Using Variance Components Analysis to Improve Vegetation Monitoring for the San Diego Multiple Species Conservation Program (MSCP)

Final Report

Natural Community Conservation Planning Program
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EXECUTIVE SUMMARY

Deutschman DH, S Strahm, D Bailey, J Franklin and R Lewison. 2008. Using Variance Components Analysis to Improve Vegetation Monitoring for the San Diego Multiple Species Conservation Program (MSCP). Final Report for Natural Community Conservation Planning Program Local Assistance Grant #P0685105.

Introduction: San Diego's Multiple Species Conservation Program (MSCP) is a comprehensive Habitat Conservation Plan developed with the goal of conserving native vegetation communities and associated species in a nearly 2,500-square-kilometer area in southwestern San Diego County. A biological monitoring program was proposed in 1996, but was never widely adopted. Over the past 10 years, several attempts have been made to develop a comprehensive monitoring program that is supported by the many jurisdictions and stakeholders. The objective of this NCCP Local Assistance Grant project is to evaluate different sampling designs and field protocols for monitoring coastal sage scrub (CSS) and chaparral vegetation communities. This effort addresses one of the two broad goals of the monitoring program, namely monitoring biodiversity and ecosystem function.

Design Objectives: One of our key project 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 in nearly every plot (double sampling). 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.

Sites, Methods and Teams: Eight sites were chosen for this sampling effort in close collaboration with MSCP monitoring partners (academic scientists, agency scientists, regulators, and stakeholders) in January 2007. These sites spanned the MSCP region from the coast to the foothills and from the Mexican border to the MSCP's northern edge. We adapted a field method proposed by Keeley and Fotheringham in 2005 as the foundation of our vegetation sampling protocol. We defined a 0.1 ha plot (50m by 20m, 1000 m^2) which was subdivided into ten 100 m^2 subplots. We estimated cover visually in each of the 10 subplots. Then we implemented two 50m point-intercept transects along the long axes of the plot. In addition, we systematically located and sampled twenty 1m x 1m quadrats (two per subplot). During data analysis, we extracted a 20m by 20m smaller plot from the larger 50m by 20m plot. These smaller plots (400 m^2) contained four 100m^2 subplots, two 20m point intercept transects and eight quadrats. Training of the field crew began in March and data collection began during the first week of April and spanned six weeks into the second week of May.

Results – Cost and Effort: We recorded effort and demonstrated that point intercept transects are faster than visual cover or quadrat methods. We also showed that the time it took to estimate visual cover was highly variable among field teams. In addition, 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, regardless of field protocol used.

Results – Vegetation Communities: In total, 186 species were detected by one or more of the field teams. Of those species, 139 were native species, including 49 native shrubs, 83 native forbs, and 7 native grasses. We encountered 41 non-native species, including 21 forbs and 20 grasses. The most widespread plant species in the CSS were the native shrubs *Eriogonum fasciculatum* and *Artemisia californica,* the native forbs *Dichelostemma capitatum* and *Cryptantha* species, and the non-native species *Bromus madritensis* and species of *Erodium*. In chaparral, we found both *Adenostoma*

fasciculatum and *Xylococcus bicolor* in every plot sampled. The most common non-native plants were *Bromus madritensis* and *Centaurea melitensis*.

The presence and percent cover of the species exhibited substantial variation among sites, among plots within a site, and at finer scales. In addition, the choice of field protocol and the members of the field team influenced the precision of our estimates. We quantified these different sources of variability by estimating their contributions to the overall variance (variance components analysis). The variance components analysis that we present has six sources of variation. Three components (vegetation communities, sites, and plots) describe variability across the landscape. The other three components (method, team, and plot size) describe variability due to our field crew and the protocols they used.

Several sets of variables were analyzed using variance components including species richness, percent cover of the major functional groups (native shrubs, non-native forbs/grasses, and native forbs), and the percent cover of several individual 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*. In contrast, the cover of *Bromus madritensis* was explained by site-to-site variability. For *Hirschfeldia incana* (Mediterranean mustard) the largest component of variation was field team. Despite these differences several strong general conclusions can be reached. Variation among sites and plots within sites is often the largest component of the variance. Variability among teams was small for common and easily identified species (e.g. *Adenostoma fasciculatum*, *Salvia mellifera* , *Brassica nigra* and *Bromus madritensis*) but large for some species that were prone to misidentification (*Gutierrezia* sp., *Hirschfeldia incana*, *Bromus hordeaceus)*. 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.

Conclusions: We demonstrate the usefulness of the variance components analysis for informing decisions about monitoring. In this report, we developed several graphical and numerical summaries of this fairly abstract and mathematically difficult concept. Variance components analysis will be even more useful when we can include estimates of inter-annual variation. We found that site-to-site and plot-to-plot variability were high for most variables examined, suggesting that more sites and more plots within sites are needed to monitor shrub communities in the MSCP. However, smaller plots and rapid methods are adequate to estimate species abundance for all but the rarest species, and therefore to monitor overall community composition.

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I. INTRODUCTION

San Diego's Multiple Species Conservation Program (MSCP) is a comprehensive Natural Community Conservation Plan (NCCP) and Habitat Conservation Plan (HCP) developed with the goal of conserving native vegetation communities and associated species in a nearly 2,500-square-kilometer area in southwestern San Diego County. The reserve system currently includes over 500 square kilometers of land. Monitoring and management responsibility for this large network of land lies with multiple jurisdictions, particularly the County and City of San Diego, and participating Federal and State agencies such as U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Game (CDFG), and U.S. Geological Survey (USGS).

The MSCP intends to conserve plant and animal communities in southwestern San Diego County through preservation and adaptive management of habitat (Page 1-1, Final MSCP Plan, 1998). The final plan was developed to "*conserve both the diversity and function of this ecosystem.*" The MSCP was also designed to "*conserve specific species*" thereby "*maintaining ecosystem functions and persistence of extant populations of covered species*" (Page 1-5 Final MSCP Plan, (Ogden 1998).

These broad goals are discussed in more detail in Section 6.4 of the final plan (Section: Biological Monitoring and Research). In this section, the MSCP document identified several objectives for biological monitoring. These were to "*document ecological trends; evaluate the effectiveness of management activities; provide new data on species populations and wildlife movements; and evaluate the indirect impacts of land uses and construction*. " (Page 6-13). Section 6.4 of the final MSCP plan also listed potential research topics including "*basic inventories of biodiversity, habitat value, and covered species populations*."

The wildlife agencies (USFWS and CDFG) are responsible for "*coordinating the monitoring program, analyzing data, and providing information and technical assistance*" (Page 6-12). The initial Biological Monitoring Plan (BMP) for the Multiple Species Conservation Program (MSCP) in San Diego was developed by Ogden Environmental and Energy Services in 1996 (under contract with the City of San Diego, CDFG and USFWS). The BMP predates the final MSCP document and is explicitly referenced in the final (1998) MSCP document (Page 6-12).

The proposed monitoring plan in the BMP addressed the stated goal of "*detecting changes in habitat quality and population trends in those habitats and plant and animal species considered covered by the MSCP*." (Page 1-1). The BMP proposed to meet this overall goal by achieving six specific objectives (Table 1). The objectives included documenting the establishment of the preserve itself (acreage), estimating habitat value, measuring species dispersal and movement, as well as solving long-term funding and enforcement issues. For the intent of this report, we focused largely on objective 2: "*Document changes in preserved habitats… of covered species*" (Ogden 1996).

Objectives of the Biological Monitoring Plan for the Multiple Species Conservation Program (1996)

1. "Document the protection of habitats and covered species. (e.g. acreage)"
2. "Document changes in preserved habitats or preserved populations of covered species. This will be accomplished through monitoring temporary habitat changes, habitat value, and covered species."
3. "Describe new biological data collected, such as new species sightings and information on wildlife movements and corridors. Although not the focus of the monitoring program, collection of new biological data will occur…"
4. "Evaluate impacts of land uses and construction activities in and adjacent to the preserve. Impact evaluation will occur on both a landscape level (tracking permanent habitat losses) and at a local level (monitoring habitat value)."
5. "Evaluate management activities and enforcement difficulties. An assessment of the effectiveness of specific management and enforcement activities will occur through the habitat monitoring, corridor monitoring, and covered species monitoring components of this program."
6. "Evaluate funding needs and the ability to accomplish resource management goals. An assessment of funding needs and management goals will be provided every three years, as specified in the reporting program. Accomplishment of management goals will be measured against specific habitat and species conservation targets set forth in subarea plans and implementing agreements."

Table 1: Six specific objectives originally listed in the BMP in order to achieve the stated goal of detecting changes in habitat quality and population trends in those habitats, and plant and animal species considered covered by the MSCP.

MSCP – Previous Monitoring Efforts

In the ten years following the development of the initial BMP much new research has been published about the design of biological and resource monitoring programs (Figure 1). In addition, more information has been collected on some of the 80+ species covered by the MSCP. In 2001, the California Department of Fish and Game and the City of San Diego contracted with the Conservation Biology Institute (CBI) to review and refine the MSCP monitoring protocols from the initial Biological Monitoring Plan. In their report, CBI emphasized that refining the protocols would require analysis of existing monitoring data, additional testing of protocols, and evaluation of the types of monitoring being implemented at individual reserves within the MSCP network (CBI 2001). They did not believe they had adequate data to recommend updated protocols at that time. Neither the original monitoring plan nor CBI's revisions have been widely implemented, and there is still debate about how to meet the monitoring goals of the MSCP.

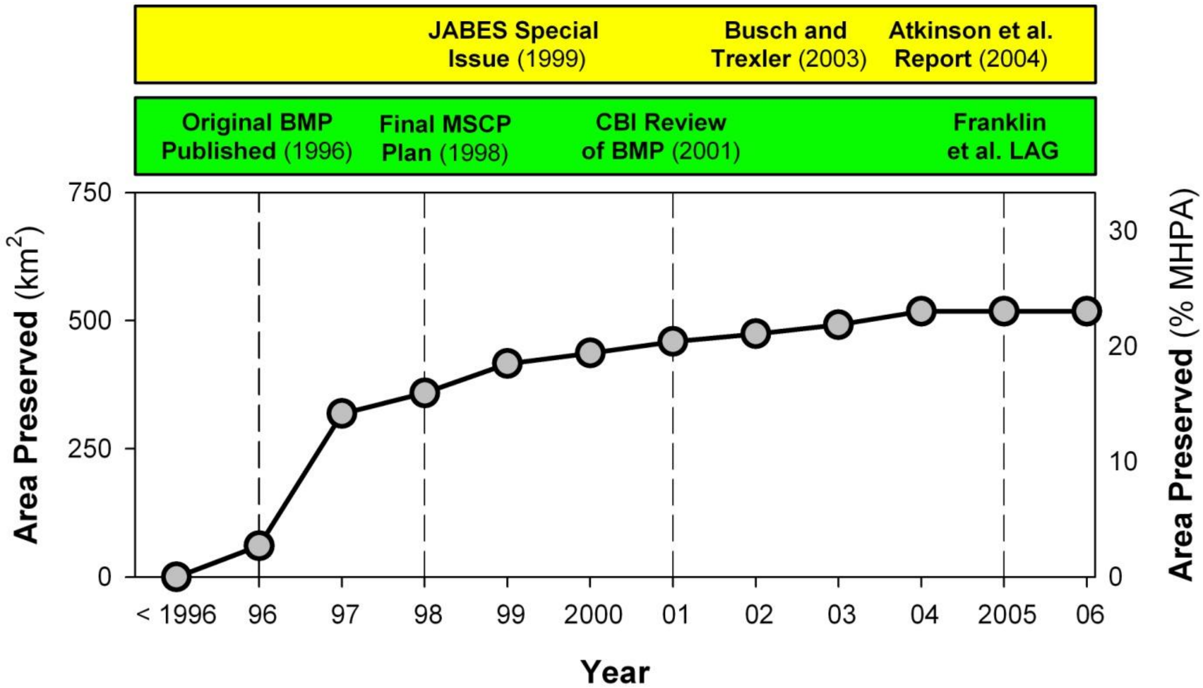

Figure 1: Timeline of MSCP land acquisition (gray circles), MSCP monitoring documents (green band), and some key publications about the design and analysis of monitoring programs (yellow band). The Y axis represents the acreage of land included inside the MSCP preserved lands.

In 2005, the California Department of Fish and Game awarded a local assistance grant to San Diego State University (PI Dr. Janet Franklin, Agreement #P0450009). This project was to review the existing San Diego MSCP BMP and its implementation and assess the status of the program relative to the critical steps for monitoring program development identified by Atkinson et al. (2004; see Figure 2). They evaluated the current status of the monitoring program (Report 1), developed a prioritization method for covered species (Report 2) and vegetation communities (Report 3), developed several conceptual models for key species and communities (Report 4), and evaluated sampling protocols and monitoring schemes (Report 5) (Hierl et al. 2005, Franklin et al. 2006, Regan et al. 2006, Deutschman et al. 2007, Hierl et al. 2007).

This work has also led to the publication of several peer-reviewed articles including “Assessing and prioritizing ecological communities for monitoring in a regional habitat conservation plan” published in Environmental Management (Hierl et al. 2008) and “Species prioritization for monitoring and management in regional multiple species conservation plans” published in Diversity and Distributions (Regan et al. 2008).

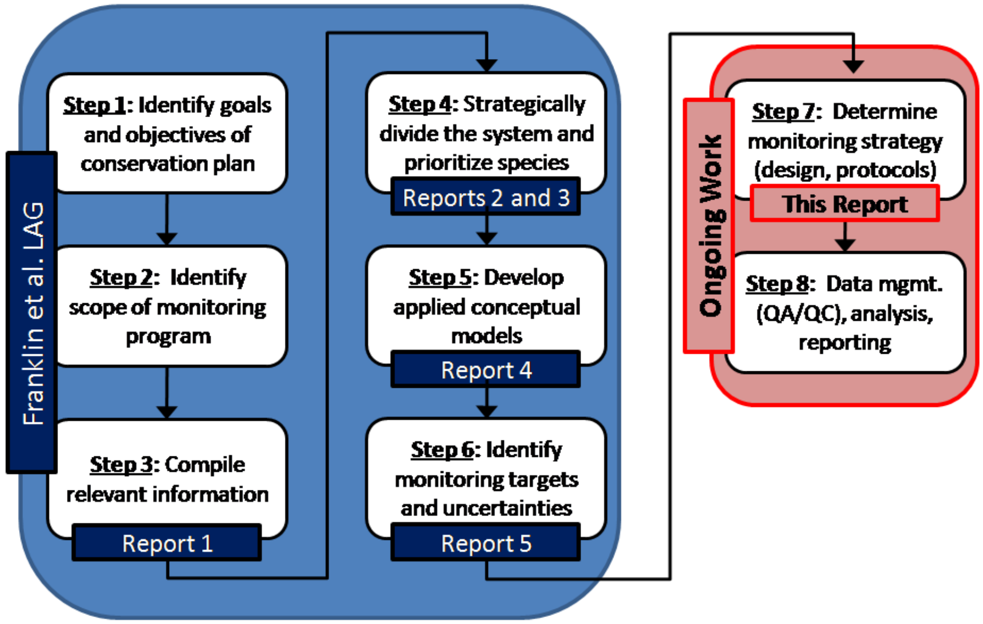

Figure 2: Stepwise evaluation of the BMP based on the Atkinson et al. (2004) technical report. Steps 3 through 6 were implemented as part of the previous LAG to Franklin et al. (#P0450009). This report focuses on Step 7, determining monitoring strategy.

Goals of this Project

The objective of this Natural Community Conservation Planning (NCCP) Local Assistance Grant project is to evaluate the accuracy of different sampling designs and field protocols for monitoring Coastal Sage Scrub (CSS) and chaparral vegetation communities. This effort addresses the first of these two broad goals (diversity and function of ecosystem through management of habitat) and will resolve many of the questions raised in the 2001 CBI report and subsequent discussions among scientists and managers. This project builds on the Franklin, Regan and Deutschman LAG project (Agreement #P0450009) and complements two other recently awarded LAG grants. These projects include a review of the rare plant monitoring program for the MSCP by McEachern et al. (Agreement # P0350011) and a review of the animal monitoring portion of the MSCP by the USFWS (Agreement #P0585100).

We proposed to monitor CSS and chaparral vegetation communities on several reserves throughout the MSCP. CSS and chaparral habitats are the dominant vegetation communities within the MSCP, comprising 35.9% and 43.1% of the non-urban lands, respectively. These communities also contain the highest number of at-risk animal and plant species (Reports 2 and 3, 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 original goals of the MSCP and the conceptual model that we developed during the previous project (Report 4, Hierl et al. 2007). We 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 proposed to analyze data from this first field season using a variance components approach (Report 5, Deutschman 2007). The analysis partitioned observed variance into spatial heterogeneity (site, plot, and subplot scales), protocol differences, and differences among field teams.

II. Field Sampling Design

Eight sites were chosen for this sampling effort in close collaboration with the MSCP monitoring partners at the January 2007 workshop of the Franklin et al. LAG project. The sites are distributed throughout the planning region spanning 40 miles North to South, from the border with Mexico to the northernmost extent of the MSCP planning area and 25 miles East to West, from sites located in view of the beach to sites located in the foothills at the eastern extreme of the planning area (Figure 3). The elevation at sites ranges from very near sea level (30m) to 500m. Sites also span a gradient of fragmentation and human impact, including small sites surrounded by urbanization to large sites located in large patches of open space. Access and safety were also important factors in site selection.

Each site is described below. Additional information, such as plot location and elevation and site maps are available in Appendix 4.

Coastal Sage Scrub Sites

Coastal sage scrub is a Mediterranean vegetation type comprised of low, soft-woody subshrubs to about 1 meter high, many of which are facultative drought-deciduous plants. Dominant shrub species in this vegetation type may vary, depending on local site factors and levels of disturbance. Dominants 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) (Westman 1981). Other, less frequent, constituents of this community include *Rhamnus crocea* (spiny redberry), *Lotus scoparius* (deerweed), and *Baccharis sarothroides* (broom baccharis). Nomenclature follows the San Diego Natural History Museum's vascular plant checklist for San Diego county (Rebman and Simpson 2006).

Blue Sky Ecological Reserve (BS)

BSER is located in the City of Poway, off Espola Road. The reserve contains 700 acres of CSS and riparian habitats. BSER is managed by the California Department of Fish and Game and the City of Poway, and is supported by the nonprofit Friends of Blue Sky Canyon and the Blue Sky Community Foundation. BSER is open to the public, receiving about 40,000 visitors each year. BSER is bordered by permanent open space except for the urban area to the west. Lake Poway is to the south, Mt. Woodson open-space area is to the east, and Lake Ramona is to the north.

Lake Hodges (LH)

Lake Hodges is a large, man-made lake owned by the City of San Diego, and part of a larger, regional water storage system administered by the San Diego County Water Authority (SDCWA). In addition to water storage, the lake and the uplands surrounding it are open to the public and used for a large number of recreational activities, ranging from fishing and bird watching to hiking, jogging and mountain biking. The lake is located just south of Escondido and winds its way through the hills near Rancho Bernardo, Rancho Santa Fe, Del Dios, Lake Hodges Hills and Bernardo Mountain.

