in all three chaparral plots sampled. Of the 27 native species, 8 were native forbs, but none of them occurred in multiple plots. *Bromus madritensis* and *Vulpia myuros* (rat-tail fescue) were the most widely distributed non-native grasses, each occurring two of three plots sampled. *Brassica nigra* was the most widespread non-native forb, occurring in all three chaparral plots.

We found a total of 25 species in the two grassland plots sampled in 2007. Of those, 2 were native grasses. Of those native grasses *Nassella* species were found at both plots and *Sisyrinchium bellum* (blue - eyed grass) at one. It is likely that there were at least two *Nassella* species; however, this could not be determined decisively due to a complete lack of fruit at the time of sampling. A combination of *Bromus madritensis, Avena* sp. (wild oat) and *Lolium multiflorum* (Italian ryegrass) were found at both grassland plots. Grassland diversity results were probably the most dramatically affected by low rainfall as many diagnostic species are annual, and likely did not germinate this year.

Species Detections

The number of species detected (richness) varied by team. Although we were only able to qualitatively rank order the experience level of our field teams, it seemed clear that more experienced field team had an advantage in terms of timing and observed richness. Our most experienced "expert" team (Team 1) detected 51 species (Table 2). The other less experienced team (team 5) detected 39 species. This result is comparable to that we observed in San Diego County.

Species Richness	Both Teams	Experience Level	
		Most	Least
All Plots	55	51	39
CSS	28	28	15
Chaparral	32	27	25
Grassland	25	24	14

Table 2: Species richness by team for the Orange County lands.

Regardless of experience, no single team detected all 55 species which were reported. Our most experienced team did not detect 4 species identified by the other team. The less experienced team had a substantially smaller species list. In our analysis, we cannot distinguish between one team missing a species when it is present and a second team falsely detecting a species (i.e. misidentification) when it is absent. In either case, the observed disparity demonstrates that field experience is a significant factor when designing a monitoring program that tracks plant species richness. A full species list is available in Appendix 2.

FUNCTIONAL GROUP COVER

All plant species were classified into the following six functional groups: native shrubs, native forbs, native grasses, non-native forbs, non-native grasses and other species (including all vines and unidentified samples. Absolute cover calculations are described in the "Response Variable" section in this report.

We found that the shrub communities in Orange County (CSS and chaparral) have a high proportion of native shrubs on average (Figure 10, left panel). In chaparral, all other functional groups (both native and non-native) averaged around one percent cover. In CSS, native grasses contributed 6.5 percent cover, with the other four functional groups contributing under a percent each. Native grasslands also have an encouragingly high proportion of native grass (39%). Native grasslands also had the highest non-native grass cover of the three habitat types evaluated (24%). Native grasslands were the only vegetation type this year to register a notable amount of native forb cover as well (2.5%). Native shrubs also contributed about 17% cover to native grasslands (Figure 10, left panel)

We found that the shrubland communities in Orange and San Diego Counties were very similar in terms of the cover of each functional group (Figure 10). San Diego may have slightly higher invasion raters, but that may also be an artifact of even lower precipitation in Orange County.

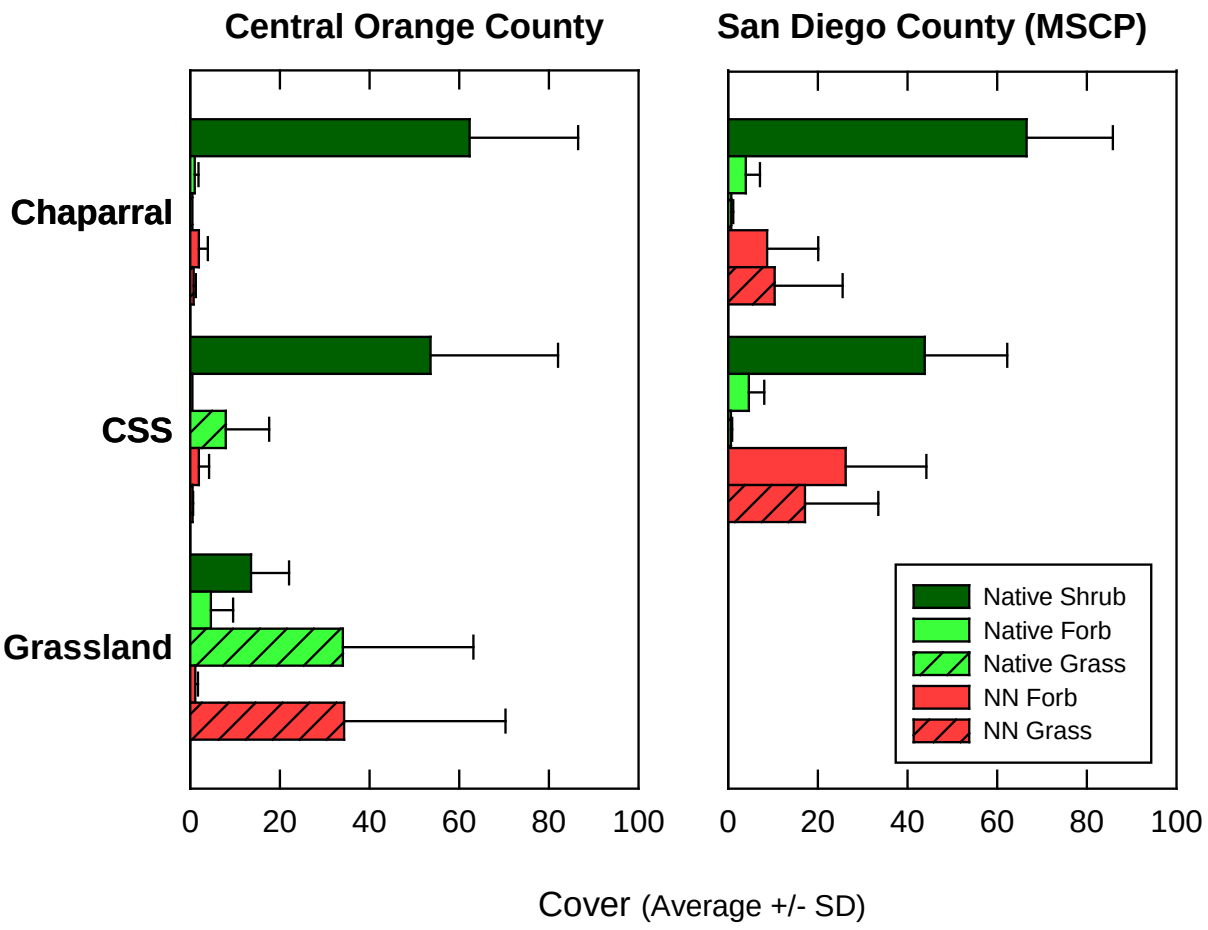

Figure 10. Average cover of functional groups in chaparral, CSS, and grasslands. Error bars are +/- 1 SD.

On average all of the vegetation types monitored met our assumptions in terms of the relative contribution of functional groups. Chaparral shrubs excluded other species where they were present, CSS shrubs were complimented by native grasses in their interspaces (and would certainly have had an herbaceous component if the rainfall had been closer to average), and grasslands supported a large amount of native grass, but were also invaded by non-native grasses.

Native and non-native forbs were nearly absent from the Orange County sites. This lack of forbs was more pronounced in Orange County than in our San Diego sites (Figure 10, right panel). The near absence of both native and exotic forbs, is likely a function of the very dry year. Although it was a dry year, it was slightly wetter in San Diego, which also had slightly higher herbaceous cover.

We predict that in wet years chaparral will likely still have the fewest exotic forbs and grasses, especially as the burned locations fill in, CSS will likely have a significant annual component, due to

the natural habitat structure and large interspaces indicative of that vegetation type, and grasslands will likely see a large increase in cover across the board.