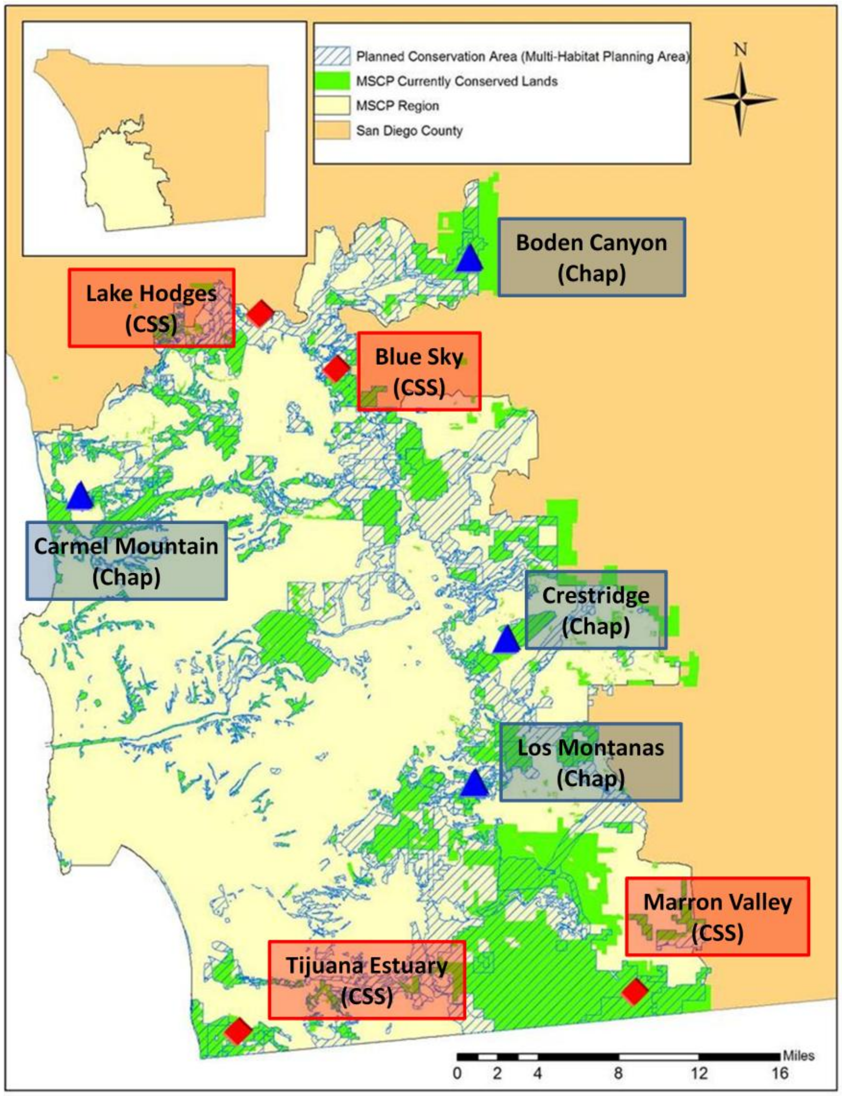

Figure 3: Site Locations inside the MSCP. CSS sites (red diamonds) from North to South: Lake Hodges, Blue Sky Ecological Reserve, Tijuana River (west most), Marron Valley (east most). Chaparral sites (blue triangles) from North to South: Boden Canyon, Carmel Mountain, Crestridge, Los Montanas.

<u>Marron Valley (MV)</u>

Marron Valley is located in southeastern San Diego County along the border with Mexico. The valley is approximately 25 miles inland, and consists of approximately 2,640 acres set aside in 1999 as part of the City of San Diego MSCP cornerstone lands (CBI, 2001). The property is owned by Metropolitan Water District and is not open to the public. The property is patrolled heavily by US Border Patrol, and access can be difficult depending on the activities and enforcement efforts going on in the valley. Field teams visited Marron Valley twice before abandoning the site for the year, after encountering potentially threatening situations during each trip.

Marron Valley provides habitat to a number of species covered in the MSCP, including the Quino Checkerspot Butterfly (*Euphydryas editha quino*), with abundant populations of *Plantago erecta*, the larva's food source. Although *P. erecta* is found in the interspaces of CSS, we intentionally avoided monitoring areas with this plant, as it is unclear what the effect of our methods could be on the larvae and its host plant.

Tijuana River Valley Regional Park (TJ)

TJRV is a 1698-acre park owned and operated by the County of San Diego. The park is open to the public and has a number of different regions designated for certain activities, for example, sports fields, riding trails, undeveloped areas and a community garden. The areas that we visited included the dense CSS located just behind the ranger station, and the top and side of Goat Mesa (just along the border). These locations allowed us to sample dense Diegan CSS, open maritime CSS, and extremely degraded CSS, all at one site.

Chaparral Sites

Chaparral is widely distributed throughout California on dry slopes and ridges at low and medium elevations. It is typically composed of broad-leaved, sclerophyllous shrubs, although species composition varies considerably with location. The plants of this community have developed the ability to survive recurrent fires by producing seeds that require a fire-related cue to stimulate germination and/or by stump sprouting after being burned. Species of the following genera are characteristic in chaparral associations: *Adenostoma, Arctostaphylos, Ceanothus, Cercocarpus, Heteromeles*, shrubby *Quercus*, and *Rhamnus*.

Boden Canyon Ecological Reserve (BC)

BCER is a 2000-acre reserve located east of Escondido and West of Ramona on SR 78. CDFG owns just over half (1,211 acres) with the remainder owned by the City and County of San Diego. The San Diego MSCP identifies Boden Canyon as a core resource area and important biological linkage to areas outside the MSCP area. Additionally, Boden Canyon is also located within the Focused Planning Area for the San Dieguito River Valley Regional Open Space Park. Public access to BCER is limited to non-motorized activities only.

Carmel Mountain and Del Mar Mesa Preserve (CM)

The Carmel Mountain and Del Mar Mesa Preserve is located adjacent to the larger Los Penasquitos Canyon Preserve, just east of I-5 and south of Highway 56, between Carmel Creek and Carmel Country roads. It is owned and operated by the City of San Diego, and provides important linkages to the Los Penasquitos Canyon and Los Penasquitos Lagoon emptying at Torrey Pines State Beach. Trails throughout the preserve are open to the public for non-motorized vehicle recreation. Some areas are restricted due to the presence of vernal pools and other plant and animal species covered by the MSCP. The preserve contains sections of old growth chaparral, as well as early and mid-successional chaparral.

Crestridge Ecological Reserve (CR)

Crestridge is a 2,638 acre ecological reserve administered by CDFG. The property was acquired and is owned in cooperation with The Nature Conservancy (TNC) and the Crestridge Conservation Bank (CBI 2002). The reserve is located approximately 3 miles east of the City of El Cajon, and due north of the community of Crest. It is open to the public for hiking and other non-motorized recreational activities.

Los Montanas (LM)

The Los Montanas site is located inside the San Diego National Wildlife Reserve, Otay-Sweetwater Unit and is part of the San Diego MSCP (USFWS 2006). The land is administered by the USFWS. The area gets its name from the Los Montanas Golf Course project, which was not completed, but still leaves a visible scar on the landscape inside this region of the refuge. The area is located adjacent to SR-94, just west of Jamul.

Field Protocols

In 2005 Keeley and Fotheringham published a study describing the relationship between plot size, shape, and dispersion and the number of plant species observed. Their study used three different sampling designs: (1) the Whittaker design, (2) Stohlgren's modified Whittaker design and the (3) Keeley design. In their study Keeley plots performed as well or better than the other published methods for capturing species richness in California shrublands. For the purposes of this study, we adopted Keeley plots as the foundation of our sampling design. Our only modification was the addition of two transects on the long sides of the plots (Figure 4).

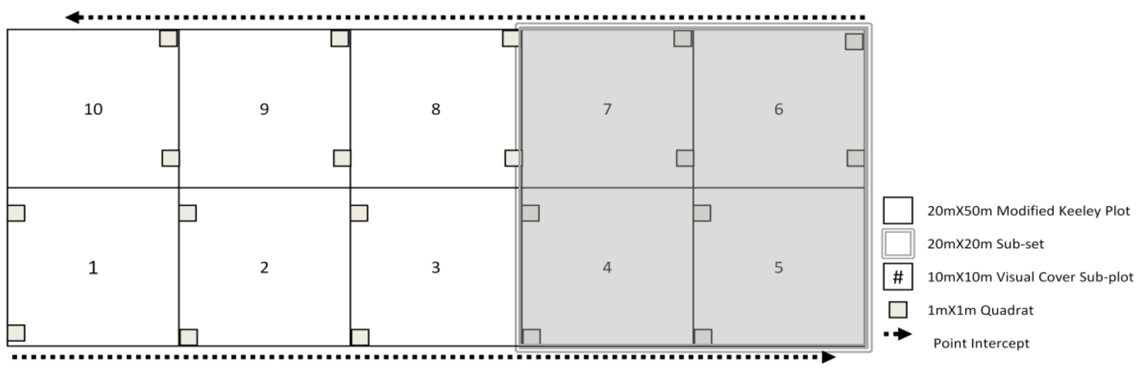

Figure 4 Modified Keeley Plot. Each plot measured 20m X 50m (0.1 ha). This plot was divided into ten 10x10m subplots, each with two 1x1m quadrats located on the starting end in the exterior and interior corners. Two 50m long point intercept transects were added to the Keeley plot in order to offer three 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 .04 ha (20m x 20m) in order to compare the effects of plot size.

This design allowed for the direct comparison of three different sampling protocols in all sites in two vegetation communities. The $10m^2$ sub-plots were evaluated for absolute cover of plant species using a visual estimation (relevé) technique. The transects were read using a standard point-intercept method, including all vegetation touching a vertical point every 1 meter as well as ground cover. The $1m^2$ quadrats were read for absolute cover of plant species using a technique similar to the visual estimation, but applied on a finer scale.

Plots were located subjectively (purposively), following Stohlgren et al. (1995, 1998) as cited by Keeley and Fotheringham (2005). Plot locations were selected to fit within homogeneous stands, in terms of vegetation community, structure and mix of bare ground and cover. If obvious environmental gradients were present (such as a slope), the long axis was placed parallel to them. We chose plots to span the natural variability of each site. For example, while we would not include stands of different ages in a single plot, we did try to locate plots within sites in differently aged stands. Another key feature influencing the selection of plot locations was access. Due to the need for multiple sampling of the same plots by different teams, they needed to be easy to reach and to find.

Figure 5. Implementation of the three protocols: visual cover, point-intercept, and quadrats.

Visual Cover (ten 0.01ha visual cover estimates)

Each 20x50m plot was subdivided into ten $100m^2$ (10m by 10m) subplots. We utilized a cover estimation technique similar to those described in the California Native Plant Society's (CNPS) Relevé and Rapid Assessment techniques. The main goal of these methods is to rapidly estimate approximate plant cover, not measure it precisely (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 to estimate the percent cover of each species visible from their vantage point (Figure 5, left panel). We used absolute cover, to allow for overlap of species and functional groups and different canopy heights (therefore teams were allowed to record more than 100% cover).

The main differences between our protocol and the Relevé protocol were: our sub-plots had a predetermined shape and dimension (10m x 10m); we generally stood just inside the sub-plots to make our estimations (instead of from a distance); and we did not utilize cover categories, but arrived at a team consensus for the percent absolute cover of each species. Cover categories were to be explored *post-hoc* during data processing.

We offered our field crew the same general suite of guidelines provided in the Relevé protocol to help them make estimations. For example, we suggested dividing sub-plots into quadrants then estimating cover based on the size of those quadrants, or aggregating species of the same type together in their mind's eye and using an imaginary $1m^2$ quadrat as a benchmark for 1 percent cover. Field crews were directed to stand directly across from 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)

Of the many transect techniques available, we decided on point intercept transects because they minimize decision making by the field teams. During a point intercept transect the observer drops a pin or dowel perpendicular to the meter tape at a predetermined distance (Figure 5 middle panel). Each species and ground cover the dowel touches is recorded for that point (note that multiple species at one point can yield absolute cover estimates over 100%). Absolute cover is calculated 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 recorded ground cover, even when overgrown by canopy plants.

The point intercept transect method was chosen over other transect methods for a number of reasons. The advantages and disadvantages of this method are well described. 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).

Quadrats (twenty $1m^2$ 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 4). The interior quadrats on the origin side of the plots (sub plots 1-5, Figure 4) 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 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 aggregating 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 more than 100%. This technique did not require an estimation of groundcover.

The primary difference between visual cover and quadrat protocols was that a more thorough effort was made to find all the species in each quadrat. In general, quadrat techniques take more time than visual cover or transect techniques because of the importance placed on detecting every species present (Figure 5, right panel).

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 sites, most plots at each site, and using all field protocols (Figure 6).

Our original plan was to use a factorial design, where all teams would visit 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 sites and plots such that each site and plot would be sampled at least twice.

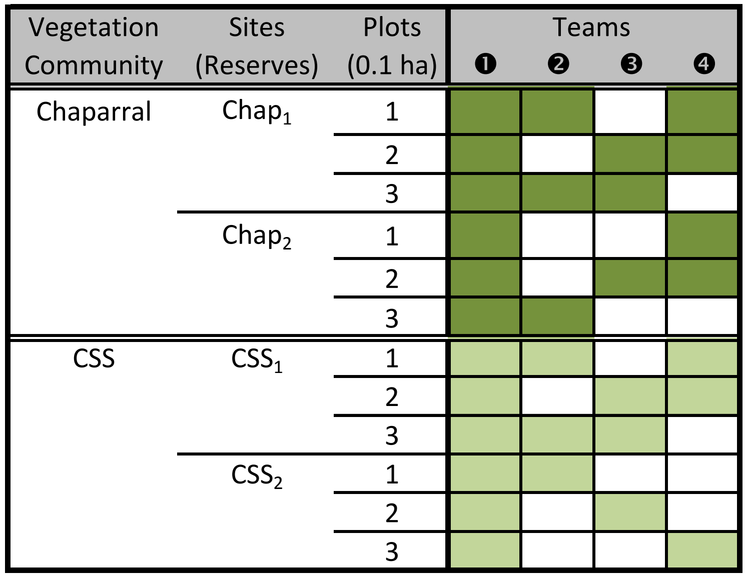

Figure 6. Schematic of the partial-factorial, multiple-observer design. Shaded boxes indicate that a team visited a plot. Typically, three teams visited each plot, with team 1 visiting all plots. All teams implemented all three methods, visual cover, point intercept transects, and quadrats.

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 estimation, 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 1m^2 quadrats along the sides and in the center of the plot, and then estimated species cover.

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 ranked, albeit somewhat arbitrarily, based on previous field experience and university courses completed in the areas of botany and field ecology.

III. Field Work Performed

Preparation for field work started several months before data collection. Prior to making site visits, access permits were acquired, 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. A master schedule was created to share available 4-WD vehicles and to assure that field teams visited each site within a short time period.

Training

All field crews were trained by the expert team. Additional training was not practical 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 (unknown) 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 (included in the MSCP, but not formally sampled this year).

Teams practiced navigating with the global positioning system (GPS) units, performing all three protocols, 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 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 carried a quick-reference guide to 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.

Some additional volunteers who contributed to the data collection efforts did not attend this first training session. Most were experienced biologists who had used similar protocols in southern California and had previous field experience with the sites being sampled.

Site Visits

All visits to a single site were scheduled to occur within a period of two weeks following the first data collection trip to that site (Figure 7). We designed this schedule to assure that differences in metrics such as diversity and cover would not be confounded by seasonal changes in the state of the vegetation (species abundance, presence of flowers or fruits, and so forth). Fieldwork began during the first week of April and spanned six weeks into the second week of May. Ideally, CSS sites, and recently burned chaparral sites, would have been scheduled first this year due to the short growing season, and the higher probability of encountering annuals at these sites. Although this factor did help guide the schedule, the time required to secure access permits was often a limiting factor for when a site could be sampled.

			April				May		
Veg Type	Site	Plot	1	2	3	4	1	2	Visits
Chap	LM	1	■	■■■■					5
	LM	2		■■■					3
	LM	3	■					■	2
	CM	1		■	■■		■		4
	CM	2		■	■■		■		4
	BC	1				■■			2
	BC	2				■■	■		3
	BC	3				■■■	■		4
	CR	1					■■■		3
	CR	2					■■	■	3
	CR	3					■■■		3
CSS	MV	1	■						1
	MV	2	■						1
	MV	3	■						1
	LH	1	■■	■■		■■			6
	LH	2	■	■■					3
	LH	3	■	■					2
	TJ	1			■	■			2
	TJ	2			■	■■			3
	TJ	3				■■			2
	BS	1					■■		2
	BS	2				■	■■		3
	BS	3				■	■		2

Figure 7. Site visits by all teams. Typically, each site was visited by 2 or 3 teams within a 2-week period. Chaparral sites were: Los Montanas (LM), Carmel Mountain (CM), Boden Canyon (BC) and Crestridge (CR). CSS sites were Marron Valley (MV), Lake Hodges (LH), Tijuana River Valley Regional Park (TJ), and Blue Sky (BS).

Most plots were visited 2-3 times (Figure 7), with the exception of Marron Valley. At Marron Valley, the initial plot set-up trip went without incident; however field teams encountered potentially threatening situations on the next two visits. Water district authorities were unable to estimate when it would be safe to return to the valley. As a result, the Marron Valley site was abandoned, with only one complete visit (by the expert team). This site may be revisited next year, with additional safety precautions in place.

Effort

Time spent in the field is an important constraint to consider when designing a vegetation monitoring program which must be completed in a finite 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 (as we did) 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 San Diego State University (SDSU) and traveled to the field site. 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. Counter to our initial assumptions, point intercept transects were the fastest protocol; rather than visual cover which is specifically designed for speed. Travel time between plots is not related to data collection protocol, and always took up a significant amount of time (Figure-8).

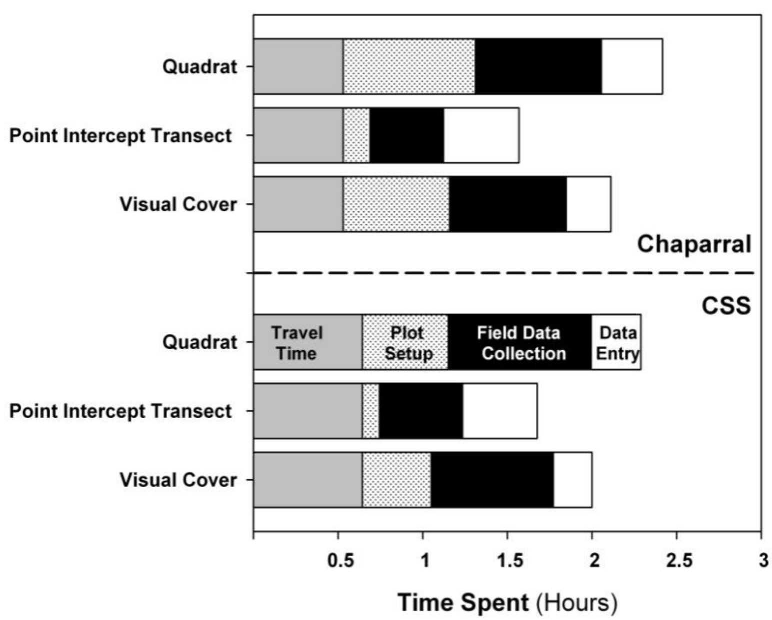

Figure 8. Average time (hours) spent on three protocols (visual cover, point intercept transects, and quadrats) for each team. Visual cover and quadrats were more time consuming in the field than point intercept transects. Point intercept transects were more time consuming to enter and validate. Despite 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 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.

Field Data Collection

We found point intercept was the fastest field protocol over all (Figure 9). For each 0.1ha plot, data collection varied between 27 minutes (average for point intercept) and three quarters of an hour (both visual cover and quadrats; Figure 9).

Interestingly, volunteer teams, 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 (30 minutes vs. 50 minutes) and visual cover (65 minutes vs. 43 minutes) much slower 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 instead of standing off at the edges. Strikingly, the point intercept method took both SDSU teams and volunteer teams an average of 27 minutes, which indicates that this methodology is fairly predictable in terms of effort/time. 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 due to 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 SDSU teams.

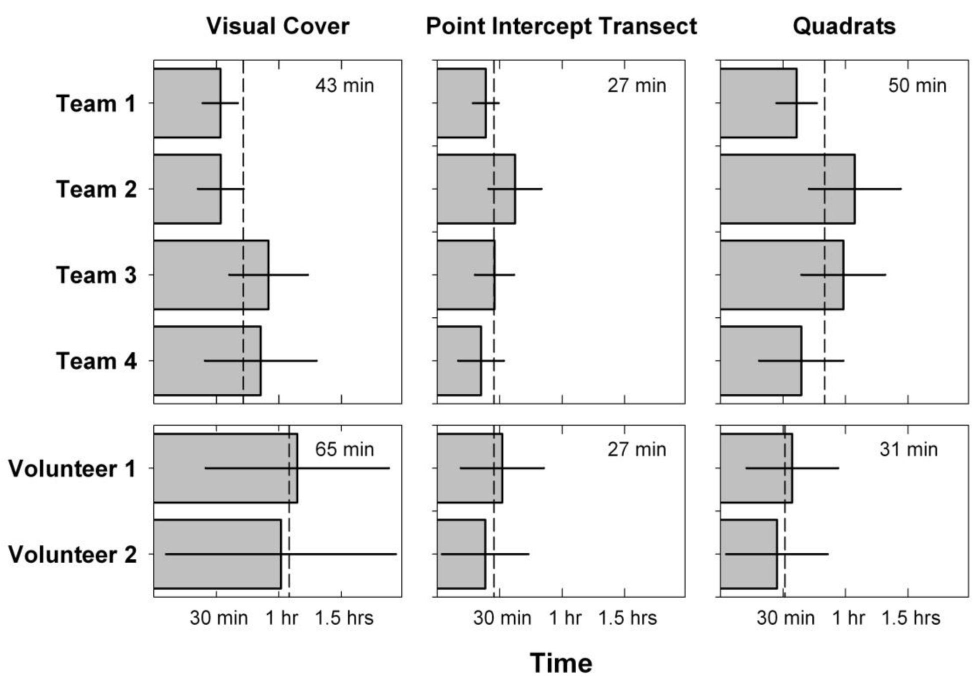

Figure 9. Average time spent collecting data in the field for three protocols (visual cover, point intercept transects, and quadrats) for each field team. Point intercept transects were quickest and the least variable among teams.

Comparison of Effort (Cost)

Visual cover was, on average, only slightly faster for SDSU teams (43 minutes vs 50 minutes, Figure 9) than quadrat measurements, and much slower than transect point-intercepts (27 minutes). The unexpected slowness of the visual cover protocol is due to two factors, setup time and data collection time (Figure 8). 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. Presumably, during a relevé rapid assessment protocol, squaring and locating plots would not be an issue (CNPS, 2004). Data collection was also slow because of the decision making process that teams went through before recording percent cover.

As expected, quadrats were the slowest (50 minutes, Figure 9) protocol tested by SDSU teams. Reading took longer because there were two quadrats in each subplot. Although the quadrats are small ($1m^2$) the protocol requires that teams search for hidden, cryptic and uncommon species, potentially obscured by larger plants.

Point intercept transects were the fastest method. This was due to rapid set-up time and 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 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, any other plant is not considered. This process eliminates many of the judgment calls that may make visual cover and quadrats challenging.

IV. Vegetation Communities

CSS and chaparral communities were sampled separately at different sites throughout the MSCP. At sites where CSS and chaparral were mixed, transect locations were sited to reflect the dominant vegetation type. In this section we will first address how the various monitoring protocols quantified species richness throughout our sites and plots. We will then focus on how the different protocols quantified common species in the CSS and chaparral in terms of percent cover.

Species Richness

We recorded a total of 186 species throughout the county in 2007 based on species detections by all teams combined (Table 2). Of those species, 139 were native species, including 49 native shrubs, 83 native forbs, and 7 native grasses. We identified a total of 41 non-native species, including 21 forbs and 20 grasses. *Eriogonum fasciculatum* was the most prevalent native shrub, occurring in 91% of all plots throughout the county (21 of 23), in both CSS and some chaparral sites. *Dichelostemma capitatum* (blue dicks) was the most prevalent native forb, appearing in 57% of sampled plots. *Nassella* sp. (needle grasses) was the most prevalent native grass, occurring in 35% of all sampled plots. The most prevalent non-native forb was *Erodium* sp. (stork's bill) which was encountered at 83% of our plots. *Bromus madritensis (red brome*) was the most prevalent non-native grass, found at all but one of the plots we sampled (96%).

We found a total of 117 species across the four CSS sites. Of these, 83 (71%) were native and 29 (25%) were non-native grasses and forbs. We also encountered 5 "other" species (mostly vines). The most widespread native shrubs were *Eriogonum fasciculatum* and *Artemisia californica* occurring in

100% and 83% of CSS plots, respectively. The most widespread CSS forbs included *Dichelostemma capitatum* and *Cryptantha* species. The most widespread non-natives included *Bromus madritensis* (grass) and *Erodium* sp. (forb), which were detected at every CSS plot we sampled.

Species Richness	All Species	Native Shrub	Native Forb	Native Grass	Non-Native Forb	Non-Native Grass	Other Species
All Sites	176	49	83	7	21	20	6
CSS	117	31	48	4	19	10	5
Blue Sky	56	9	24	1	12	7	3
Lake Hodges	57	8	27	3	11	8	0
Marron Valley	39	16	11	2	2	5	3
TJER	38	17	7	0	8	5	1
Chaparral	132	35	67	6	14	6	4
Boden Canyon	61	15	24	3	12	6	1
Carmel Mtn	28	10	11	2	4	1	0
Crestridge	85	24	38	3	11	5	4
Los Montanas	48	14	23	3	5	2	1

Table 2: Species richness across the MSCP, 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 included a tree and several vines.

In chaparral, we found a total of 132 species, including 108 (82%) natives, 20 (15%) non-natives and 4 other species. Both *Adenostoma fasciculatum* (chamise) and *Xylococcus bicolor* (mission manzanita) were found on every plot sampled. Of the 108 native species, 67 of the species were native forbs. *Dichelostemma capitatum* was again the most common forb, but was only found at 64% (7 of 11) of chaparral plots sampled. *Bromus madritensis* was the most widely distributed non-native grass, occurring in 91% (10 of 11) of plots sampled. *Centaurea melitensis* (tocolote) was the most widespread non-native forb, occurring in 73% (8 of 11) of chaparral plots.

Species Detections

The number of species detected (richness) varied by team. Although we were only able to rank order the experience level of our field teams, it seemed clear that more experienced field teams detected more species. Our most experienced “expert” team (Team 1) detected 130 species (Table 3). Two of the other teams detected 95 species (Team 2, intermediate level) and 67 species (Team 3, less experienced).

		Experience Level		
	All Teams	*Most*		*Least*
Species Richness	**Combined**	**Team 1**	**Team 2**	**Team 3**
All Sites	186	130	95	67
CSS	117	92	61	43
Blue Sky	56	50	32	16
Lake Hodges	57	35	23	23
Marron Valley	39	39	-	-
TJER	38	31	27	14
Chaparral	132	96	66	45
Boden Canyon	61	51	28	19
Carmel Mtn	28	17	14	9
Crestridge	85	70	46	29
Los Montanas	48	23	20	17

Table 3: Species richness by team shown for three of the teams. Species totals for the MSCP, within vegetation communities, and at each site for each team. Experience level was approximated by the years of field experience in San Diego County.

Regardless of experience, no single team detected all 186 species which were reported. Our most experienced team failed to detect 46 species identified by the other two teams. The less experienced teams had substantially smaller species lists. 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.

Dominant species in CSS

Dominant shrub species in this vegetation type vary, depending on local site factors and levels of disturbance. Characteristic dominants include *Artemisia californica* (California sagebrush), *Eriogonum fasciculatum* ssp. f*asciculatum (*flat-top buckwheat), *Malosma laurina* (laurel sumac), *Salvia apiana* (white sage), and *Salvia mellifera* (black sage).

CSS was largely dominated by *Eriogonum fasciculatum* and *Artemisia californica* (Figure 10) throughout the county. The next three most prevalent species were non-native species, including *Erodium* sp., *Bromus madritensis*, and *Centauria melitensis* . Other dominant natives found in CSS included: *Lotus scoparius*, *Salvia apiana*, *Malosma laurina* , and *Encelia californica* (bush sunflower, Figure 10).

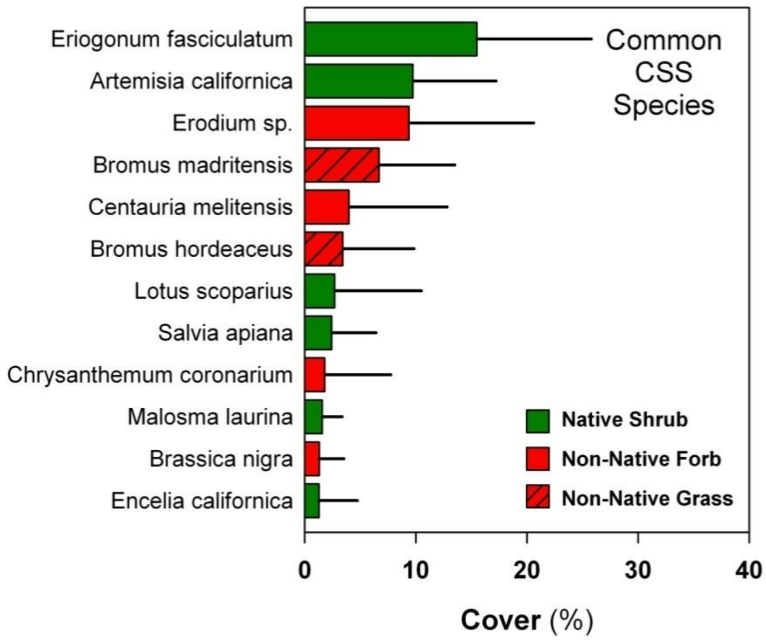

Figure 10. Dominant CSS species. Bars represent average cover (+/- 1 SD) for each species. Bar color and fill denote habit (shrub, forb, grass) and origin (native, non-native).

As expected, individual plots were often dominated by different species, even within a single site. For example, at Tijuana River Valley Regional Park, *Eriogonum fasciculatum* cover was around 40% at plot 1, but barely present at plots 2 and 3 (Figure 11). Even at Blue Sky Ecological Reserve, where *Eriogonum fasciculatum* was a significant component in the cover of all plots, cover values ranged from as low as 15% to as high as 40%. Like *Eriogonum fasciculatum*, *Artemisia californica* cover had similar average cover throughout each site, but often varied dramatically among plots within a site. High plot-to-plot variability for single species was common for non-native species such as *Erodium* sp. (Figure 11) which varied significantly among sites with much higher cover values at Lake Hodges and Marron Valley than at Blue Sky or Tijuana River Valley Regional Park.

Dominant Species in Chaparral

Adenostoma fasciculatum and *Xylococcus bicolor* were the dominant chaparral species in the MSCP preserves that were sampled (Figure 12). It is important to note that we did not work in the more montane regions of San Diego (outside of the MSCP) which may have a significantly different composition, including *Arctostaphylos* and *Ceanothus* species. In addition to *Adenostoma fasciculatum* and *Xylococcus bicolor*, several species of shrubs common in CSS were found in chaparral, including *Eriogonum fasciculatum*, *Malosma laurina*, and *Artemisia californica*. Chaparral had lower cover of non-native grasses and forbs than CSS. *Bromus madritensis* and *Centauria melitensis* were the only two non-native species found to have significant cover values throughout the county.

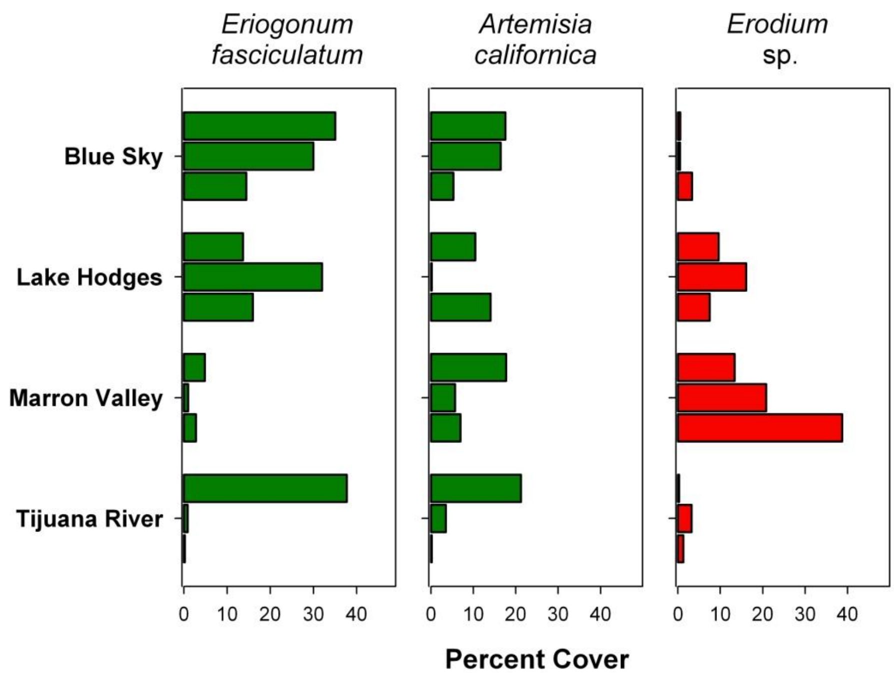

Figure 11. Dominant CSS species at three plots within each site. Bar color and fill denote habit (shrub, forb, grass) and origin (native, non-native).

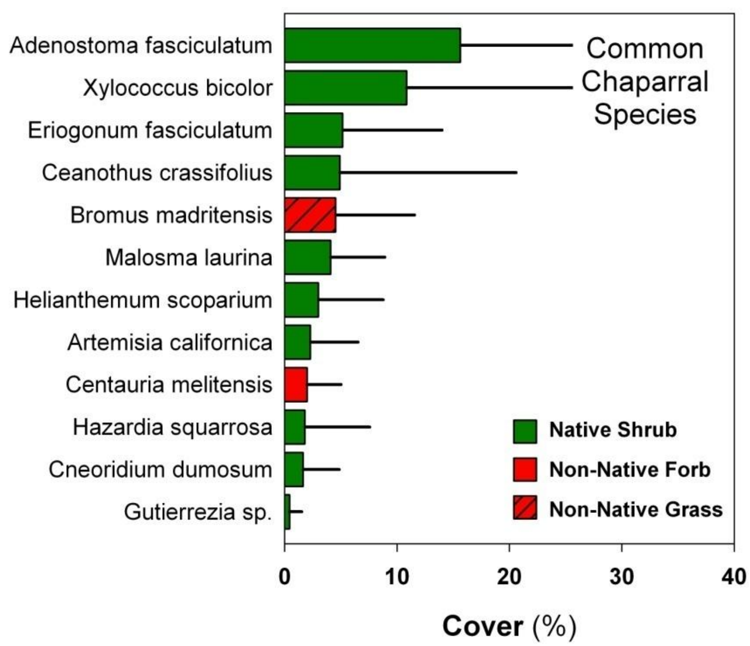

Figure 12. Dominant chaparral species. Bars represent average cover (+/- 1 SD) for each species. Bar color and fill denote habit (shrub, forb, grass) and origin (native, non-native).

As observed in CSS, individual plots were often dominated by different species, even at the same site. For example, *Xylococcus bicolor* cover varied from nearly 0 to over 50% at the three plots located at Los Montanas (Figure 13). In addition, *Bromus madritensis* was common on one plot at Boden Canyon and barely present at the other two plots.

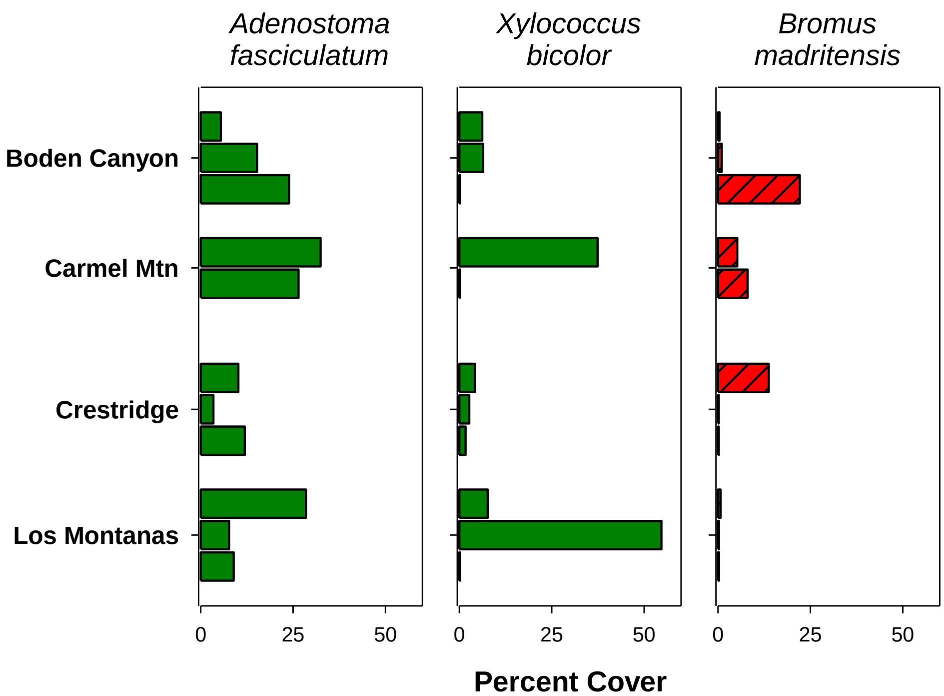

Figure 13. Dominant chaparral species at three plots within each site. Bar color and fill denote the habit (shrub, forb, grass) and origin (native, non-native) (see caption Figure 12). Please note that only two plots were visited at Carmel Mountain.

Spatial Variability in CSS and Chaparral

The patterns presented for the common species demonstrate that cover varies at several scales. For example, *Adenostoma fasciculatum* and *Xylococcus bicolor* occur exclusively in the chaparral while *Eriogonum fasciculatum* and *Artemisia californica* occur in the both CSS and chaparral vegetation communities. There were also different patterns of cover both at the site and plot levels. For example, the cover of *Erodium* sp. was high on all three plots at Marron Valley and moderately high on all three plots at Lake Hodges but was low at the other two CSS sites. In contrast, cover of *Xylococcus bicolor* was very high on two plots (Carmel Mountain plot 1, Los Montanas plot 2) but low on the companion plots at each site. It is important to quantify these differences in the scale of spatial variation in order to design a monitoring program, and this issue will be addressed in the next section.

V. 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. 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 analysis that we present has six distinct sources of variation (Figure 14). Three sources of variation result from the spatial variation of plants and plant communities on the landscape. Three additional sources are a result of the methodological challenges in monitoring biological communities.

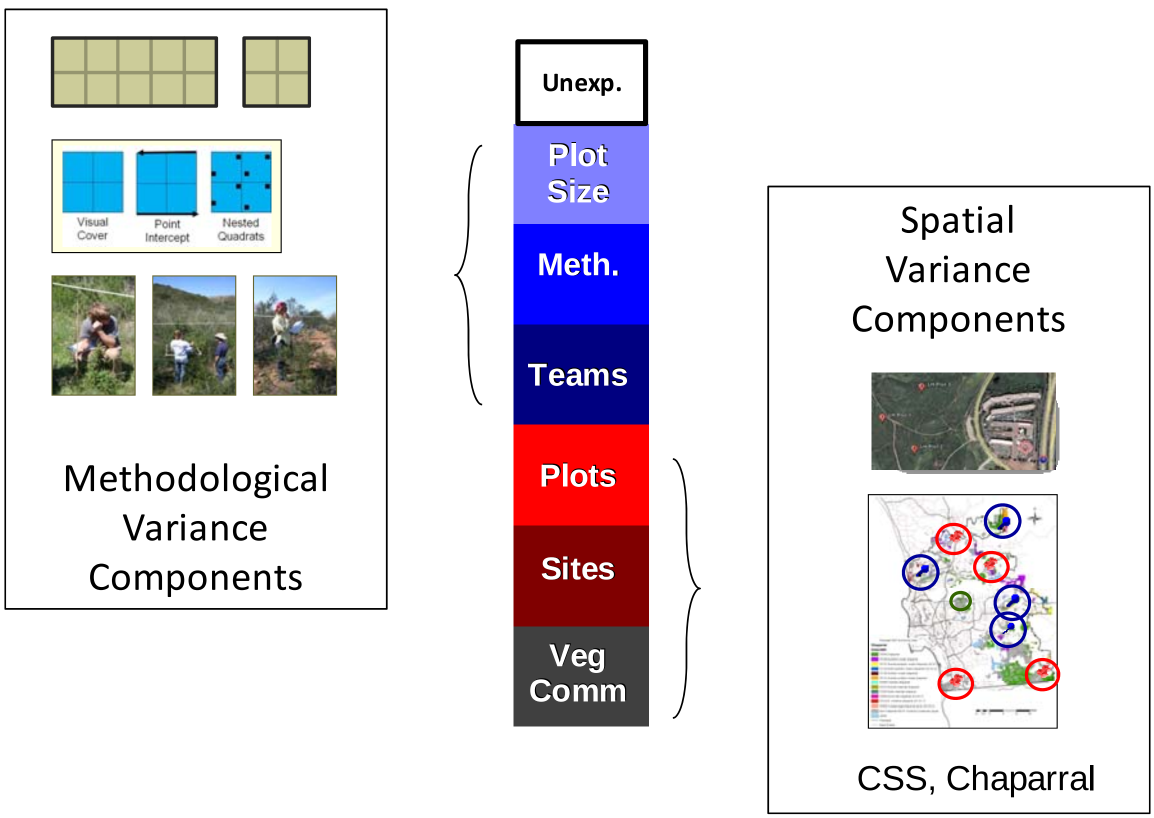

Figure 14. Illustration of the six sources of variation for the variance components analysis. The six sources of variation are partitioned into two groups, spatial variation (right: vegetation community, sites and plots) and methodological variation (left: teams, methods, and plot size). The remainder is unexplained variation (white)

The variance components analysis for species richness is used to illustrate how we present the results from this type of analysis (Figure 15). The bottom left panel shows the average species richness for CSS and chaparral vegetation communities. The average richness is similar in both communities, and thus there is little variation between the two communities (less than 1% of the variance). In contrast, species richness varied among the 8 sites (middle left panel). As a result, the variance component attributed to site-to-site variability is large (39%). The plot-to-plot variation within each site is modest (11%). There are substantial differences in the estimate of species richness that can be attributed to teams (17%), methodology (12%) and plot size (12%). From this 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 if species richness was the primary response variable. 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.