COMMON SPECIES

Dominant species in these vegetation types vary, depending on local site factors and levels of disturbance. Characteristic dominants of the CSS include *Artemisia californica* (California sagebrush), *Eriogonum fasciculatum* ssp. *fasciculatum* (flat-top buckwheat), *Malosma laurina (laurel sumac)*, *Salvia apiana* (white sage), and *Salvia mellifera* (black sage). Species of the following genera are characteristic in chaparral associations: *Adenostoma, Arctostaphylos, Ceanothus, Cercocarpus, Heteromeles*, shrubby *Quercus*, and *Rhamnus*. *Nassella* sp. (needle grasses) is the primary genera associated with native grasslands, other indicator species include *Sisyrinchium bellum* (blue-eyed grass), *Calochortus* sp. (mariposa lily), and *Clarkia* sp. (wine-cup), among others. Various non-native grass species are also often found in high numbers inside native grasslands.

Adenostoma fasciculatum was the dominant chaparral species in central Orange County (Figure 11). In addition to *Adenostoma fasciculatum* several species of shrubs common in CSS and chaparral where found including: *Salvia mellifera*, *Malosma laurina*, and *Artemisia californica*. Chaparral had low cover of non-native grasses and forbs, with *Brassica nigra* (black mustard) as the most prevalent exotic in chaparral.

We found that CSS throughout the Orange County plots was often dominated by *Artemisia californica* and *Salvia mellifera* (Figure 11). Other dominant natives found in CSS included: *Malosma laurina*, and *Nassella* sp. Although exotic species were found in the CSS, no single exotic species dominated CSS.

Grasslands were, as expected, dominated by *Nassella* sp. and a mixture of exotic grasses including *Lolium multiflorum*, *Avena* sp. (wild oat) and *Bromus diandrus* (Figure 11).

The patterns presented for the common species demonstrate that cover varies at several scales. Some species are restricted to a single vegetation community and others are more widely distributed. For example, *Adenostoma fasciculatum* only occurs in the chaparral while *Malosma laurina* and *Salvia mellifera* occur in both CSS and chaparral, and *Artemisia californica* occurs in all three vegetation communities.

At finer scales, we see differences among plots within a vegetation community. For example, the one year old chaparral had much lower native shrub cover than the ten and forty year old stands (Figure 11, top left). The plots in the CSS varied more dramatically. CSS plot 1 was recovering from the 2006 fire as well, and while the majority of the cover was that of native shrubs, the total absolute cover was just under 30% cover for all functional groups combined. The other CSS plots differed in several large species, such as *Rhus integrifolia* (lemonade berry) and *Malosma laurina.* In the grasslands we observed a striking difference in the ratio of native to non-native grasses (Figure 11, bottom graphs). Plot 1 was dominated by *Nassella*, but plot 2 was dominated by non-native grasses. We conclude that while vegetation types throughout the central Orange County lands meet our expectations, that variability between plots is high enough to warrant a larger number of plots.

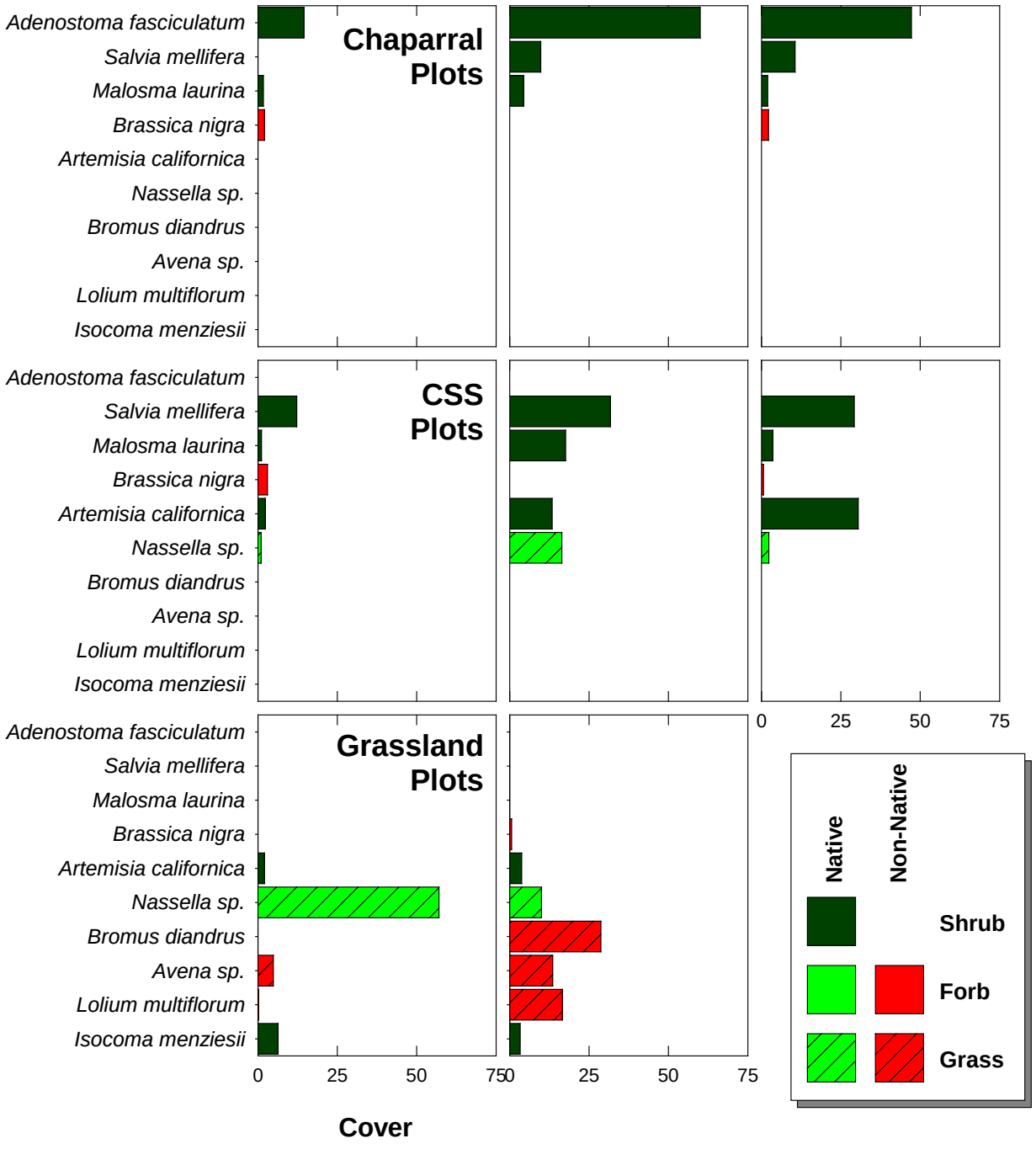

Figure 11. Cover of individual species in the 8 sampled plots. Species codes are listed in Appendix 2.

VARIANCE COMPONENTS ANALYSIS

The presence and cover of individual plant species exhibit substantial variation among sites, among plots within a site, and at finer scales. In addition, the choice of field protocol influences the precision in our estimate. We quantified these 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 cost estimates are necessary to develop an optimal (or at least near optimal) monitoring plan and to estimate statistical power. The formal power analysis will not be conducted until the second year of this study, as a comprehensive power analysis requires information about temporal (inter-annual) variability. This information will not be available until we can revisit the plots in year two. The variance components analyses that we present has seven distinct sources of explained variation (Figure 12).

SOURCES OF VARIATION

Four sources of variation result from the spatial variation of plants and plant communities on the landscape (Figure 12, red and grey shading). Vegetation community refers to the target vegetation type (chaparral, CSS or grasslands). County refers to which county the monitoring was conducted in (San Diego or Orange County). Site refers to which section of the county a plot was located in. Since our plots were clustered primarily in the inland part of central Orange County, and since the county's open spaced is less spaced out and fragmented than San Diego's, we did no assign Orange County sites. Instead we rated Orange County as a single site with multiple plots. Plots are the specific spatial locations where sampling occurred.

Three additional sources are a result of the methodological challenges in monitoring biological communities (Figure 12, blue shading). Different teams introduce observer bias, but must be used in order to collect enough data. Method refers to different response designs that can be used. Some methods may address different questions better, but may also be hard to replicate across different teams. Plot size was calculated *a posteriori* and represents the difference between our original 0.01ha modified Keeley plot design and a smaller 0.04 ha design that theoretically could save some time in the field.

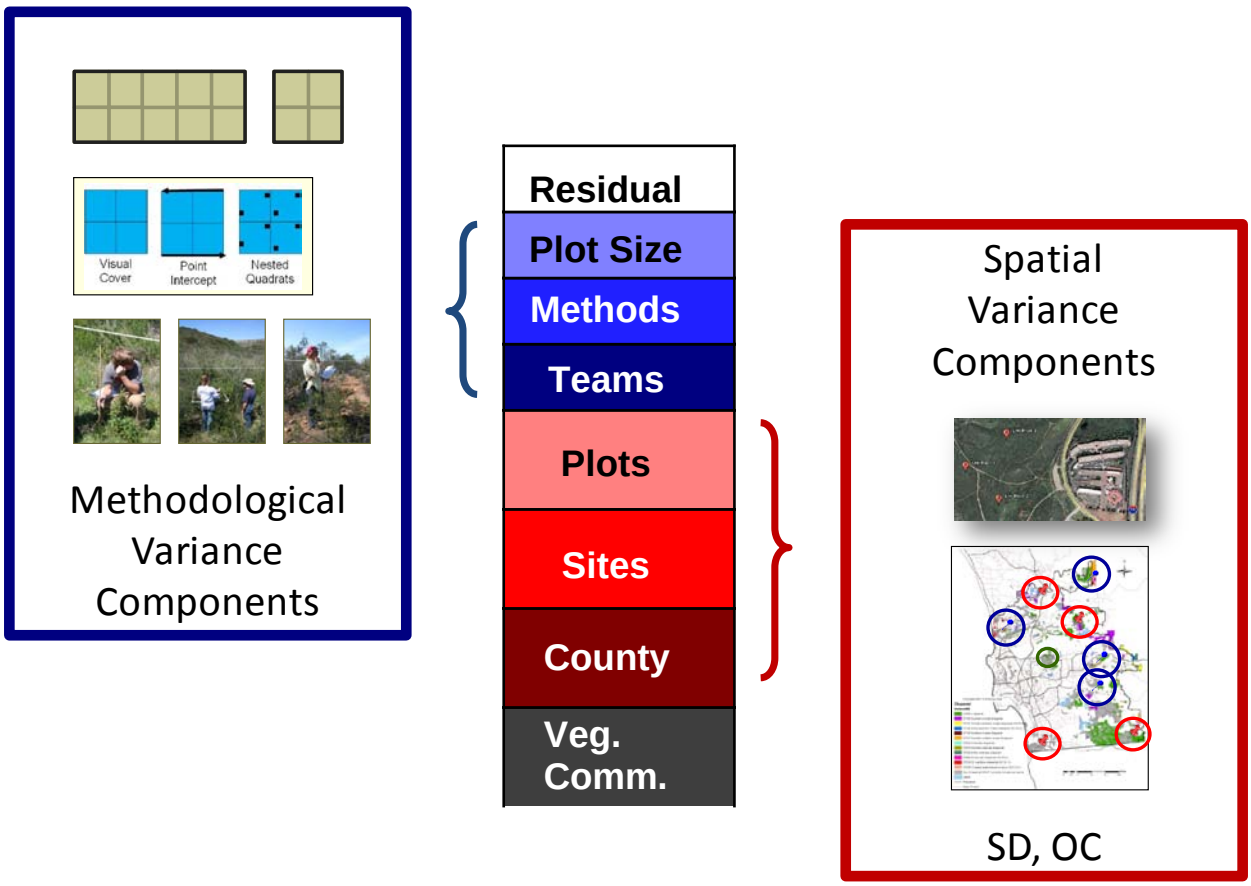

Figure 12. Illustration of the seven sources of explained variation for the variance components analysis. The seven sources of variation are partitioned into three groups, vegetation community (gray), spatial variation (county, sites and plots; reds) and methodological variation (teams, methods, and plot size; blues).

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 13). The bottom left panel shows the average species richness for CSS and chaparral vegetation communities for Orange and San Diego Counties. The average richness is similar in both communities, and thus there is little variation between the two communities (less than .1% of the variance and little variation between the two counties (4%). In contrast, species richness varied among the 11 sites (middle left panel). As a result, the variance component attributed to site-to-site variability is large (36%). The plot-to-plot variation within each site is modest (12%). There are substantial differences in the estimate of species richness that can be attributed to teams (17%), methodology (12%) and plot size (0.1ha V. 0.04ha, 12%).

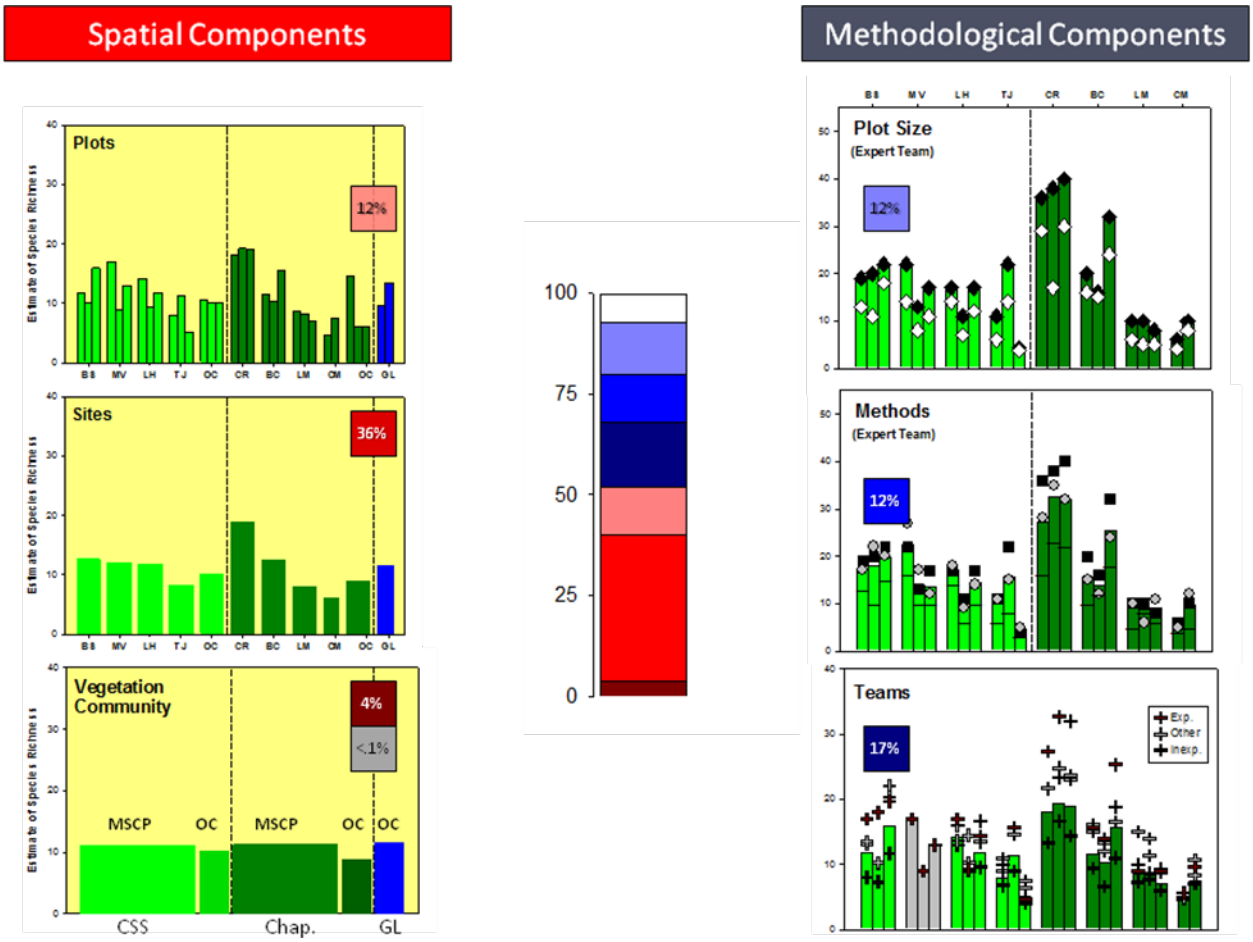

Figure 13: Illustration of the variance components analysis for species richness in San Diego and Orange Counties. The 3 left panels depict spatial variability by plotting mean richness of the vegetation communities (bottom), sites (middle) and plots within sites (top). Orange County lands were evaluated at the level of a site as it is smaller and less diffuse than San Diego's MSCP lands, which exist in distinct patches. The three right panels depict methodological variability among teams (bottom), methods (middle) and plot size (top). The middle figure depicts the absolute variance components for all sources of variation. The different types of variation are color coded (spatial - gray and reds; methodological – blues; unexplained - white).