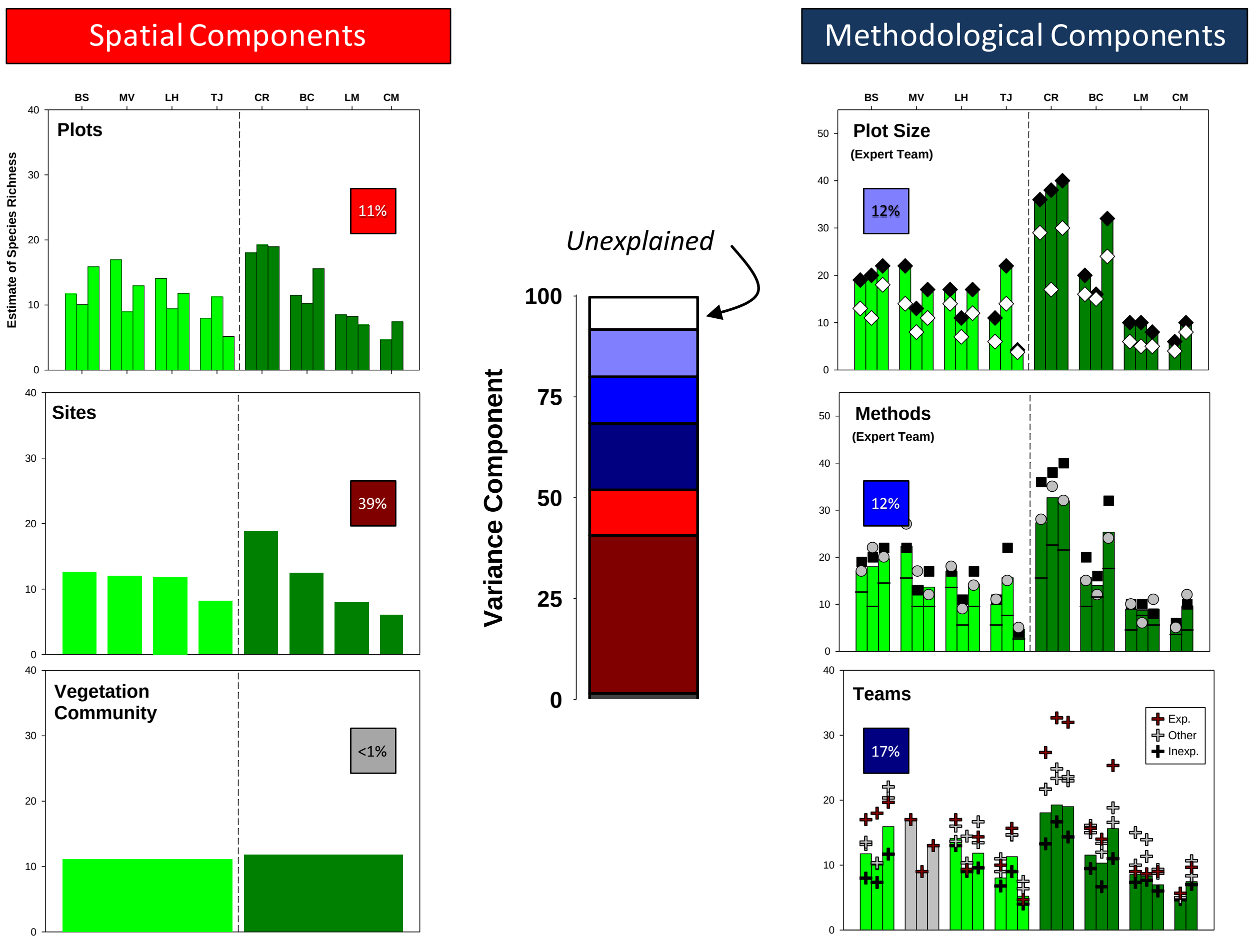

Figure 15. Illustration of the variance components analysis for species richness. The three left panels depict spatial variability by plotting mean richness of the vegetation communities (bottom), sites (middle) and plots within sites (top). The three right panels depict methodological variability among 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).

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 16). 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 5 components of variance added together (Table 4). In contrast, the cover of *Bromus madritensis* was not associated with vegetation community. Instead, the two plots with highest cover were recorded at two different CSS sites (Marron Valley and Lake Hodges). However, *Bromus madritensis* was rare at the other two CSS 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. The largest component of variance was field team. This species is not very common and some teams failed to identify it at the two sites where it was somewhat common (average cover around 3%). This result likely hinges on the fact that other mustards in the genre *Brassica* look similar to *Hirschfeldia incana* and are better known (in particular *Brassica nigra*, black mustard). In fact, until recently, *Hirschfeldia incana* was grouped in *Brassica* as *Brassica geniculata*.

Despite the differences among the response variables, several strong general conclusions can be reached (Table 4). Variation among sites is the largest component of the variance in five of the eleven variables. Plot-to-plot variation within sites is often large and is the second largest component of variation for five of the 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 (*Gutierrezia* sp. (match weed), *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.

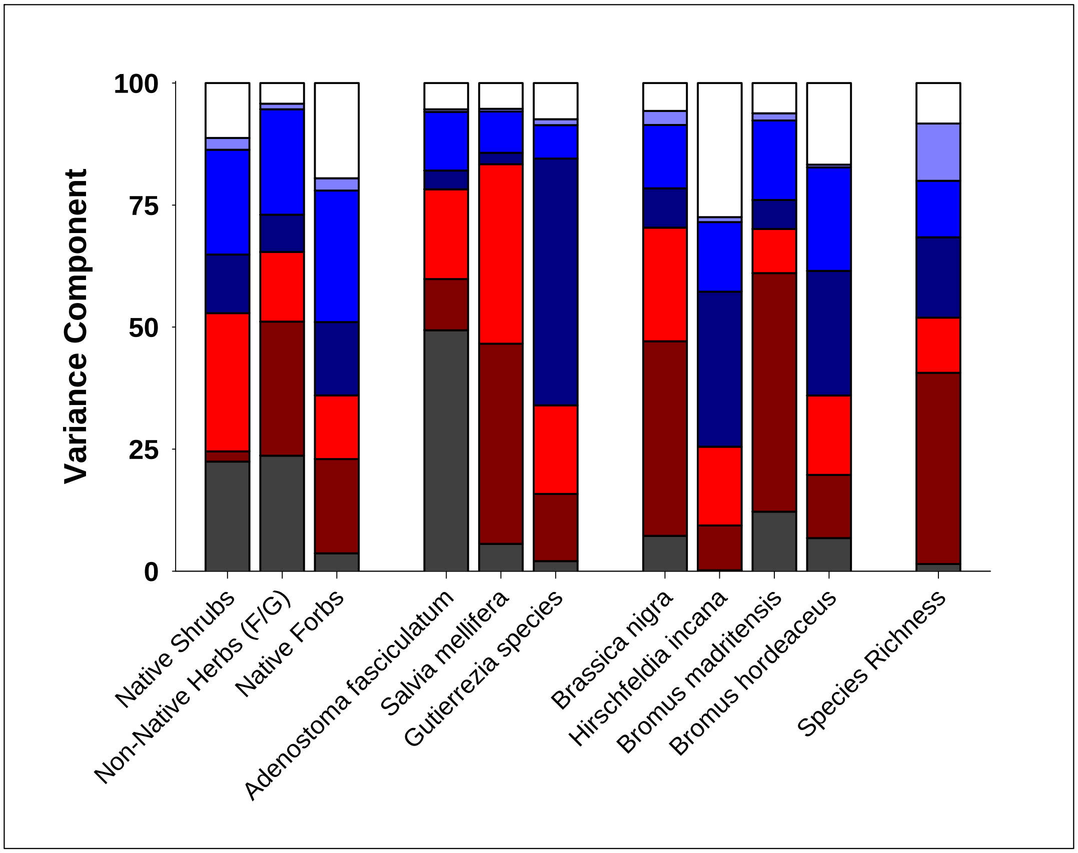

Figure 16. Comparison of the variance components analysis for eleven response variables. The different types of variation in the stacked bars are color coded as in Figure 15 (spatial - gray and reds; methodological – blues; the remainder (white) up to 100 percent is unexplained variation).

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, cryptic, or misidentified 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, <u>temporal</u>, and methodological sources of variation.

Variance Components	Average Cover	Vegetation Community	Site	Plot	Team	Method	Plot Size
Native Shrubs	61.0%	22.5	2.1	**28.4**	12.0	21.5	2.4
Non-Native Herbs (F/G)	41.3%	23.7	**27.5**	14.3	7.6	21.6	1.1
Native Forbs	4.9%	3.7	19.3	13.1	15.0	**26.9**	2.5
Adenostoma fasciculatum	10.4%	**49.4**	10.5	18.4	3.9	12.0	0.5
Salvia mellifera	1.1%	5.6	**41.0**	36.8	2.3	8.5	0.6
Gutierrezia species	1.3%	2.1	13.8	18.1	**50.6**	6.8	1.2
Brassica nigra	2.2%	7.2	**39.9**	23.3	8.1	13.0	2.9
Hirschfeldia incana	0.2%	0.2	9.2	16.1	**31.8**	14.3	1.0
Bromus madritensis	13.3%	12.2	**48.9**	9.0	5.9	16.3	1.5
Bromus hordeaceus	2.0%	6.8	12.9	16.3	**25.5**	21.2	0.6
Species Richness	-	1.5	**39.2**	11.3	16.5	11.6	11.7

Table 4: Variance components for 11 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.

VI. Discussion

We monitored CSS and chaparral vegetation communities on several reserves throughout the MSCP. CSS and chaparral habitats were chosen because they are the dominant vegetation communities within the MSCP. 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 original goals of the MSCP and the conceptual model that we developed during the previous project (Hierl et al. 2007). We also evaluated relative accuracy and cost (labor) of alternative field protocols, and estimated 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 (site, plot, and subplot scales), protocol differences, and differences among field teams.

In the first field season, we tested three protocols at 23 plots distributed throughout the MSCP and across two vegetation communities. In a 6-week period between April 1, 2007 and May 15, 2007 we made 64 plot visits with 2-person teams. 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 more than 150 plant species across the two vegetation communities. At these sites, CSS is dominated by smaller native shrubs like *Eriogonum fasciculatum*, *Artemisia californica*, and *Salvia* sp. Since CSS is more open, it is also heavily invaded by several non-native forbs and grasses, notably *Bromus* sp., *Brassica* sp. and *Erodium* sp. Chaparral is dominated by larger shrubs including *Adenostoma fasciculatum*, *Xylococcus bicolor* and *Ceanothus* sp. The closed-canopy chaparral stands often had fewer invasive species.

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 the MSCP. 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 2008

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 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 2008, 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 17). 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.

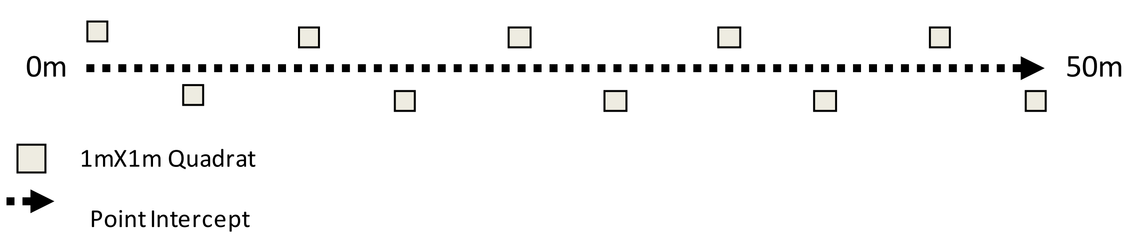

Figure 17. 2008 transect/plot field protocol. A 50 m transect will be located using a restricted stratified random sampling procedure, quadrats will be read every 5 meters on alternating sides.

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 stratified random 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 three or four 50m long transects per day, barring unforeseen circumstances. Several (three to six) new transect plots will be established at each site.

Team Training

We would like to implement a more extensive training procedure for all field crew in 2008. 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

VII. Conclusions

In 2007 we were able to draw several firm conclusions, both about MSCP vegetation communities, as well as the methods we used to collect data and sources of variability in those data.

Species and cover in the MSCP:

- We recorded 186 plant species across the two vegetation communities.
- CSS is dominated by smaller native shrubs like *Eriogonum fasciculatum*, *Artemisia californica*, and species of *Salvia.*
- CSS is also heavily invaded by several non-native forbs and grasses, notably species of *Bromus*, *Brassica*, and *Erodium*.
- Chaparral is dominated by larger shrubs including *Adenostoma fasciculatum*, *Xylococcus bicolor* and species of *Ceanothus*.
- Chaparral stands often had fewer invasive species than CSS stands.

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 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 not only as a data collection effort, but as an opportunity to refine these tools.

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VII: APPENDICES

APPENDIX 1: 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. Ecological communities were evaluated 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, LA, HM Regan, J Franklin and DH 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 evaluating 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 to 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 guillemots.* 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.

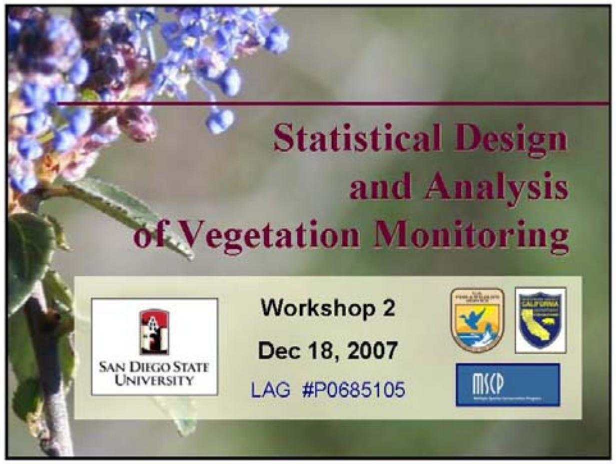
APPENDIX 2: LIST OF PARTICIPANTS IN THE DEC. 2007 WORKSHOP

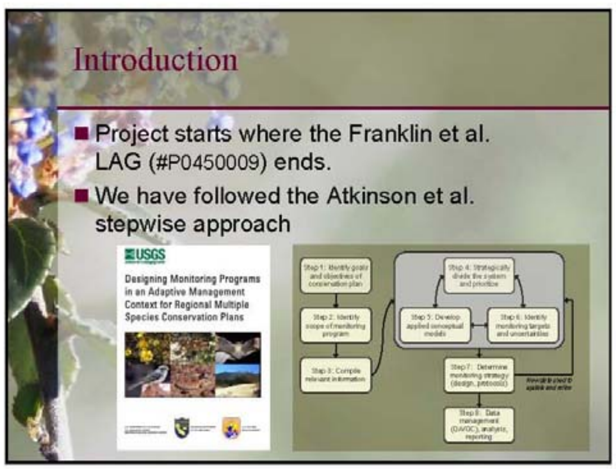
The following is a list of participants in the December monitoring workshop. We thank all of the participants. We apologize to those individuals whose affiliation is currently unknown to us. Please feel free to contact Spring Strahm (sstrahm@sciences.sdsu.edu), and we will update your information in our database.

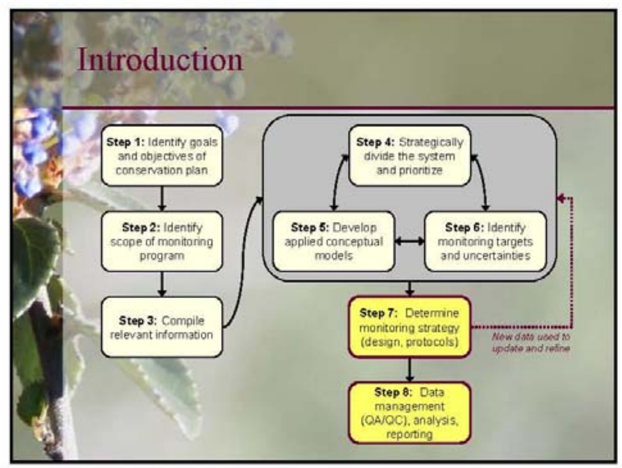
Last Name	First Name	Affiliation
Bailey	Dave	SDSU
Beyers	Jan	Forest Service, USDA
Billett	Clare	
Brenne	Chris	City of San Diego
Buegge	Jeremy	County of San Diego
Burnett	Christina	SDSU
Clark	Denise	USGS
Cleary-Rose	Karin	California Department of Fish and Game
Deutschman	Douglas	SDSU
Endress	Brian	San Diego Zoo
Fege	Anne	San Diego Natural History Museum
Fleming	Genie	San Diego Natural History Museum
Franklin	Janet	SDSU
Grant	Tyler	US Fish and Wildlife Service
Greer	Keith	SANDAG
Haines	Jennifer	County of San Diego
Hamada	Yuki	SDSU
Huie	Amy	
Johnson	Brenda	California Department of Fish and Game
Klein	Michael	
Lewison	Rebecca	SDSU
Li	Yuying	AMEC Earth and Environmental
Lincer	Jeff	Wildlife Research Institute
Martin	John	US Fish and Wildlife Service
Hawke	MaryAnn	San Diego Natural History Museum
Mauritz	Marguerite	SDSU
McConnell	Patrick	Center for Natural Lands Management
McFarland	Kellie	SDSU
Menuz	Diane	California Department of Fish and Game
Miner	Karen	California Department of Fish and Game
Newton-Reed	Steve	California Department of Fish and Game
Oberbauer	Tom	County of San Diego

Last Name	First Name	Affiliation
Ostermann	Stacey	US Fish and Wildlife Service
Paymard	Halleh	AMEC Earth and Environmental
Reed	Brenda	County of San Diego
Rochester	Carlton	USGS
Rom	Catharine	
Root	Brian	US Fish and Wildlife Service
Rusev	Amy	Soil Ecology Restoration Group
Schafer	Christina	
Scott	Tom	
Shanney	Christina	
Spears-Lebrum	Linnea	EDAW
Spiegelberg	Markus	Center for Natural Lands Management
Stow	Doug	SDSU
Strahm	Spring	SDSU
Thompson	Andrew	US Fish and Wildlife Service
Vinje	Jessie	Center for Natural Lands Management
Wagschal	Adam	County of San Diego
White	Mike	Conservation Biology Institute

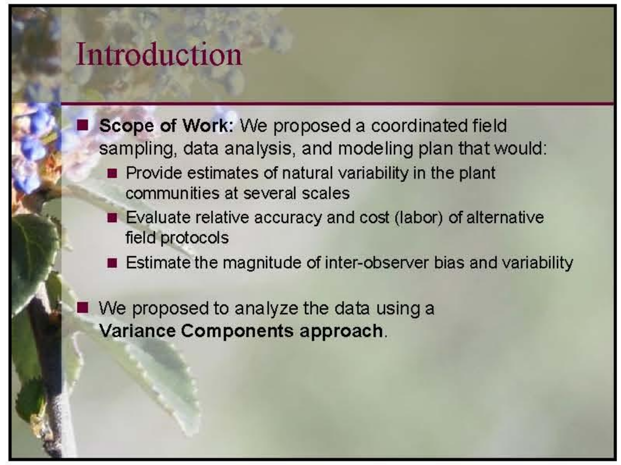
APPENDIX 3: WORKSHOP PRESENTATION

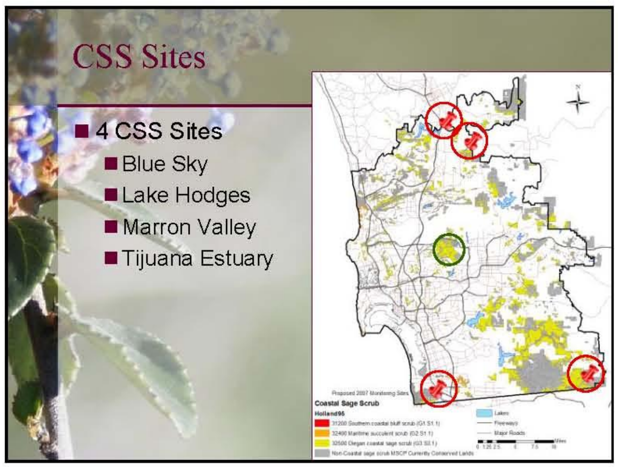


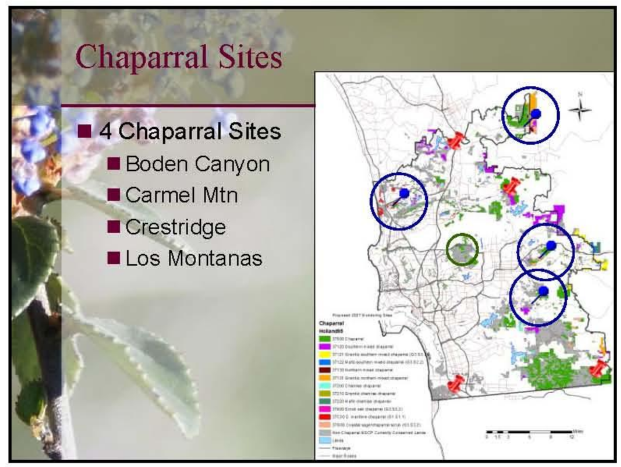




Presentation - *December 18, 2007*







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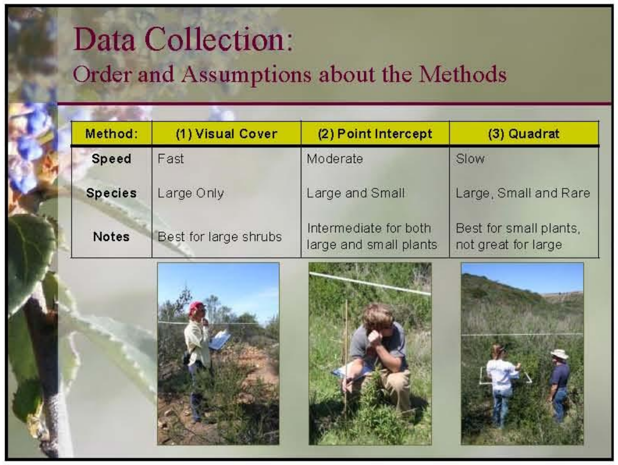