From the variance components analysis for species richness, we conclude that site-to-site variation is the dominant source of variation in species richness. The second largest source of variation is team-to-team variability. This suggests that a good monitoring program would require visiting many sites, but would require few plots within each site. In addition, a good monitoring program must try and reduce the large team-to-team differences in estimating richness, perhaps by hiring experienced biologists and/or conducting extensive field training.

Full Variance Components Analysis

Several suites of variables were analyzed using variance components. First, we estimated the variance components of species richness (above). Second, we analyzed the cover of the major functional groups (native shrubs, non-native forbs/grasses, and native forbs). Finally, we analyzed the cover of several individual species (Figure 14). These species were selected out of the pool of identified species as proof of concept for a number of trends that occurred in the data. Similar analyses can be performed on all plant species; however presentation of such an analysis would be cumbersome and provide little additional information. The species selected for individual analysis fell roughly into two groups: common, easily identified species well known to lay botanists and less common or easily misidentified species. Species in the second group are not necessarily rare, but generally receive less attention than more prevalent species.

The comparison among different response variables revealed several important patterns. The variance attributed to each component was, itself, variable. For example, vegetation community was the largest variance component for *Adenostoma fasciculatum*. *Adenostoma fasciculatum* was present on all chaparral plots and absent from all CSS plots. The variance attributed to vegetation community was larger than the other 6 components of variance added together (Table 3). In contrast, the cover of *Bromus madritensis* was not associated with vegetation community. Instead, this species was found in high abundance at several sites, but rare at most sites. Moreover, there was significant cover at several chaparral plots including Boden Canyon and Crestridge but not at Carmel Mountain or Los Montanas. As a result, most of the variance is explained by site-to-site variability. The variance components analysis of *Hirschfeldia incana* (Mediterranean mustard) revealed a different problem. This species has a disbursed distribution, and looks very similar to other species in the genus *Brassica*. Therefore, the largest component of variance was field team as some teams failed to identify it at the three sites where it was somewhat common (average cover around 3%).

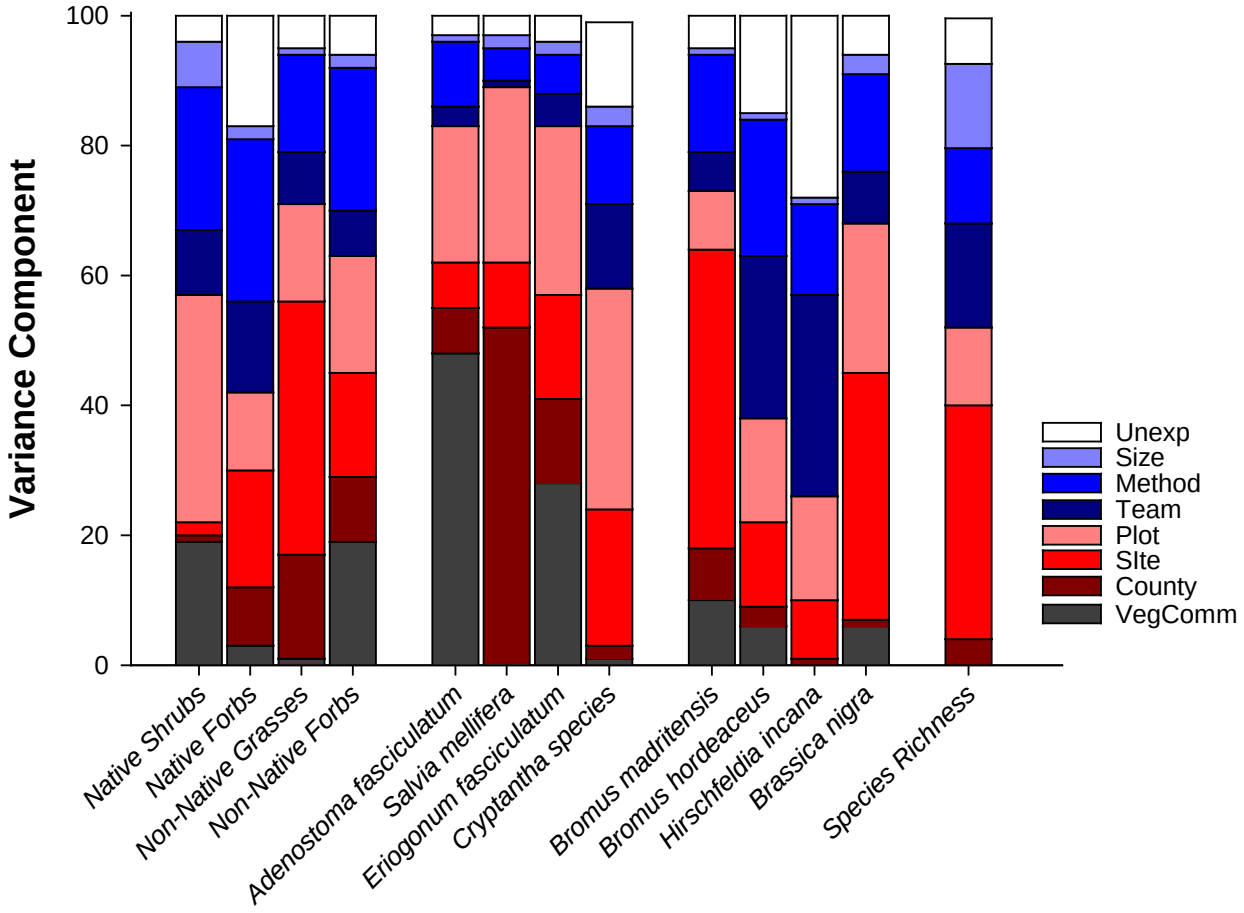

Figure 14. Comparison of the variance components analysis for thirteen response variables. The different types of variation in the stacked bars are color coded as in Figure 13 (spatial - gray and reds; methodological – blues; unexplained – white).

Despite the differences among the response variables, several strong general conclusions can be reached (Table 3). Variation among sites is the largest component of the variance in five of the eleven variables. Variability among teams was small for common and easily identified species (*Adenostoma fasciculatum*, *Salvia mellifera* , *Brassica nigra* and *Bromus madritensis*) but large for some species that were easy to misidentify (*Hirschfeldia incana*, *Bromus hordeaceus (*Soft-chess brome)). Variability among teams was also seen in the estimate of species richness. Plot size was a very small component of the variance for all estimates of cover. However, plot size was a significant variance component of species richness.

Variance Components	Average Cover (OC only)	County	Veg Community	Sites	Plots	Team	Methods	Size	Unexplained
Native Shrubs	17%	1%	19%	2%	**35%**	10%	22%	7%	5%
Native Forbs	3%	9%	3%	18%	12%	14%	**25%**	2%	18%
Non-Native Grasses	2%	16%	1%	**39%**	15%	8%	15%	1%	5%
Non-Native Herbs (F/G)	2%	10%	19%	16%	18%	7%	**22%**	2%	7%
Adenostoma fasciculatum	30%	7%	**48%**	7%	21%	3%	10%	1%	4%
Cryptantha species	< 1%	2%	1%	21%	**34%**	13%	12%	3%	14%
Eriogonum fasciculatum	2%	13%	**28%**	16%	26%	5%	6%	2%	5%
Salvia mellifera	28%	**52%**	0%	10%	27%	1%	5%	2%	3%
Brassica nigra	4%	1%	6%	**38%**	23%	8%	15%	3%	6%
Bromus hordeaceus	1%	3%	6%	13%	16%	**25%**	21%	1%	16%
Bromus madritensis	< 1%	8%	10%	**46%**	9%	6%	15%	1%	6%
Hirschfeldia incana	< 1%	1%	0%	9%	16%	**31%**	14%	1%	27%
Richness	-	4%	0%	**36%**	12%	16%	12%	13%	8%

Table 3: Variance components for 13 response variables. Each variance component is presented as a percentage of variation explained (analogous to an R_2 value). Darker shades of gray indicate large components. The single largest component for each variable is in bold type and underlined.

The variance components analysis for this single year's data collection supports the use of smaller plots and/or transects instead of the more time-consuming Keeley plots. The variance components analysis also justifies the decision to discontinue the visual cover protocol, which had higher team to team variability in effort and in cover estimates. The analyses suggest that experienced field teams and/or intensive training are needed to avoid problems with rare, misidentified or cryptic species. The analyses presented must also be viewed with some caution. These analyses come from a single field season and therefore cannot be used to evaluate inter-annual variability. Inter-annual variability is likely large in these vegetation communities due to pronounced variation in rainfall. In fact, 2007 was a very dry year, and estimates of cover and species richness may be low because of poor germination and recruitment of annuals. Re-analysis of the data after 2 or more field seasons will provide the first direct comparisons of spatial, temporal, and methodological sources of variation.

DISCUSSION

We monitored CSS, chaparral and grassland vegetation communities at several plots throughout the central Orange County lands. CSS and chaparral habitats were chosen because they are the dominant vegetation communities within the study area. These communities also contain many covered and/or at-risk animal and plant species (Franklin et al. 2006, Regan et al. 2006). We proposed a coordinated field sampling, data analysis, and modeling plan that would provide estimates of natural variability in the plant communities at several scales. Our vegetation sampling focused on species richness as well as the cover of invasive grasses and forbs relative to native shrubs. These metrics were based on the conceptual model that we developed during a previous project (Hierl et al. 2007). We also proposed to evaluate relative accuracy and cost (labor) of alternative field protocols, and estimate the magnitude of inter-observer bias and variability by deploying multiple field teams to each site. Finally, we analyzed data from this first field season using a variance components approach (Deutschman et al. 2007). The analysis partitioned observed variance into spatial heterogeneity (county, vegetation community, site, plot), protocol differences, differences among field teams, and different plot sizes. This year we tested three protocols at 8 plots distributed throughout central Orange County and across three vegetation communities. This data was later pooled with 23 plots from the San Diego MSCP to provide a more robust variance components analysis. We demonstrated that point intercept transects are faster than visual cover or quadrat methods. We also showed that the time it took to complete visual cover was highly variable among field teams. Finally, we found that travel to sites and among plots within a site is a significant portion of each team's total effort. As a result, travel imposes an upper limit on the number of plots sampled in a day. As a result of this limitation, the choice of field methods will likely be driven more by accuracy and precision than by the time it takes to apply the method in the field.

We recorded 54 plant species across the three vegetation communities, although diversity this year was likely very low. At these sites, CSS is dominated by smaller native shrubs *Artemisia californica*, and *Salvia mellifera* . Chaparral is dominated by larger shrubs *Adenostoma fasciculatum*, and *Salvia mellifera*. Grasslands were dominated by *Nassella* sp.

In this report, we demonstrate the usefulness of the variance components analysis for informing decisions about monitoring. We developed several graphical and numerical summaries of the fairly abstract and mathematically difficult variance components analysis. Variance components analysis will be even more useful when we can include estimates of inter-annual variation. We found that the largest components of variance were typically driven by differences among sites and among plots within a site. This suggests that more sites and more plots are needed to monitor shrub communities in central Orange County. However, smaller plots and rapid methods appear adequate to estimate species abundance for all but the rarest species, and therefore to monitor overall community composition

PROPOSED SAMPLING IN YEAR 2

In the first full field season, each team went to every site, and all plots were visited at least twice, but often more. We were therefore able to estimate differences among field teams at all sites. In year two we propose to reduce double sampling and to focus more resources on spatial coverage. We will therefore be able to cover more plots in NROC lands. We plan to double sample no more than ½ the plots within each site. In addition to reducing the degree of double sampling, we will also be modifying our field protocol. In the first year, we identified the visual cover protocol as the most difficult to replicate between teams, and discovered that it was not as economical as we initially anticipated. In year two we will abandon visual cover, and combine point-intercept transect and quadrat protocols. "Plots" will now consist of one 50m transect. Point intercept transect data will be collected along the 50 m (0m-49m), and ten quadrats will be sampled every 5m, on alternating sides (Figure 14) Our hope is that set- up and relocation times will decrease substantially. In addition, the time savings from abandoning the visual cover protocol should allow us to cover more plots per site.

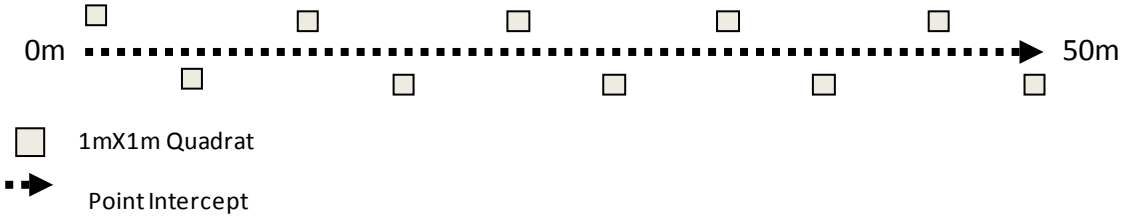

Figure 15. 2008 transect/plot field protocol. A 50 m transect will be located using a restricted stratified random sampling procedure, Quadrats will be read every 5 meters on alternating sides.

PLOT SELECTION

We will continue to use the plots we established in 2007 in order to estimate temporal effects. Plots sampled in 2007 will be referred to as "sentinel plots", and will be revisited each year. We will apply our new dual protocol by abandoning the subplots for visual cover, and the midline array of quadrats. We will re-sample the 50m point-intercept transects on both sides of the plots, as well as the quadrats located every 10m on the interior edge of the plots. In addition, we will add quadrats to the outside edge of the plots, offset from the original quadrats by 5m to produce the 5m alternating quadrat design.

New transects will be sited using a restricted randomized sampling design. Plot locations will be stratified across slope and aspect, and selected randomly with the following constraints:

- Plots will be no less than 30m from road access, and no more than 500m.
- Plots will be selected within the designated vegetation type.
- Extreme slopes will be avoided, as well as unnecessarily dangerous terrain.
- Plots will not cross into a different vegetation type.

During the set-up phase, teams will be given a list of 6 points for each site, and each point will have 3 sets of coordinates. During set up, if the first set of coordinates is unsuitable (dangerously steep,

on a road, etc.) the team will move down to the next set of coordinates. Each set of coordinates will also be associated with a random compass direction to determine how each transect will be oriented.

Based on our effort analysis this year, and given the revised data collection protocol, we believe that each team will be able to visit one sentinel and 3 or 4 50m long transects per day, barring unforeseen circumstances. Several (3 to 6) new transect plots will be establish at each site.

TEAM TRAINING

We would like to implement a more extensive and better documented training procedure for all field crew next year, and quantitatively assess experience level before and after the field season. Our hope is to reduce inter-team variability. One observation we made in 2007 was that confidence seems to matter; a field crew confident in their ability to perform a given protocol will perform much more efficiently than one with less experience. This may be one of the many reasons why point intercept transects were the least time consuming, because the decision making process (whether or not the plant is touching the stick) is simplified.