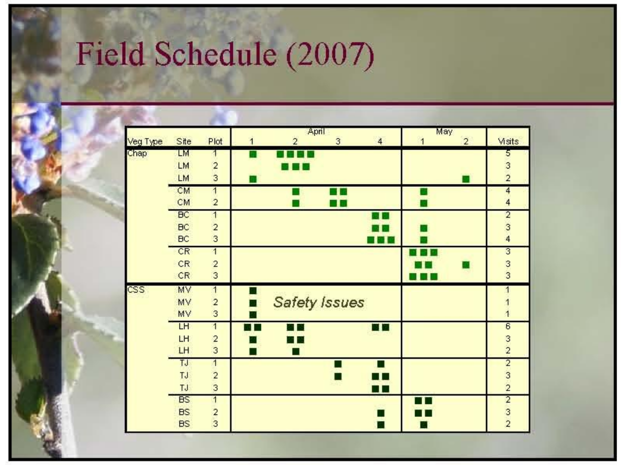

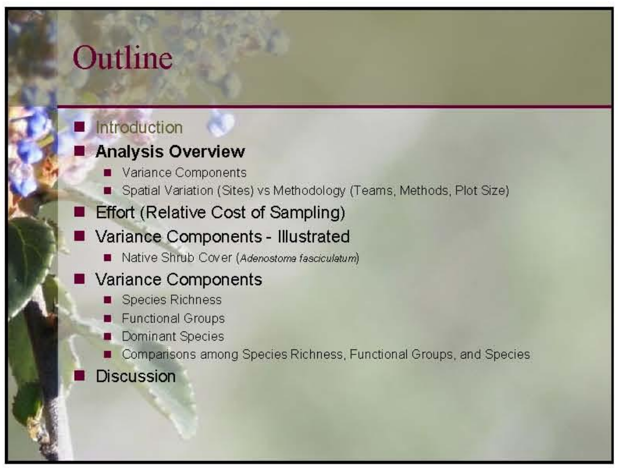

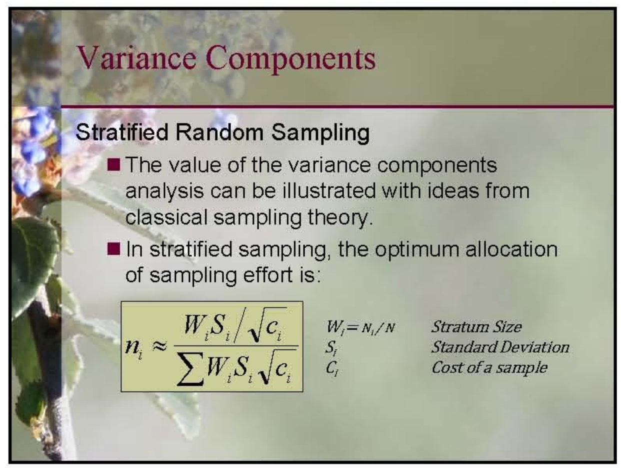

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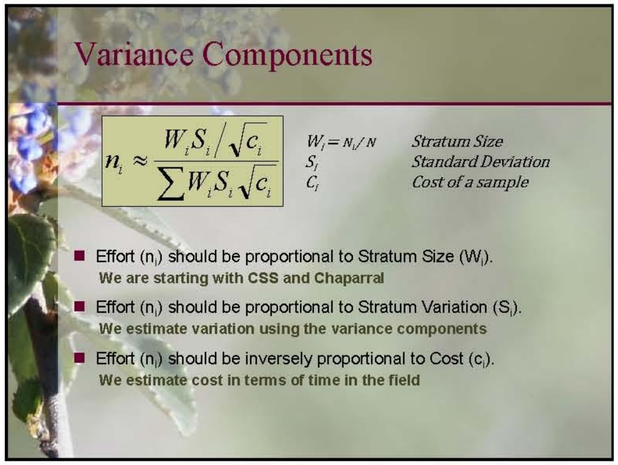

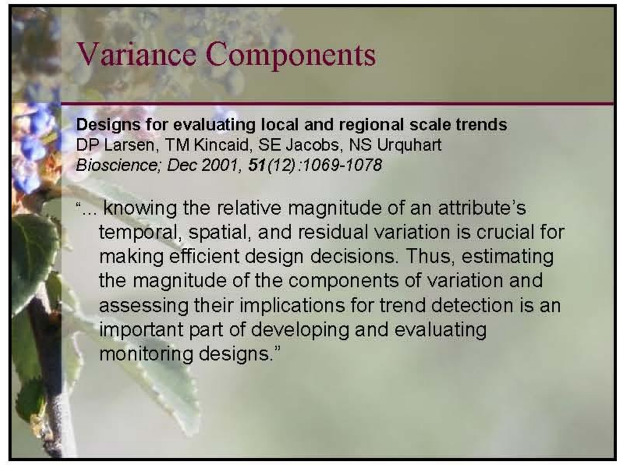

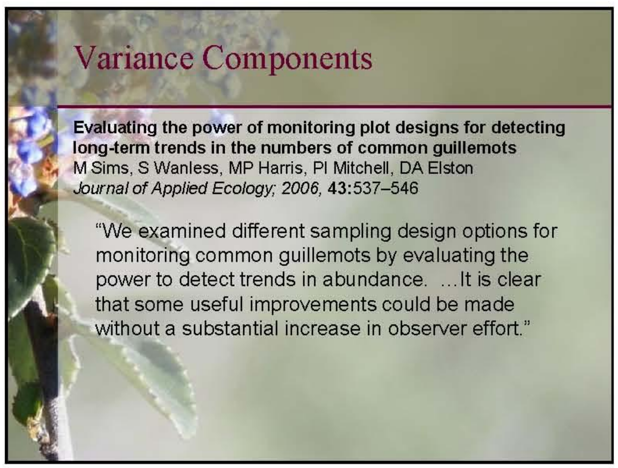

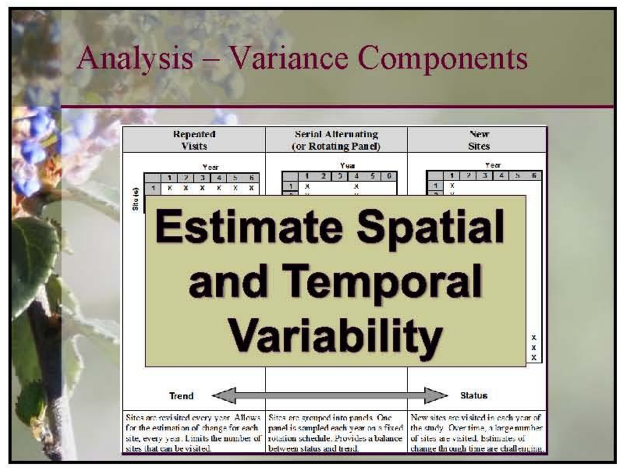

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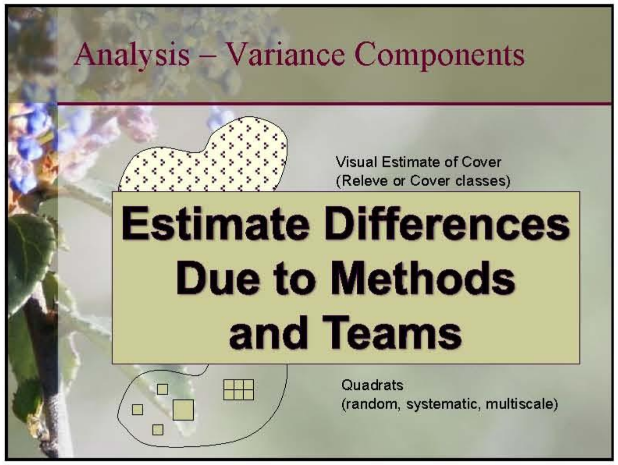

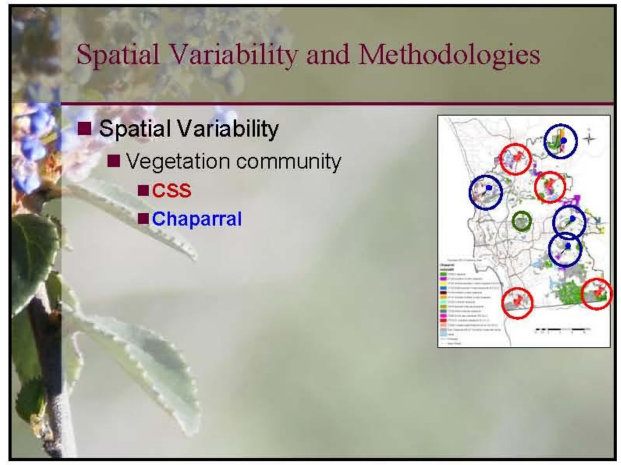

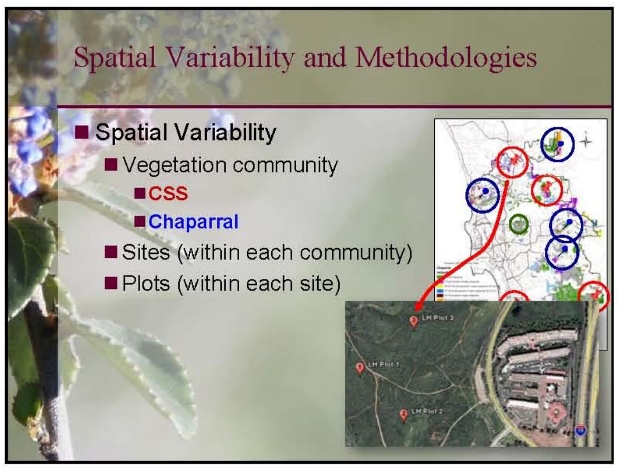

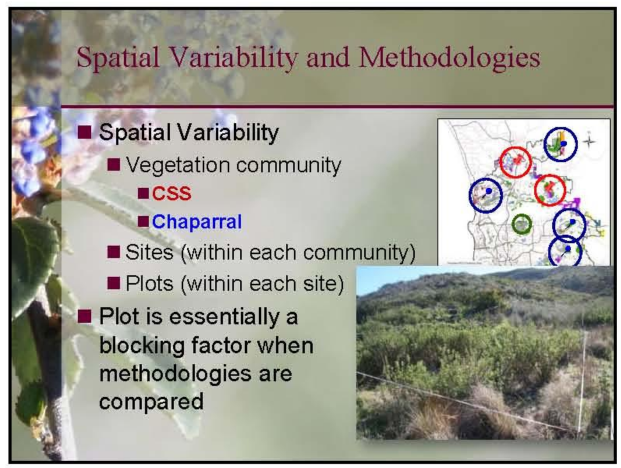

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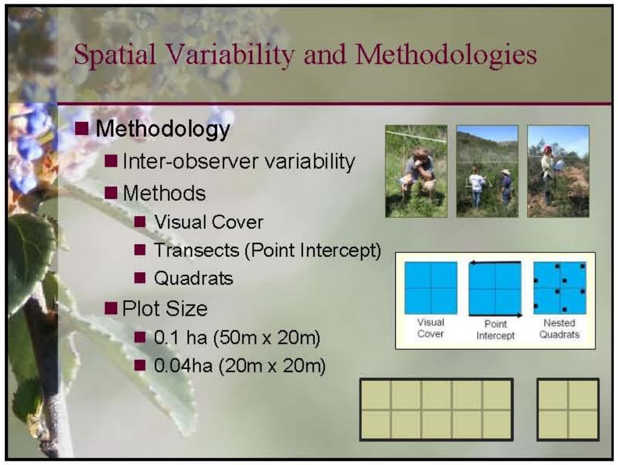

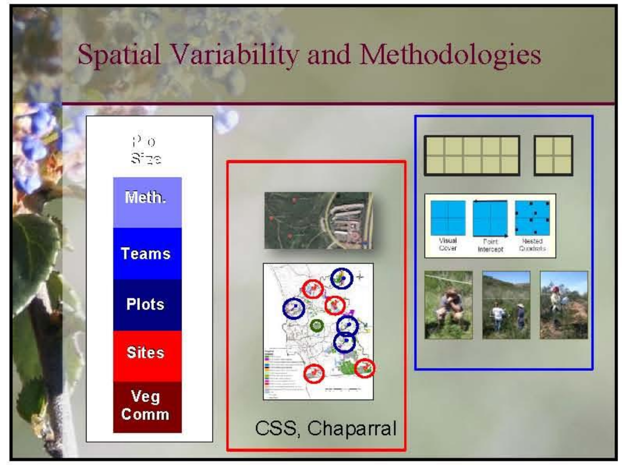

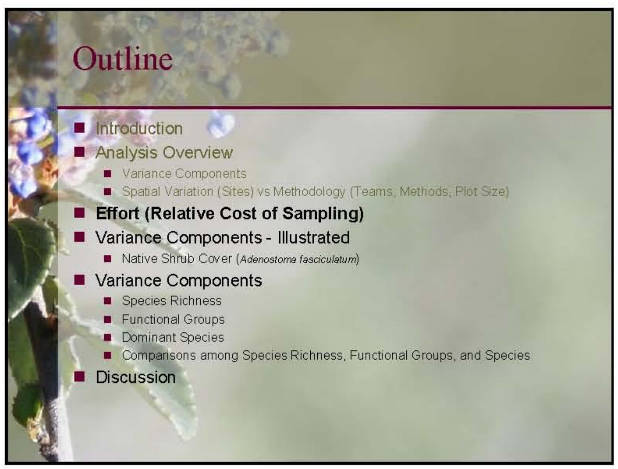

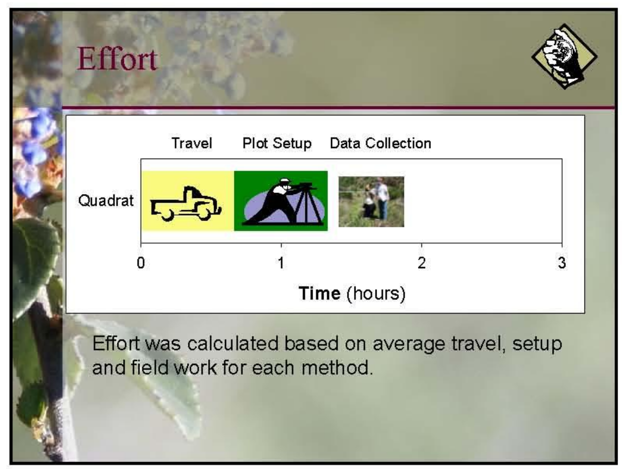

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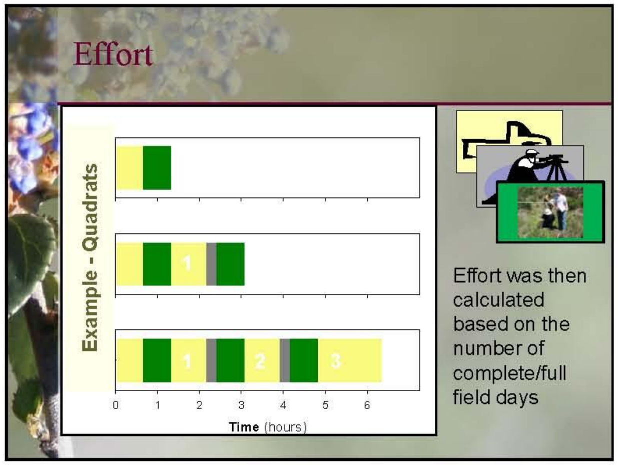

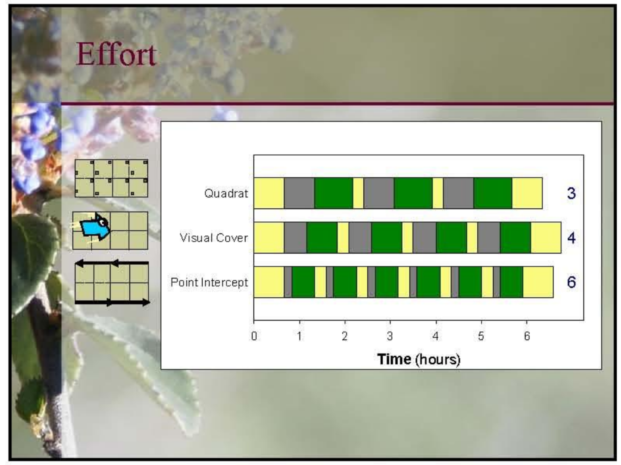

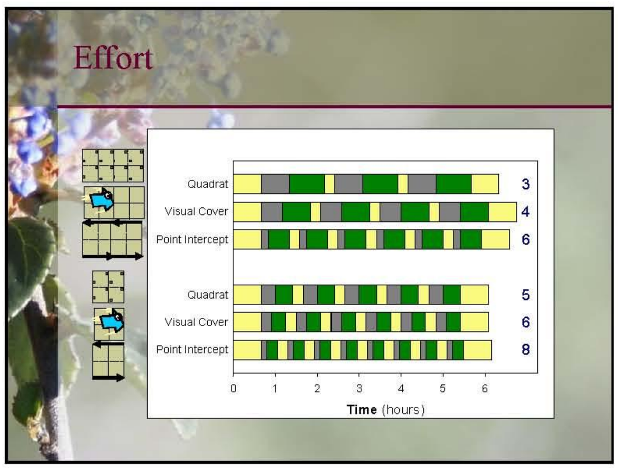

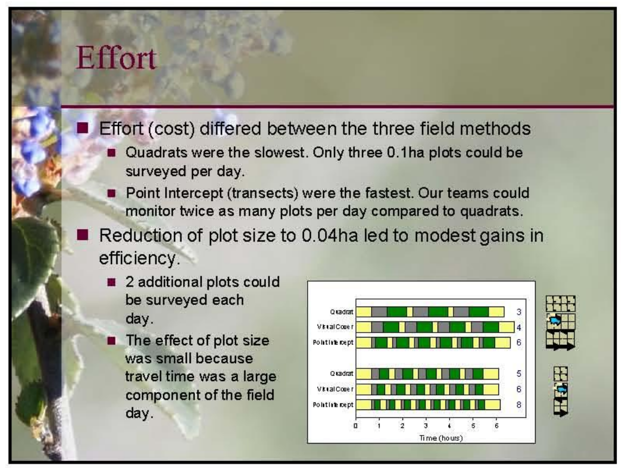

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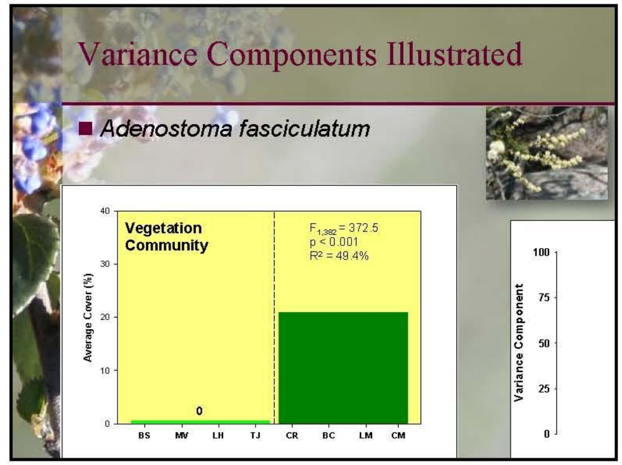