This year we will create a *species list* for inclusion in each team's set of instructions. We also now have a list of commonly *unidentified species*, for which we can provide illustrations and specific diagnostic characteristics. We can do the same for groups of species that had to be analyzed at the genus level such as the *Erodium* sp., *Bromus* sp. and *Gallium* sp. In addition, training will involve a site visit supervised by one of our expert biologists. For the first site visited by each team, one member of the "expert" team will ride along, answer questions, and demonstrate. The "expert" will not actually do the data collection, but provide a measure of confidence for the team while they get used to the protocols and vegetation

CONCLUSIONS

This year we are able to draw several firm conclusions, both about the target vegetation communities, as well as the methods we used to collect data and sources of variability in that data.

Species and cover in the Orange County lands:

- We recorded 54 plant species across the three vegetation communities.
- CSS is dominated by smaller native shrubs like *Artemisia californica*, and *Salvia mellifera*.
- Chaparral is dominated by *Adenostoma fasciculatum*.

Monitoring methods:

- Point intercept transects are faster than visual cover or quadrat methods, but yielded similar results for large, prevalent species.
- The time it took to complete visual cover was highly variable among field teams.
- Quadrats were the best at capturing low cover and rare species.
- Travel to sites and among plots within a site is a significant portion of the total effort. As a result, travel imposes an upper limit on the number of plots sampled in a day.

Variability in the data:

- Variation among sites is the largest component of the variance, other than vegetation community
- Plot-to-plot variation within sites is often large and is the second largest component of variation
- Variability among teams was small for common and easily identified species but large for some species that were easy to misidentify
- Variability among teams was also seen in the estimate of species richness.
- Plot size was a very small component of the variance for all estimates of cover.

Plot size was a significant variance component of species richness.
These results demonstrate that this approach (field sampling to estimate variance components) can be used as a framework for regional NCCP and other conservation entities to design their monitoring programs. For example, in some cases cover of dominant species may be the key factor of interest, and therefore a method that is quick and provides a reasonable estimate (e.g. point intercept transects) may be chosen over a method which takes longer, but provides better information on low cover and rare species (e.g.quadrats). Each subsequent year of monitoring should be looked at as not only a data collection effort, but an opportunity to refine these tools.

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APPENDIX 1: PLOT LOCATIONS AND FIELD MAPS

Habitat	Plot	Ownership	N	W	Elevation	Area Description
CHAP	1	TNC	33.79392	117.6845	2047 ft	Interior Inland, on power line access road
CHAP	2	TNC	33.79128	117.69066	1834 ft	Interior Inland, on power line access road
CHAP	3	TNC	33.79531	117.67872	2013 ft	Interior Inland, on power line access road
CSS	1	TNC	33.78647	117.71211	1174 ft	Interior Inland, on MWD access road
CSS	2	NROC	33.79931	117.74178	710 ft	Interior Inland, on MWD access road
CSS	3	TNC	33.75008	117.71372	1297 ft	Limestone Canyon Regional Park vicinity
GL	1	TNC	33.81196	117.74771	885 ft	Interior Inland, on MWD access road
GL	2	NROC	33.71782	117.65993	1388 ft	Limestone Canyon Regional Park vicinity


gl1 33.81195 N, 117.74771 W
33.79931 N, 117.74178 W
CSS2
Irvine Park Rd
© 2007 Navteq
Image © 2007 DigitalGlobe
Google
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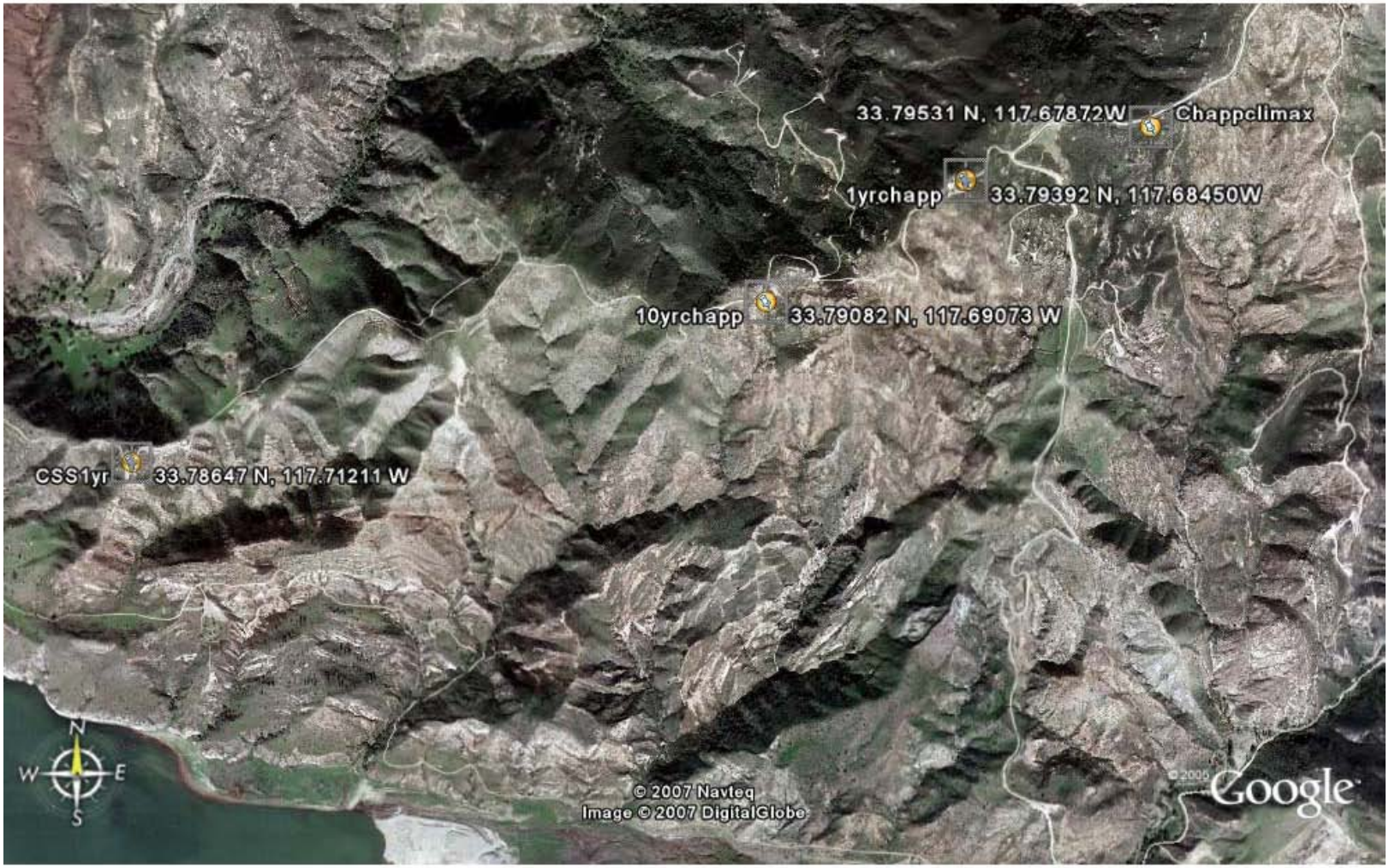
33.79531 N, 117.67872W
Chappclimax
1yrchapp
33.79392 N, 117.68450W
10yrchapp
33.79082 N, 117.69073 W
CSS1yr
33.78647 N, 117.71211 W
N
W
E
S
© 2007 Navteq
Image © 2007 DigitalGlobe
Google


33.75008 N, 117.71371 W
CSS 3
GL 233.71782 N, 117.65993 W
© 2007 Navteq
Image © 2007 DigitalGlobe
Google
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APPENDIX 2: SPECIES LIST AND CODES