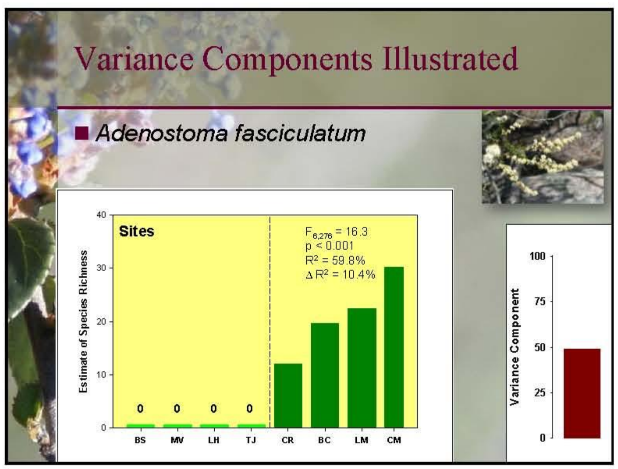

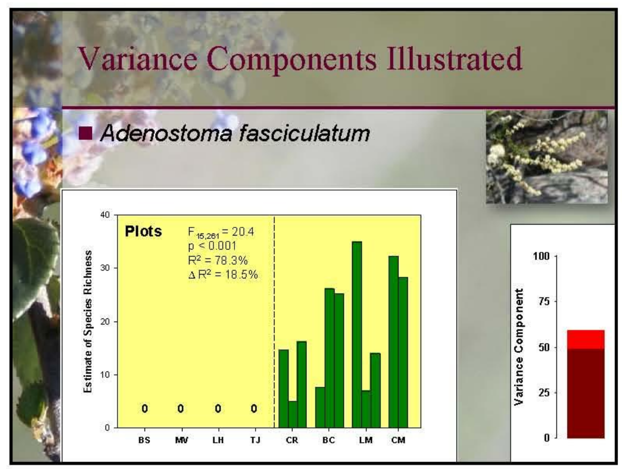

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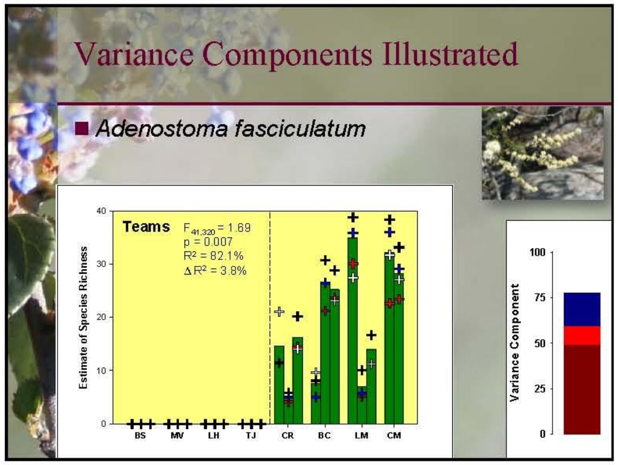

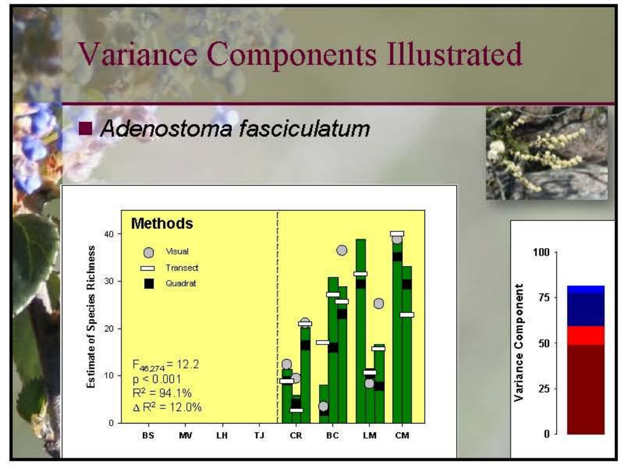

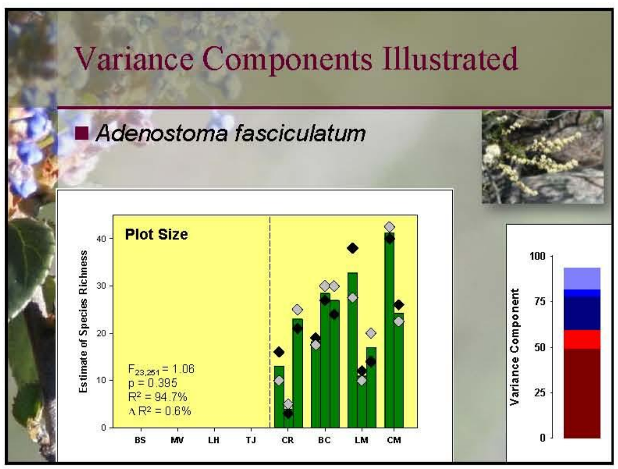

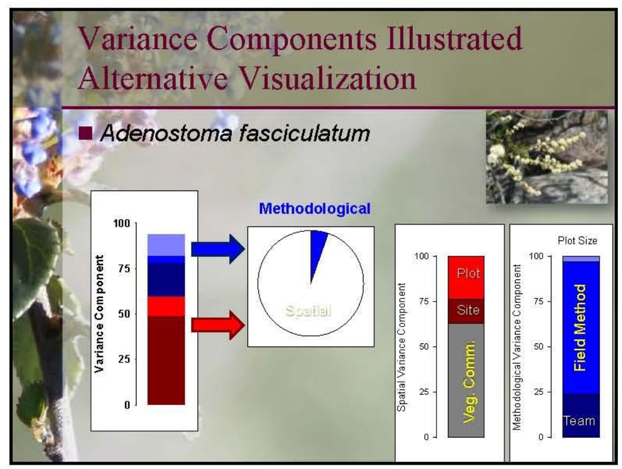

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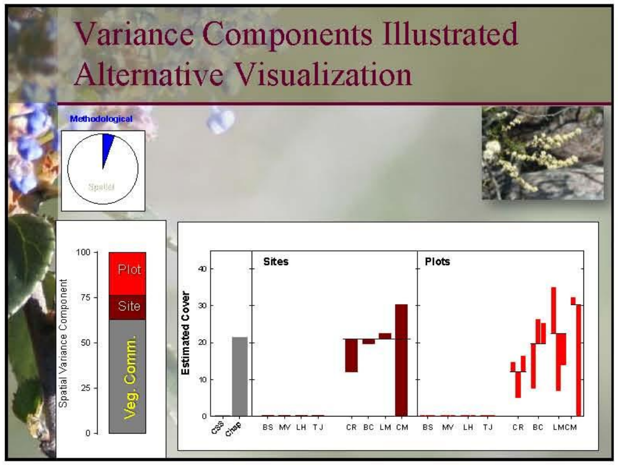

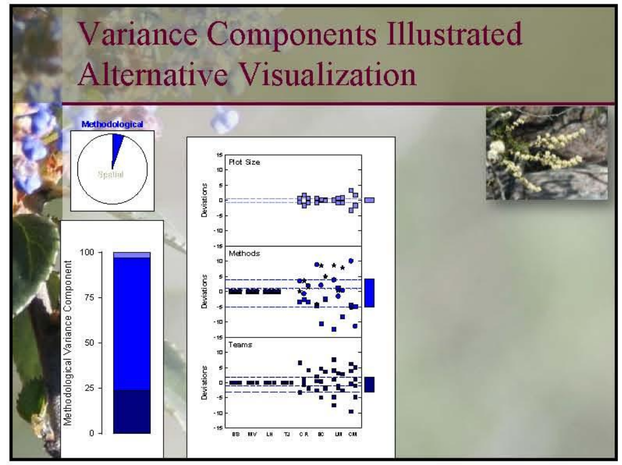

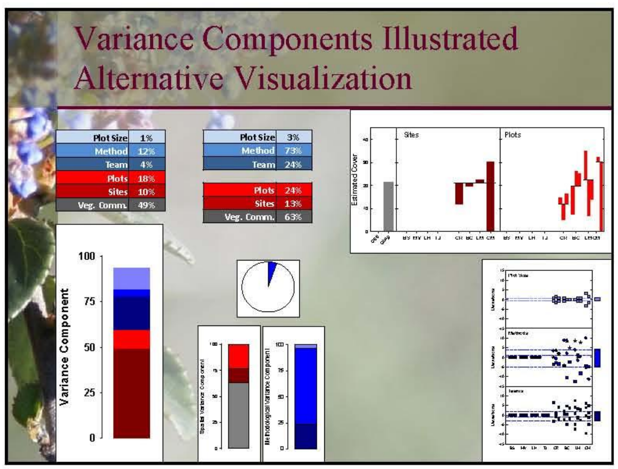

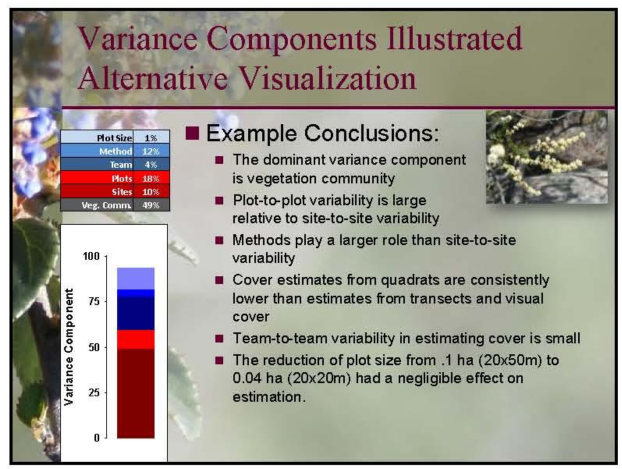

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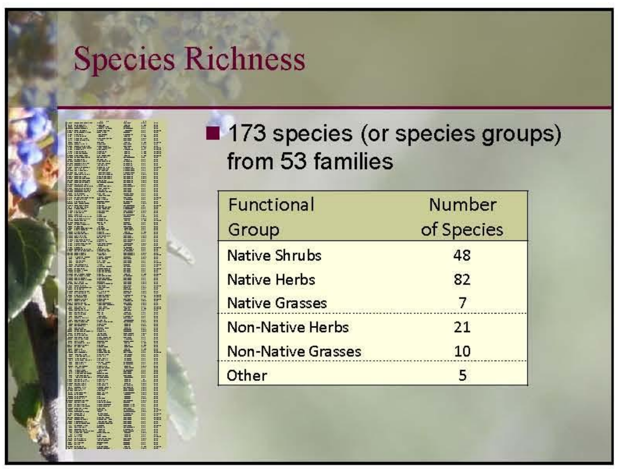

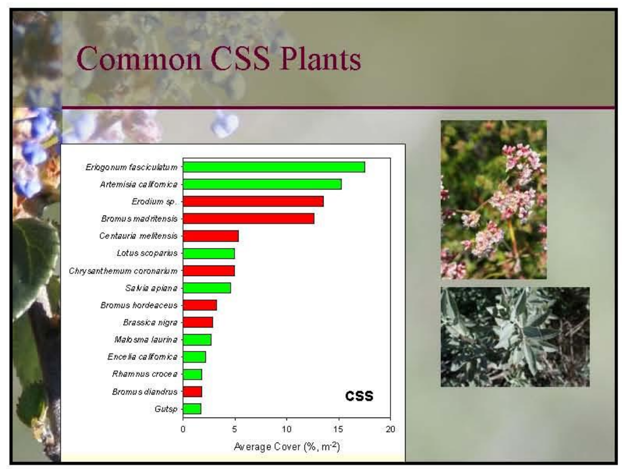

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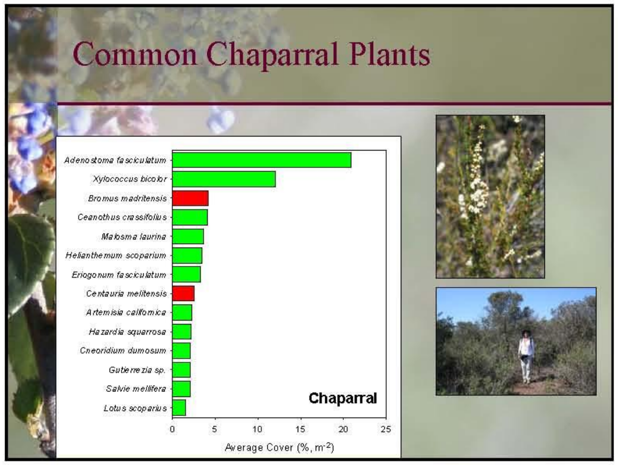

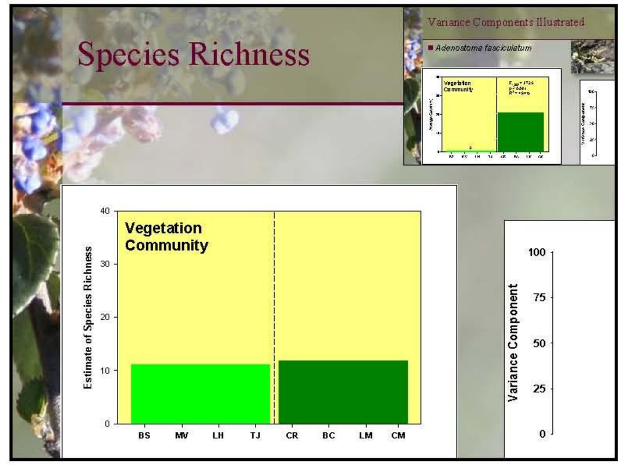

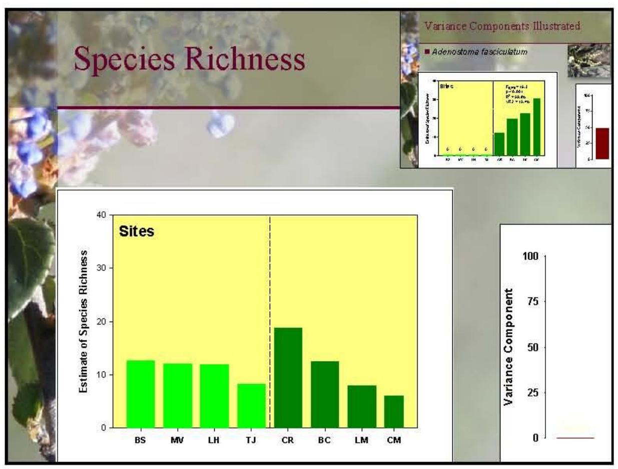

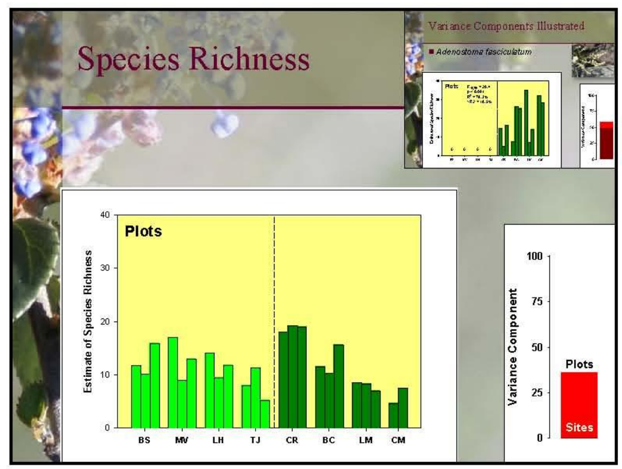

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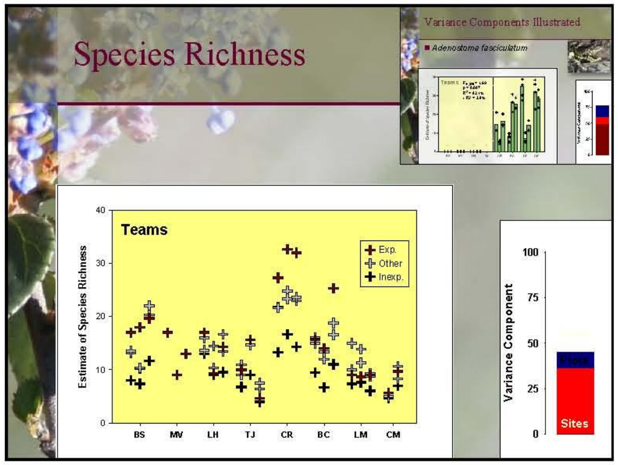

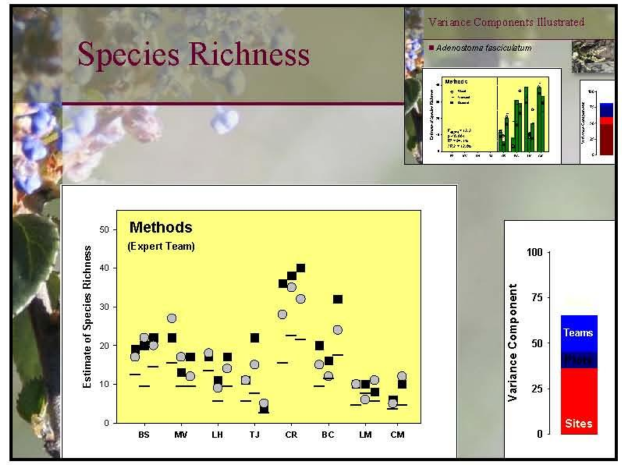

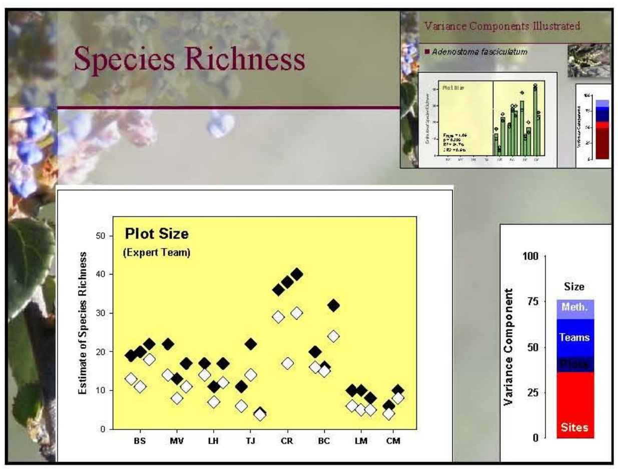

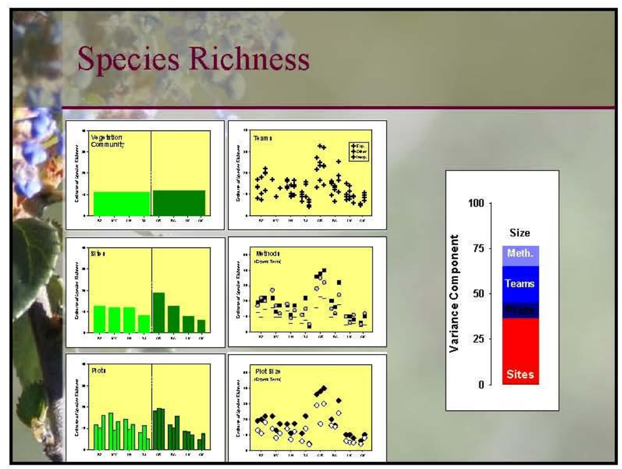

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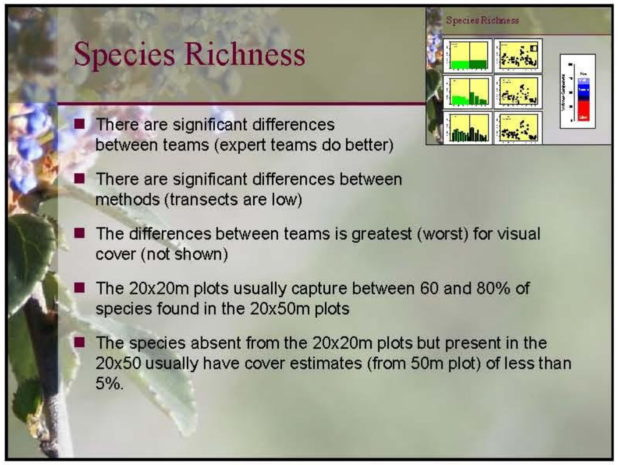