Code	Species Name	Functional Group
	Agavaceae	
Heswhi	Hesperoyucca whipplei	Native Shrub
	Amaranthaceae	
Saltra	Salsola tragus	Non-native Shrub
	Anacardiaceae	
Mallau	Malosma laurina	Native Shrub
Rhuint	Rhus integrifolia	Native Shrub
Rhuova	Rhus ovata	Native Shrub
	Asteraceae	
Ambpsi	Ambrosia psilostachya	Native Forb
Artcal	Artemisia californica	Native Shrub
Cenmel	Centaurea melitensis	Non-native Forb
circar	Cirsium species	Non-native Forb
Ericon	Eriophyllum confertiflorum	Native Forb
Gnacal	Gnaphallium californicum	Native Forb
Gutsp	Gutierrezia species	Native Shrub
Helgra	Helianthus gracilentus	Native Shrub
Isomen	Isocoma menziesii	Native Shrub
Lesfil	Corethrogyne filaginifolia	Native Forb
Leycon	Corethrogyne filaginifolia	Native Forb
	Boraginaceae	
Crysp	Cryptantha species	Native Forb
Phacic	Phacelia cicutaria	Native Forb
	Brassicaceae	
Branig	Brassica nigra	Non-native Forb
Hirinc	Hirschfeldia incana	Non-native Forb
	Cactaceae	
Opulit	Opuntia littoralis	Native Shrub
	Cistaceae	
Helsco	Helianthemum scoparium	Native Shrub
	Convolvulaceae	
Calmac	Calystegia macrostegia	Native Vine
	Fabaceae	
Lotsco	Lotus scoparius	Native Shrub
	Fagaceae	
Queber	Quercus berberidifolia	Native Shrub
	Hydrophyllaceae	

Code	Species Name	Functional Group
Ericra	Eriodictyon crassifolium	Native Shrub
	Iridaceae	
Sisbel	Sisyrinchium bellum	Native Grass
	Lamiaceae	
Salapi	Salvia apiana	Native Shrub
Salmel	Salvia mellifera	Native Shrub
	Malvaceae	
Malfas	Malacothamnus fasciculatus	Native Shrub
	Poaceae	
Avebar	Avena species	Non-native Grass
Brodia	Bromus diandrus	Non-native Grass
Brohor	Bromus hordeaceus	Non-native Grass
Bromad	Bromus madritensis	Non-native Grass
Brosp	Bromus species	Non-native Grass
Elysp	Elymus species	Native Grass
Lolmul	Lolium multiflorum	Non-native Grass
Naspul	Nassella species	Native Grass
Nassp	Nassella species	Native Grass
Vulmyu	Vulpia myuros	Non-native Grass
	Polygonaceae	
Erifas	Eriogonum fasciculatum	Native Shrub
	Rhamnaceae	
Ceacra	Ceanothus crassifolius	Native Shrub
Ceasp	Ceanothus species	Native Shrub
Ceatom	Ceanothus tomentosus	Native Shrub
	Rosaceae	
Adefas	Adenostoma fasciculatum	Native Shrub
Cermin	Cercocarpus minutiflorus	Native Shrub
Hetarb	Heteromeles arbutifolia	Native Shrub
	Rubiaceae	
Galang	Galium angustifolium	Native Forb
	Solanaceae	
Solpar	Solanum parishii	Native Forb
	Urticaceae	
Urtdio	Urtica dioica	Native Forb

APPENDIX 3: ANNOTATED BIBLIOGRAPHY

The following is a list of key documents, collected here to provide the reader with background information that informed the design of this project. We have summarized the scope of each document and its relationship to the work presented in this report.

Atkinson, AJ., PC Trenham, RN Fisher, SA Hathaway, BS Johnson, SG Torres, and YC Moore. 2004. Designing monitoring programs in an adaptive management context for regional multiple species conservation plans. U.S. Geological Survey Technical Report. USGS Western Ecological Research Center, Sacramento, CA. 69 pages. *http://www.dfg.ca.gov/habcon/nccp/pubs/monframewk10-04.pdf*	This is an excellent overview to the challenges of developing a monitoring program. It describes a 9-step approach from identifying the goals and objectives of a monitoring program to implementation of adaptive management. The document illustrates the process with numerous real-world examples. It also has an extensive bibliography with about 90 references (of which about 40% are technical reports, 35% are peer-reviewed journal articles or chapters from books, and 25% are books)
Deutschman, DH, LA Hierl, J Franklin and HM Regan. 2006. Developing Conceptual Models to Improve the Biological Monitoring Plan for San Diego's Multiple Species Conservation Program. California Department of Fish and Game Local Assistance Grant P0450009. 39 pages. *http://www.dfg.ca.gov/habcon/nccp/pubs/mscpconceptualmodels4mon.pdf*	This report was one of 5 technical reports prepared for the NCCP LAG grant that preceded this project. This report discusses the role of conceptual models in the development of a monitoring program. The report contains conceptual models of several species of plants and animals as well as the coastal sage scrub vegetation community.
Field, SA, AJ Tyre, and HP Possingham. 2005. *Optimizing allocation of monitoring effort under economic and observational constraints.* Journal of Wildlife Management **69**(2):473-482.	Explores how monitoring programs can be thwarted by observational and economic constraints. The authors use simulations to explore the relationship between sample design and species prevalence and detectability. They discuss the implications for multi-species monitoring programs more complex monitoring problems.

Franklin, J, LA Hierl, DH Deutschman and HM Regan. 2006. Grouping and Prioritizing Natural Communities for the San Diego Multiple Species Conservation Program. California Department of Fish and Game Local Assistance Grant P0450009. 57 pages. *http://www.dfg.ca.gov/habcon/nccp/pubs/mscpnatcompriorities2006.pdf*	This report was one of 5 technical reports prepared for the NCCP LAG grant that preceded this project. This report discusses spatial structure and environment of the natural communities within the MSCP relative to the planning area. Some of this report has been published in Hierl et al. 2008 in Environmental Management (see below)
Fuller, WA. 1999. *Environmental surveys over time.* Journal of Agricultural, Biological and Environmental Statistics 4(4) 331-345.	This is one of several excellent articles in a special issue of the JABES. It discusses the statistical, economic, and logistical issues that arise in monitoring through time. It ends with some very amusing (and accurate) aphorisms like "every step in the process sounds easier than it is."
Hierl, LA, J Franklin, DH Deutschman, HM Regan, and BS Johnson. 2008. Assessing and Prioritizing Ecological Communities for Monitoring in a Regional Habitat Conservation Plan. Environmental Management 42:165–179.	Resources are limited making it impossible to monitor all components of a multi-species reserve system. We evaluate ecological communities based on four criteria derived from basic principles of conservation and landscape ecology—extent, representativeness, fragmentation, and endangerment—to prioritize communities in the San Diego MSCP. This framework may be useful to other conservation planners and land managers for prioritizing communities for monitoring.
Hierl, L.A., H.M. Regan, J. Franklin and D.H. Deutschman. 2005. Assessment of the Biological Monitoring Plan for San Diego's Multiple Species Conservation Program. California Department of Fish and Game Local Assistance Grant P0450009. *http://www.dfg.ca.gov/habcon/nccp/pubs/mscpmonprogassmt8-05.pdf*	This document is the first report for previous Local Assistance Grant (Franklin et al #P0450009). The report focuses on assessing the implementation of the monitoring program and reviewing information relevant to successful monitoring program design. The report identified a preliminary set of recommendations on how to improve the monitoring program.

Keeley, JE and CJ Fotheringham. 2005. Plot shape effects on plant species diversity measurements. Journal of Vegetation Science. 16:249-256	The authors compared three 0.1-ha sampling designs that differed in the shape and dispersion of $1m^2$ and $100m^2$ nested subplots. They compared designs which had square clustered subplots, dispersed rectangular subplots, and a third design that overlaid square subplots. Our 0.1-ha plot was based on the third design described in this paper.
Larsen, DP, TM Kincaid, SE Jacobs, NS Urquhart. 2001. Designs for elevating local and regional scale trends. Bioscience. 51(12):1069-1078.	This paper describes a framework for evaluating the effects of spatial and temporal variability on the power of different survey designs. It follows the more technical work published by the authors, most notably Urquhart. The paper defines the terms "sampling design" and "response design" as they are used in this report.
Legg, CJ and L Nagy. 2006. Why most conservation monitoring is, but need not be, a waste of time. Journal of Environmental Management 78:194-199.	An important and highly critical review of ecological monitoring. The authors assert that many ecological monitoring programs will fail because they suffer from the lack of details of goal and hypothesis formulation, survey design, data quality and statistical power. Like Huff in his 1956 book How to Lie with Statistics, they conclude that results from inadequate monitoring are dangerous because they create the illusion that something useful has been done.
McDonald, TL. 2003. Review of environmental monitoring methods: survey designs. Environmental Monitoring and Assessment. 85: 277-292.	This paper reviews and summarizes statistical survey design for environmental monitoring. The paper differentiates between two aspects of the design, the membership design and the revisit design. Membership designs often are simple random or systematic samples. Revisit designs include always revisit, never revisit, or some rotating design. This paper advocates a new unified short-hand notation for describing these designs.

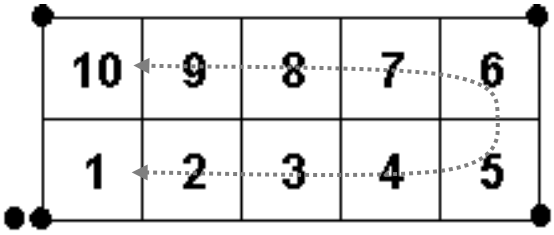
NRC. 1995. Review of EPA's Environmental Monitoring and Assessment Program: Overall Evaluation. National Research Council. Washington, DC. 178 pages. ISBN-13: 978-0-309-05286-3	EPA's Environmental Monitoring and Assessment Program (EMAP) was established monitor the nation's ecological resources. The National Research Council (NRC) was asked to evaluate the program. NRC concluded that EMAP's goals are laudable but was critical of the EMAP program. They were unconvinced (pessimistic) that the program could surmount the many difficult scientific, practical, and management challenges.
Regan HM, LA Hierl, J Franklin, DH Deutschman, HL Schmalbach, CS Winchell, and BS Johnson. 2008. Species prioritization for monitoring and management in regional multiple species conservation plans. Diversity and Distributions 14:462–471.	This paper was an outgrowth of the work done during the preceding LAG grant. In this paper, we present a strategy for prioritizing species for monitoring and management. We use existing assessments of threatened status, and the degree and spatial and temporal extent of known threats to link the prioritization of species to the overarching goals and objectives of the MSCP.
Sims M, S Wanless, MP Harris, PI Mitchell and DA Elston. 2006. Evaluating the power of monitoring plot designs for detecting long-term trends in the numbers of common guillemonts. Journal of Applied Ecology 43:537-546.	The authors investigated the power of different monitoring design options for detecting long-term trends in abundance at a colony of guillemots (seabird). The ability to detect trends in abundance was reduced by the large temporal and spatial variability in colony attendance. They conclude that design decisions depend on the relative magnitude of these variance components.
Stohlgren, TJ, KA Bull, and Y Otsuki. 1998. Comparison of rangeland vegetation sampling techniques in the Central Grasslands. Journal of Range Management51:164-172.	Four rangeland vegetation sampling techniques were compared to see how well they captured local plant diversity. The methods tested included transects, large quadrats, and a Modified-Whittaker multi-scale vegetation plot. They conclude that multi-scale methods are best for monitoring the status and trends of common, rare, and exotic plant species at several scales.

Urquhart, NS, TM Kincaid. 1999. Designs for Detecting Trend from Repeated Surveys of Ecological Resources. Journal of Agricultural, Biological and Environmental Sciences. 4(4):404-414.	This is one of several excellent articles in a special issue of the JABES. It describes different types of revisit designs including never revisit, always revisit, and panel/alternating revisits. Although some of the simulations are more mathematically dense, the paper is very accessible.

APPENDIX 4: DATA SHEETS AND DESCRIPTION

Visual Cover Data Sheets:

Visual cover estimated were made in 10 separate 10m x 10m subplots located within each 0.1ha plot (see diagram). Sub-plots were numbered 1-10, with 1-5 being located on the origin side, increasing sequentially away from the origin. For ease of reading, and to reduce trampling, we number the sub-plots on the opposite side such that teams could read them sequentially, while moving back toward the front of the plot (like a U, see diagram).



Visual cover data sheets can be located on the following two pages.

Visual Cover

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

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

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

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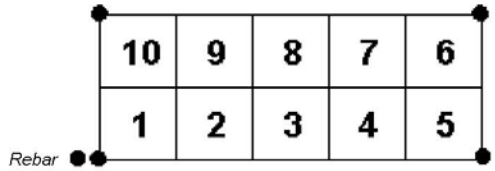
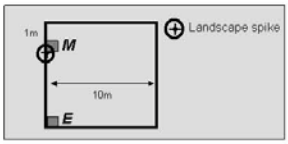
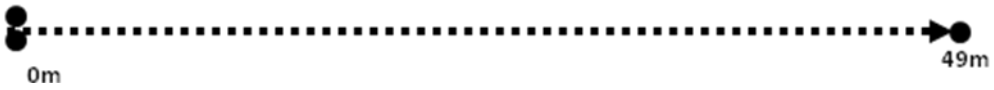




Point Intercept Transect Data Sheets:

Point intercept transects were read on the long (50m) side of each plot. Intercepts started at 0 at the origin, and were spaced (and numbered) every 1m to 49 on the origin side (see diagram). On the non-origin side transects were read from 50m (0m from the corner diagonal to the origin, see diagram). Again, to avoid trampling the second transect was number so to bring field teams back toward the origin.



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

Transect 1 

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

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**

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

Transect 2

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

50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74

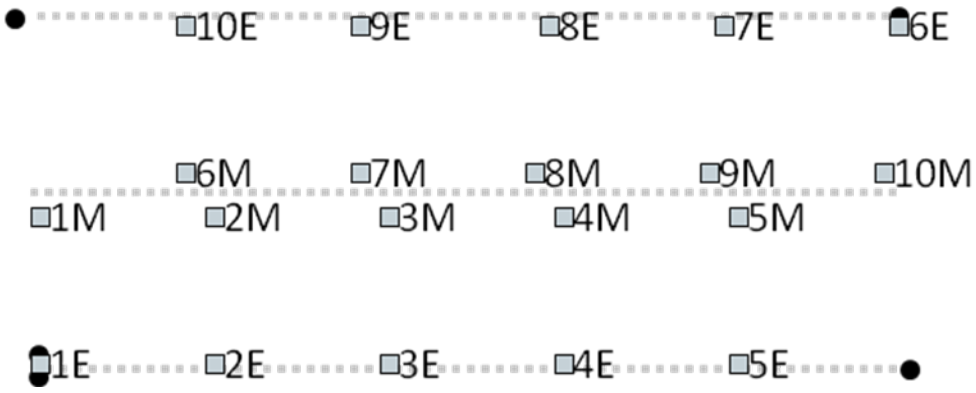
Transect 2

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

75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99

Quadrat Data Sheets:

Twenty quadrats per 0.1ha plot were read in two rounds: 10 quadrats were located along the exterior edges of the plots, and 10 were located along a midline located in the center of the plot along the long axis (see diagram). Quadrats were 1m2. Exterior quadrats were positioned along the edge every 10 m from 0m to 40m on the origin side and likewise on the non origin side (see diagram). Quadrats along the midline were positioned similarly, but were off-set from dead center by 1m, to ensure that each quadrat was separated by at least 2m. We always positioned quadrats so they rested from 0m to 1m, 10m to 11m, and so on. The quadrat sections were read exterior first then midline, like two "U"s positioned inside one another.



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

Quadrats

Exterior

Site	
Plot	
Field Crew	

Date	
Start Time	
End Time	

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

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

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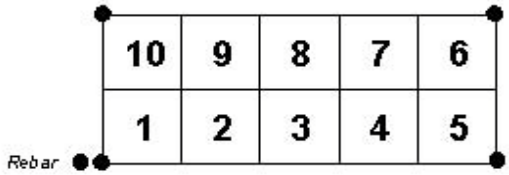

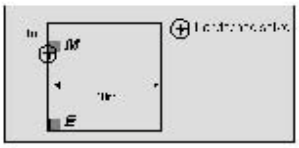

Quadrats

Int (Midline)

M

Site	
Plot	
Field Crew	

Date	
Start Time	
End Time	

Species/Cover Type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Bare										
Rock										
Litter										

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

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