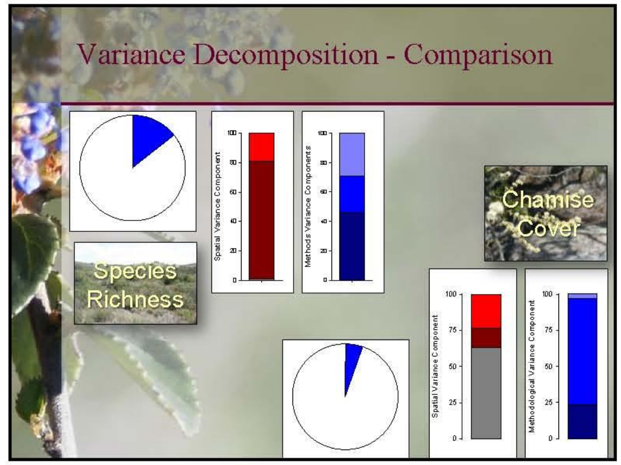

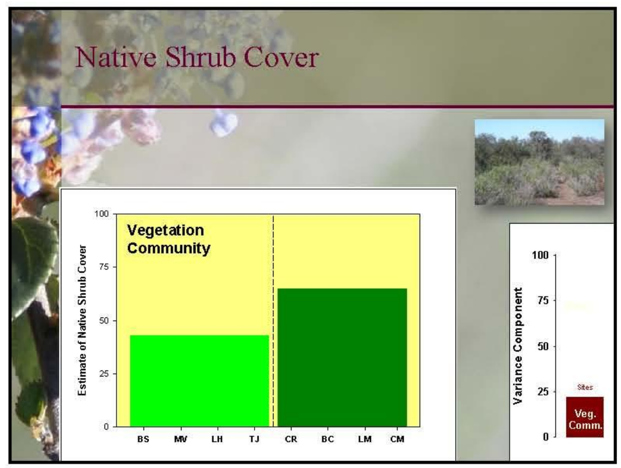

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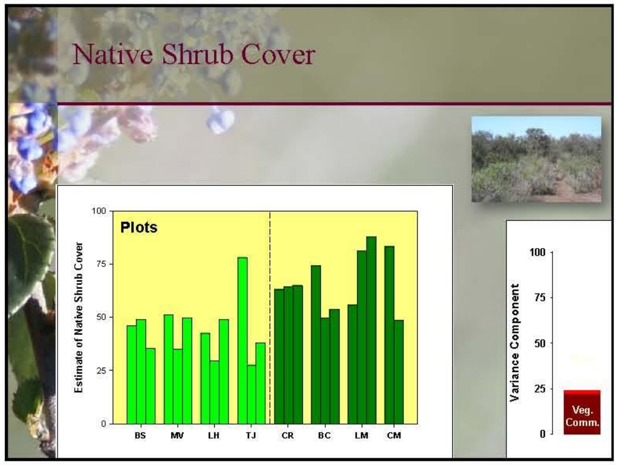

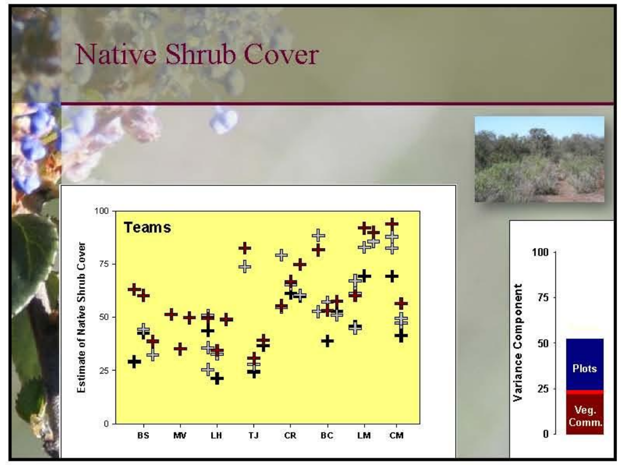

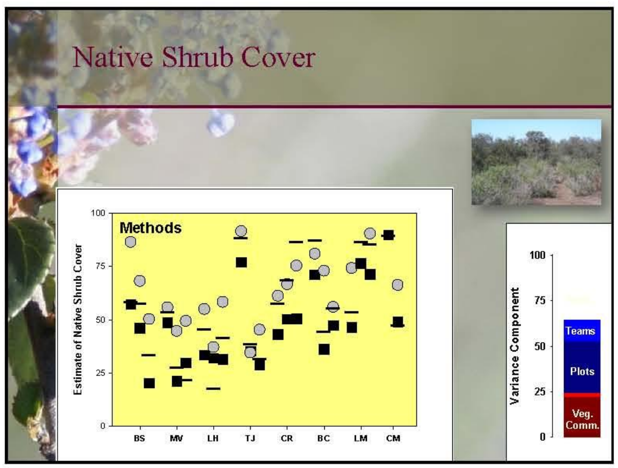

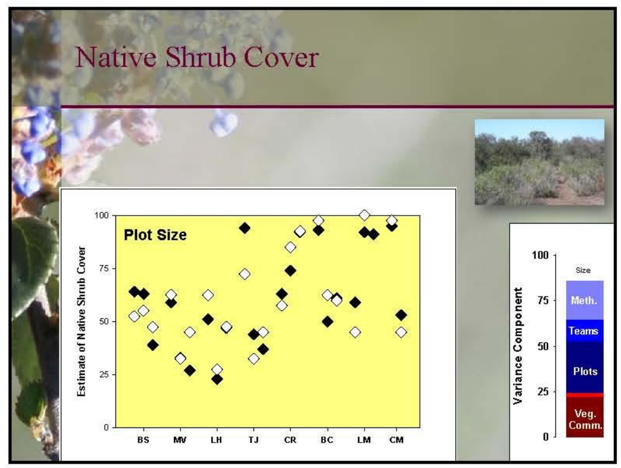

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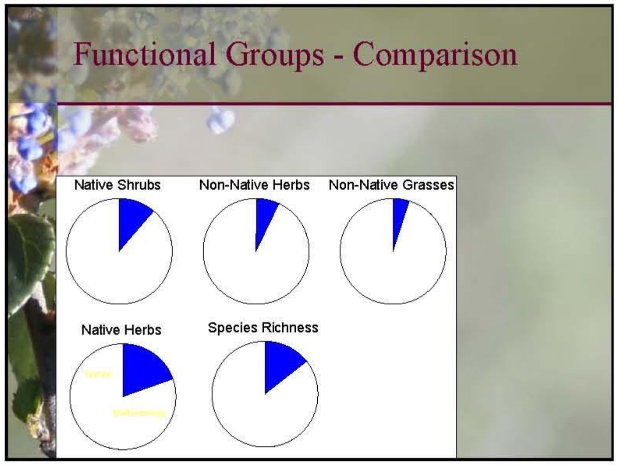

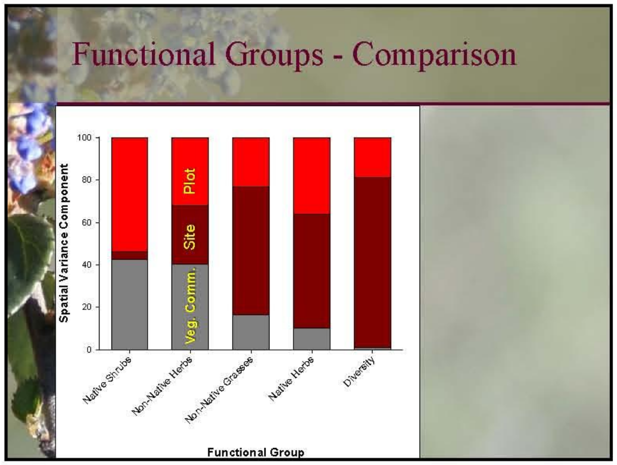

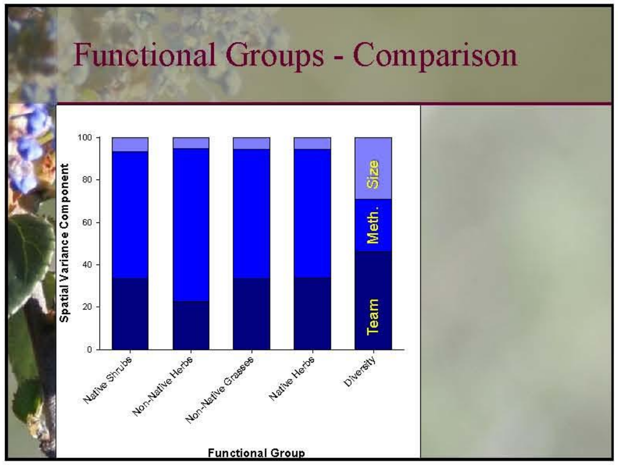

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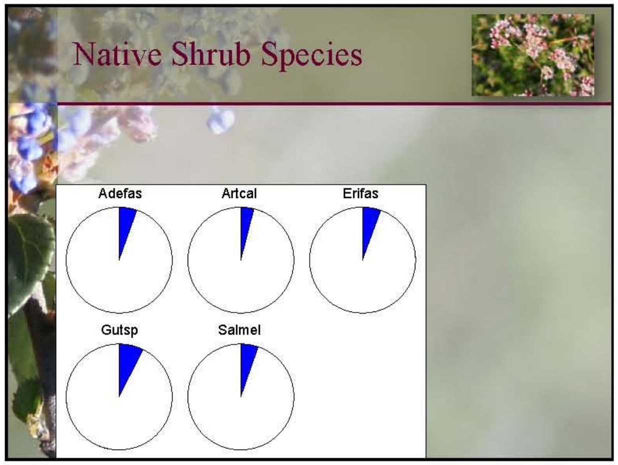

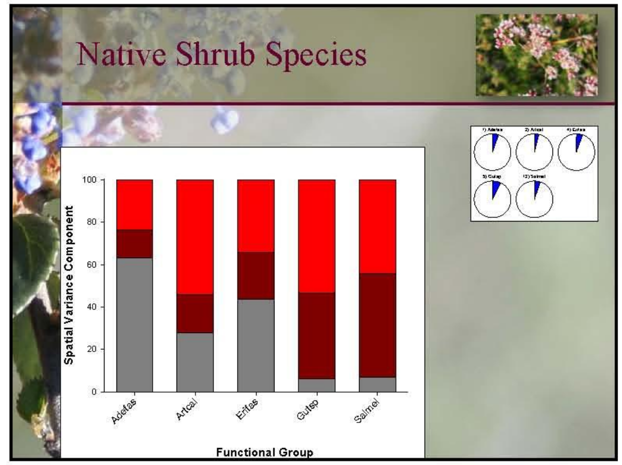

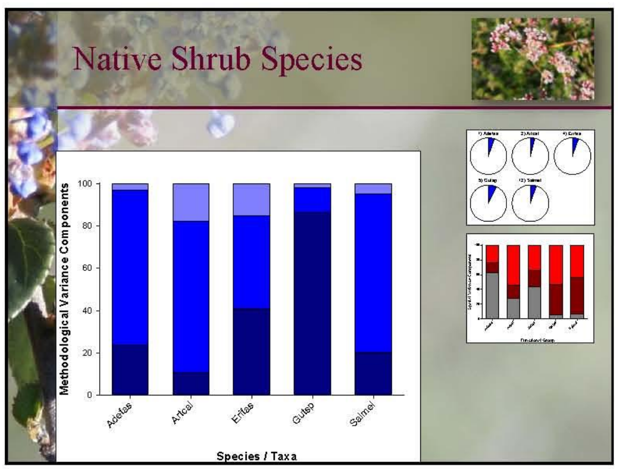

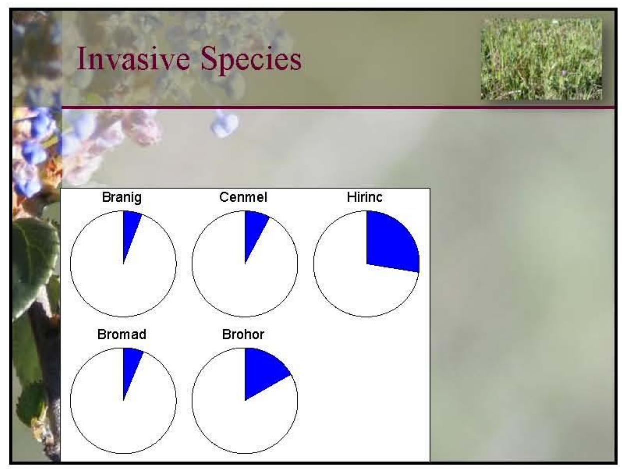

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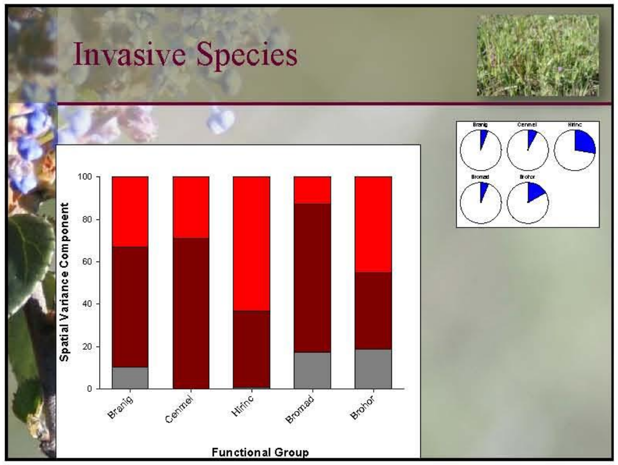

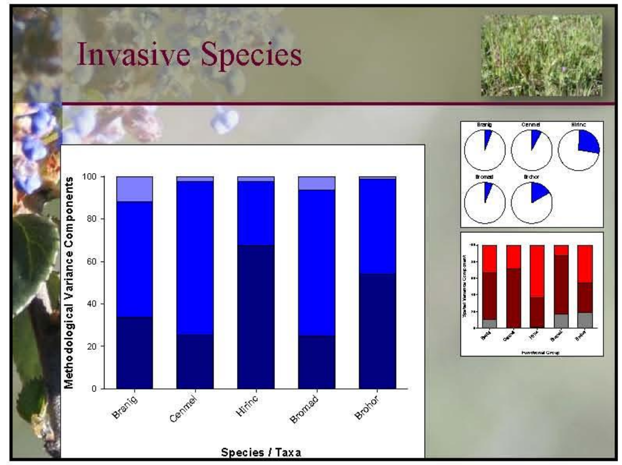

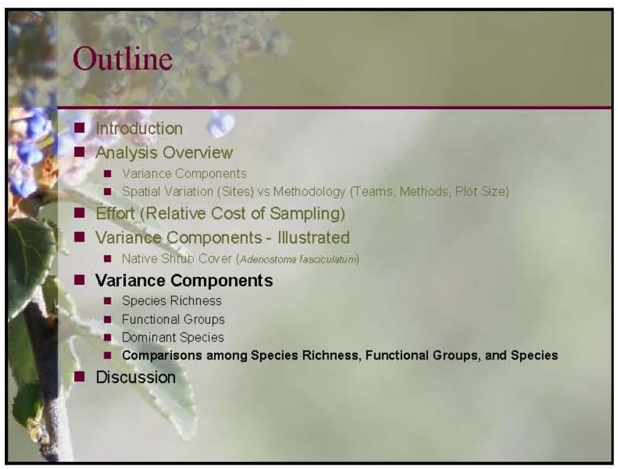

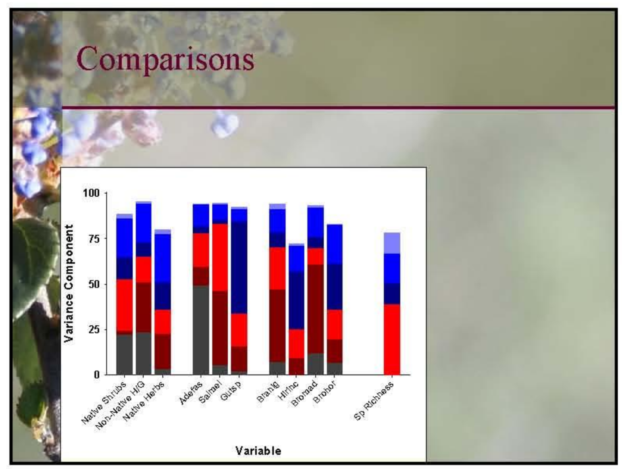

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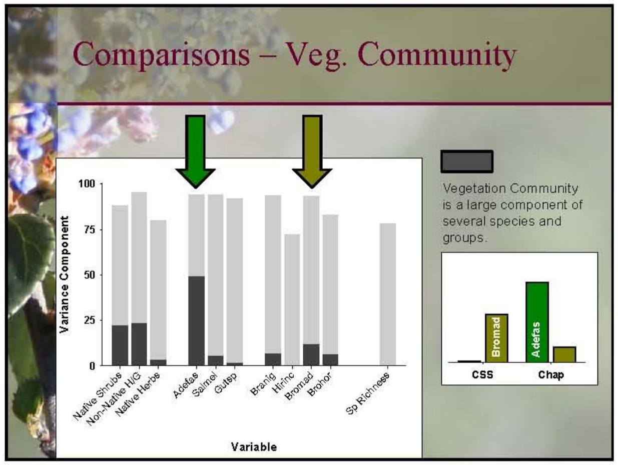

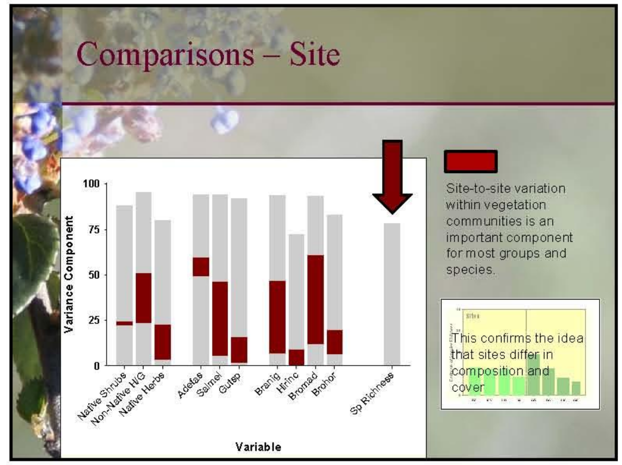

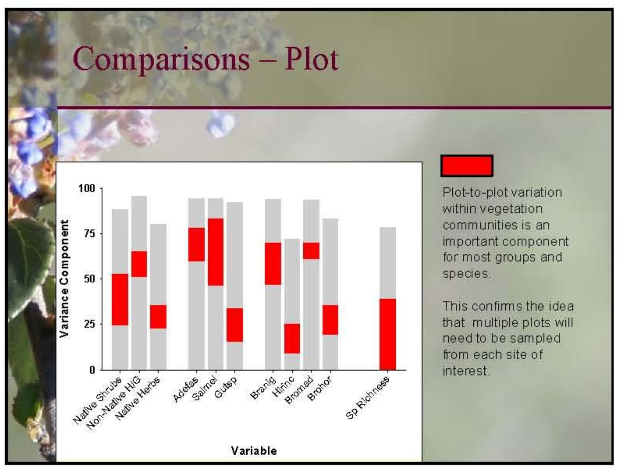

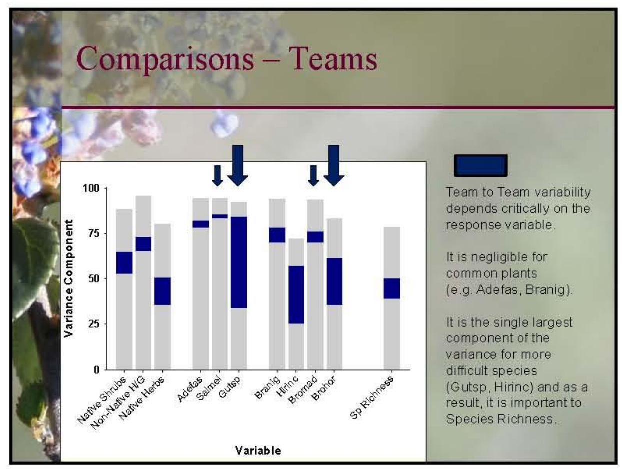

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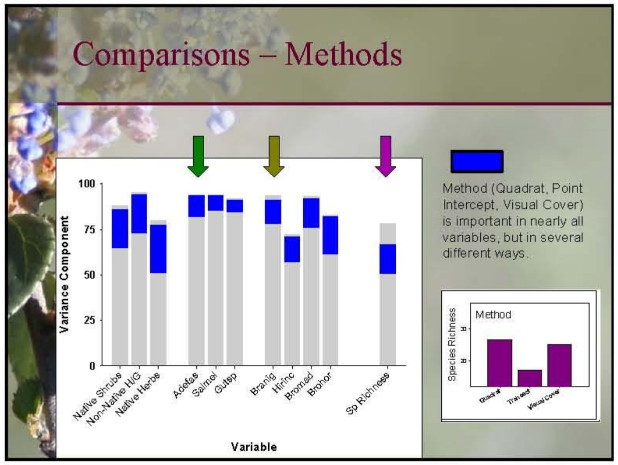

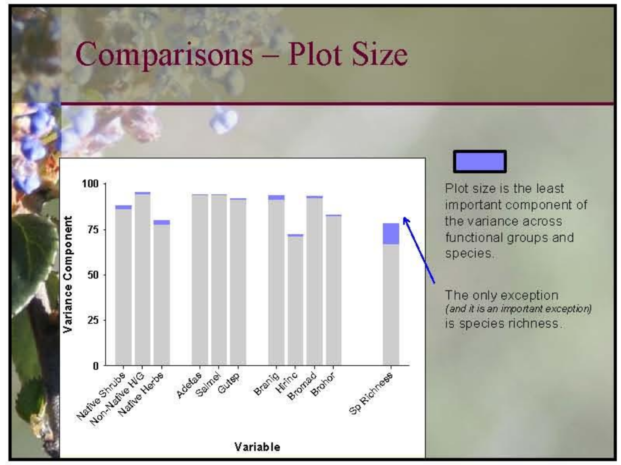

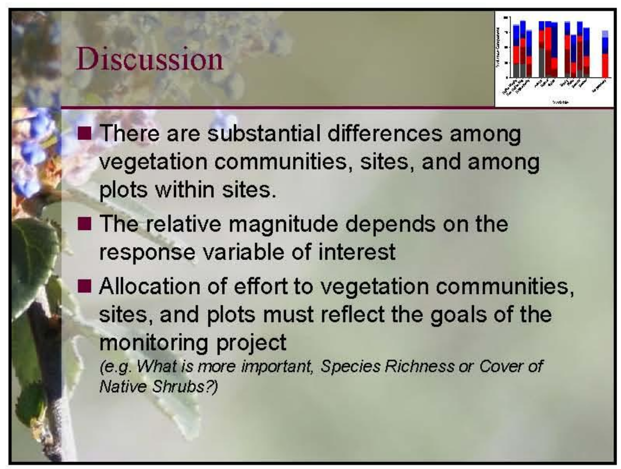

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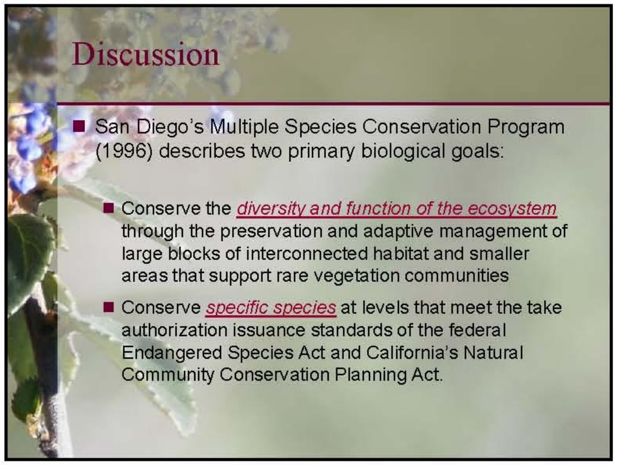
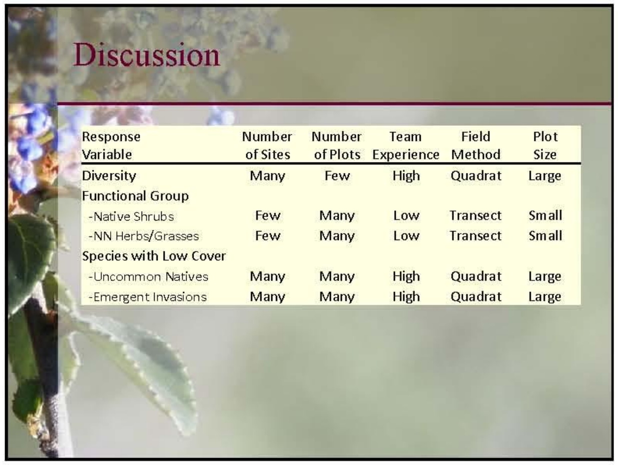




Appendix 4: Response to Comments

The following matrix records comments and responses given during the December 18th, 2008 workshop. We would like to thank everyone who offered their comments during the workshop or via e-mail as they helped guide the content of the final report. In most cases answers and explanations to questions and comments are reflected in the text of the final report.

Commenter	Agency	Comments	Response
John Buegge	SD County	Would like to have a county team participate in training and do an extra plot and/or site	
John Buegge	SD County	Attached rare plant monitoring form, suggests there may be a link between our design and the recent plant monitoring revision.	
John Buegge	SD County	Monitoring goals for habitat based metrics need to be discussed, suggests staring on the January 28th monitoring meeting. Suggests the following possible goals: -provide an objective look at ecosystem form and function (i.e., it avoids observer bias over time) - allows comparison of different management regimes (i.e., provides accountability for management) - provides data for unknown future needs (the more data we have, the easier it will be to ask questions retrospectively) - provides a historic record of conditions (how much would we give for actual data from 1892 for any area? Why not provide that to future scientists?	Defining the goals and objectives of the MSCP monitoring program is beyond the scope of this project. Our hope is to provide a tool box to help make monitoring decisions with.
Michael White	Conservation Biology	Recognized that optimal sampling design will be based on objectives of habitat based monitoring goals	

Commenter	Agency	Comments	Response
Michael White	Conservation Biology	Suggests: the objectives of the regional vegetation monitoring program should be focused on a relatively narrow set of questions related to regional status and trends of vegetation communities, related to larger scale processes (climate change, fire patterns, and land use changes).	These need to be looked at and prioritized by the stake holders, but we are providing a structure to begin making decisions about how to and what you need to monitor.
Michael White	Conservation Biology	Proposes that regional monitoring might not be appropriate for specific management decisions at individual preserves (RE: invasive species). Suggests that precise cover estimates of species (particularly rare species) may not be necessary for this program, and proposes metrics such as shrub cover, bare ground, etc. and the changes in these metrics over time.	We are providing a synthetic structure to make decisions about how to monitor based on the individualized question.
Michael White	Conservation Biology	Suggests distributing new plots to characterize a much larger area of each site. I started wondering what plot variability might look like if you tried to characterize a larger proportion of each site, which in the regional monitoring structure might reasonably be considered "sentinel locations"	Agreed and will implement this strategy next year.
Tyler Grant	FWS	Concurs with other commenter's that monitoring objectives agree important to define, but suggests that the Deutschman lab should take the lead as part of the project	Not part of our scope of work. Requires a much broader discussion with many stakeholders.
Tyler Grant	FWS	Wants us to address why % cover, etc. speak to ecosystem function	These metrics were justified by the previous LAG grant performed by Franklin et al. Please refer to the annotated bibliography for summaries of these works.
Tyler Grant	FWS	Wants the metric chosen to determine the desired precision of the method (RE: if 50% native = functional anyone can do it)	We concur, and hope to provide a tool to help inform decision makers after they have decided on their specific metric or threshold of tolerance for a certain stimulus.

Commenter	Agency	Comments	Response
Tyler Grant	FWS	While the variance components analysis will be very useful in designing a program, some of the discussion is premature. Without a question and without knowing the precision necessary to answer the question, you don't know if you need to reduce variance. Of course, reducing variance is always good, but in the context of the question you want to answer, is it necessary? If sample size and effect size are big enough, you may not have to be stuck trying to reduce your variance.	Our project was aimed at helping managers and monitors make important decisions about the need to reduce variance, and how to go about it. These estimates of variance are needed to calculate power and make informed, quantitative decisions about monitoring.
Clare Billett	Self Employed?	Would like to see "low expert" "low cost" methods employed for MSCP monitoring in order to engage volunteers, citizen scientists, etc. as an outreach mechanism. Sent literature regarding various methods which may be appropriate.	Our research is aimed at identifying the parameters that require experts, etc. so monitoring and management staff can decide how best to allocate effort and budget, and where best to include such outreach efforts.
Keith Greer	SANDAG	The Deutschman lab may want to revisit the monitoring goal based on: "The actual biological goal of the MSCP is stated as; "Maintaining ecosystem function and persistence of extant populations of covered species is the goal of the MSCP (MSCP Plan (1998) p 1.5)." Conserving diversity and functions of the ecosystem were the rational for development of the Plan, but not the stated goal."	The MSCP documents express the intent of the MSCP a number of different ways in different sections of different documents. We revisited several of these sections and felt that diversity and function were reflected in the original intent of the plan. Please refer to section 1 "Introduction" of the final report for a more in-depth discussion.
Keith Greer	SANDAG	Need to revisit the attributes of ecosystem function and not base interpretation on richness or functional group cover: "Document changes in preserved habitats or preserved populations of covered species. This will be accomplished through monitoring of temporary habitat changes, habitat value, and covered species (p 1-2)." The Conservation Biology Institute's (CBI) analysis help clarify this objective, but it did not change it.	Richness and functional group cover were selected as response variables based on recommendations made in the Franklin et al. documents. Please refer to the annotated bibliography for more information.

Commenter	Agency	Comments	Response
Keith Greer	SANDAG	Suggests: other non-floristic aspects of a site should be documented – bare ground, soil crust, soil types, litter, slope, and aspect may be more indicative of both habitat functioning (e.g., Quino Checkerspot butterfly only occurs in undisturbed, bare ground), or species occurrence (south vs. north slope).	Agreed, richness and cover of functional groups are not the only metrics of interest. They may serve are reasonable surrogates for some of the stated goals/objectives. This is not to suggest that other factors should be discounted, however, it may not be possible to treat those factors as thoroughly as direct vegetation monitoring given our scope of work.
Keith Greer	SANDAG	I believe that Janet Franklin has access to Robert Taylors' Vegetation Type Mapping data on current and historic Coastal Sage Scrub (CSS). Is there a way to take that data, the data that the U.S. Fish and Wildlife Service has collected and will collect during the California Gnatcatcher surveys and other data from the U.S. Geological Survey to increase sample size without additional field work? I would offer that in those years, a combination of remote sensing methods in conjunction with field methods be explored.	Interesting and worth investigating. Again, a little beyond our scope of work.
Keith Greer	SanDag	I believe some graduate school or similar training in the field should be the level that is needed for vegetation monitoring. I have a hard time accepting that you would need taxonomic expertise beyond a first course in native plant taxonomy to conduct the vegetation monitoring to be required.	This is probably true, although it must scale with field experience as well. We might want to try an analysis with all the rare species removed and then compare how close the "inexpert" and "expert" teams are to one another.
Keith Greer	SANDAG	Fire is important, in the context of fire recovery: I have always thought that the vegetation community could be characterized by non-dimensional attributes. Natural variation creates a non-dimensional space of "good" CSS or chaparral. We should then be able to monitor the attributes and see if the sites and any management actions are resulting in changes that lead us away from good CSS/Chaparral or towards it.	

Commenter	Agency	Comments	Response
Tom Oberbauer	SD County	Why was *Gutierrezia* so difficult for people, since it is all over, just in low cover? If this is troublesome it's just the tip of the iceberg since rare species are so patchy and include so many 0's.	We may want to address each rare species and give an explanation of what we think happened (at least in general with rare species) and then make recommendations about when to care and what to do.
John Buegge		Did you re-use the same teams or mix and match?	Teams remained the same throughout the field season.
Clark Winchell		What criterion did you use for determining experience?	Subjective. We may want to do a pre-training test, a post-training test and a post-field season test.
		Slope, soil type, and other abiotic gradients should be measured	This is beyond our scope of work, but it may be something to consider. Slope, aspect, and soil texture are easy enough.
Doug Stowe		Did you use visual aids when doing visual cover RE: projected sheets	No, but this is something to include in the training and method next year, unless we scrap it.
		Annual vs. 3-5 year monitoring power analysis on what we get in return?	We don't have multiple years yet, but the continuation of this project should begin to get at that issue. We suspect that a rotating panel design will work best (we might want to draw up a table that looks like our assumptions RE methods)
Diane Menuz	WRMSHCP	Are any individual teams consistently higher or lower on average for any method?	Some trends exist. The more experienced team was consistently the fastest.
		Who determines the goals and objective of the research and how? How do you determine functional health?	All the stake holders should be involved in this process. This is another opportunity for us to tie back into the last lag program
		Thinks that citizen scientists are more cost effective	The more data the better, but not sure where the non-experts fit in. We need to reiterate again and again that our project is a tool box for starting out a project, not the final method.
		Precision vs. Accuracy	Can sacrifice accuracy for precision, if the bias is predictable. This is a very dangerous process if the bias is unknown or changes over time.

Commenter	Agency	Comments	Response
Mike White	Conservation Biology	During the original writing of the MSCP a regional picture of health was the goal. We intended to have different components to the monitoring effort, in addition to regional site monitoring. Alternative or more targeted methods might be best for emergent invasive plants, rare species, and covered species	One needs to tailor their methods to their questions. RE: Regional vs. reserve scale questions. Our project helps look at optimization criteria.
Clark Winchell		Tom Oberbauer and Mike White were on the original team for the MSCP 15 years ago. They might be able to help us get at what the intended goals and objectives were at that time.	John Tukey said: "data analysis is important. Arriving at the right question… " The point is arriving at the right question is an iterative process
		Will you or can you arrive at adaptive management triggers linked with conservation goals?	Not yet-- need to monitor effects and determine causes. Our project provides a synthetic structure to hang this on.
Bryan Endress	SD Zoo	Plot size/shape: The selection of rectangular and square plots increases the time it takes to set-up plots (squaring plots on steep-rugged terrain!!) while also making it more difficult re-create the plots accurately year-after-year. Why not use a circular plot, with transects radiating from a permanently marked (and GPS'ed) center? I have used square, rectangular, and circular plots in a Great Basin sagebrush and perennial bunchgrass ecosystems, and circular plots are by far the most efficient. The USDA Jornada Experimental Range (New Mexico), published a monitoring manual for grassland, shrubland, and savanna ecosystems in 2005, and the methods work well. They even have datasheets that can be uploaded onto PDA's for data collection and the calculation of summary statistics. They have a website with all of the protocols, datasheets, etc. It is: http://usda-ars.nmsu.edu/Monit_Assess/monitoring_main.php . It is definitely worth looking into, if you have not already seen these.	

Commenter	Agency	Comments	Response
Bryan Endress		The other benefit I see from the sampling protocols developed by USDA is that the sampling is done on 3 transects that radiate out 50m from the center point. Species distributions tend to be clumped in many arid/semi-arid shrub lands, and having transects that radiate out over a larger area, may reduce the variance between different plots at the same site. So, conceivably you could get away with fewer of these plots than with the 20x20m plots you tested. Also with the 20x20m plots, each point-intercept data point was spatially fairly close to the others; in the USDA system, they are spread further apart--which also may pick up more species in addition to reducing the variance within sites for species abundance. Just some thoughts!	
Bryan Endress		If you are looking for more sites to add in the coming year, you would be welcome to explore our coastal sage scrub here at the Wild Animal Park. We have around 600 acres, though much of it burned. I am in the process of setting up 20 permanent plots to monitor vegetation dynamics here and any collaboration would be welcome- just let me know.	

APPENDIX 5: SPECIES LIST

Species	Common	Habit	Origin	Code
	Agavaceae			
Hesperoyucca whipplei	Our Lord's Candle	Shrub	Native	Heswhi
	Alliaceae			
Allium peninsulare	Peninsular Onion	Forb	Native	Allpen
	Anacardiaceae			
Malosma laurina	Laurel Sumac	Shrub	Native	Mallau
Rhus integrifolia	Lemonadeberry	Shrub	Native	Rhuint
Rhus ovata	Sugarbush	Shrub	Native	Rhuova
Toxicodendron diversilobum	Poison Oak	Shrub	Native	Toxdiv
	Apiaceae			
Apiastrum angustifolium	Mock Parsley	Forb	Native	Apiang
Daucus pusillus	Wild Carrot	Forb	Native	Daupus
Foeniculum vulgare	Fennel	Forb	Non-native	Foevul
Sanicula arguta	Sharp-Tooth Sanicle	Forb	Native	Sanarg
	Asteraceae			
Ambrosia psilostachya	Western Ragweed	Forb	Native	Ambpsi
Artemisia californica	California Sagebrush	Shrub	Native	Artcal
Artemisia dracunculus	Tarragon	Forb	Native	Artdra
Artemisia palmeri	Palmer Sagewort	Forb	Native	Artpal
Baccharis pilularis	Coyote Bush	Shrub	Native	Bacpil
Baccharis sarothroides	Broom Baccharis	Shrub	Native	Bacsar
Centaurea melitensis	Tocalote	Forb	Non-native	Cenmel
Chaenactis glabriuscula	Yellow Pincushion	Forb	Native	Chagla
Chrysanthemum coronarium	Crown Daisy	Forb	Non-native	Chrcor
Deinandra species	Tarweed	Forb	Native	Deisp
Encelia californica	Bush Sunflower	Shrub	Native	Enccal
Erigeron foliosus	Fleabane Daisy	Forb	Native	Erifol
Eriophyllum confertiflorum	Golden Yarrow	Forb	Native	Ericon
Filago californica	California Filago	Forb	Native	Filcal
Filago depressa	Dwarf Filago	Forb	Native	Fildep
Filago gallica	Narrow-Leaf Filago	Forb	Non-native	Filgal
Gnaphalium bicolor	Bicolor Everlasting	Forb	Native	Gnabic
Gnaphalium californicum	California Everlasting	Forb	Native	Gnacal
Gutierrezia species.	Matchweed	Shrub	Native	Gutsp
Hazardia squarrosa	Sawtooth Goldenbush	Shrub	Native	Hazsqu
Hedypnois cretica	Crete Weed	Forb	Non-native	Hedcre
Helianthus species	Sunflower	Shrub	Native	Helsp

Species	Common	Habit	Origin	Code
Hypochaeris glabra	Smooth Cat's Ear	Forb	Non-native	Hypgla
Isocoma menziesii	Coastal Goldenbush	Shrub	Native	Isomen
Lactuca serriola	Prickly Lettuce	Forb	Non-native	Lacser
Lasthenia californica	Goldfields	Forb	Native	Lascal
Layia platyglossa	Tidy Tips	Forb	Native	Laypla
Lessingia filaginifolia	California Aster	Forb	Native	Lesfil
Micropus californicus	Slender Cottonweed	Forb	Native	Miccal
Porophyllum gracile	Odora	Shrub	Native	Porgra
Psilocarphus tenellus	Woolly Marbles	Forb	Native	Psiten
Senecio californicus	Butterweed	Forb	Native	Sencal
Sonchus asper	Spiny Sow Thistle	Forb	Non-native	Sonasp
Sonchus oleraceus	Common Sow Thistle	Forb	Non-native	Sonole
Stephanomaria species	Wreath Plant	Forb	Native	Stesp
Stylocline gnaphaloides	Everlasting Nest-Straw	Forb	Native	Stygna
Taraxacum officinale	Dandelion	Forb	Non-native	Taroff
Viguiera laciniata	San Diego Sunflower	Shrub	Native	Viglac
Boraginaceae				
Amsinckia menziesii	Rancher's Fiddleneck	Forb	Native	Amsmen
Cryptantha species	Cryptantha	Forb	Native	Crysp
Eucrypta chrysanthemifolia	Common Eucrypta	Forb	Native	Eucchr
Phacelia cicutaria	Caterpillar Phacelia	Forb	Native	Phacic
Phacelia parryi	Parry Phacelia	Forb	Native	Phapar
Plagiobothrys species	Popcorn Flower	Forb	Native	Plasp
Brassicaceae				
Arabis glabra	Tower Mustard	Forb	Native	Aragla
Brassica nigra	Black Mustard	Forb	Non-native	Branig
Capsella bursa-pastoris	Shepherd's Purse	Forb	Non-native	Capbur
Caulanthus species	Jewel Flower	Forb	Native	Causp
Hirschfeldia incana	Short-Pod Mustard	Forb	Non-native	Hirinc
Isomeris arborea	Bladderpod	Shrub	Native	Isoarb
Lepidium species	Peppergrass	Forb	Native	Lepsp
Sisymbrium irio	London Rocket	Forb	Non-native	Sisiri
Thysanocarpus species	Fringe-Pod	Forb	Native	Thysp
Cactaceae				
Cylindropuntia californica	Snake Cholla	Shrub	Native	Cylcal
Cylindropuntia prolifera	Coast Cholla	Shrub	Native	Cylpro
Ferocactus viridescens	Coast Barrel Cactus	Shrub	Native	Fervir
Opuntia littoralis	Coast Prickly Pear	Shrub	Native	Opulit
Caprifoliaceae				
Lonicera subspicata	Southern Honeysuckle	Shrub	Native	Lonsub
Sambucus mexicana	Blue Elderberry	Shrub	Native	Sammex

Species	Common	Habit	Origin	Code
	Carophyllaceae			
Cardionema ramosissimum	Sand Mat	Forb	Native	Carram
Silene gallica	Windmill Pink	Forb	Non-native	Silgal
	Cistaceae			
Helianthemum scoparium	Yellow Rock-Rose	Shrub	Native	Helsco
	Convolvulaceae			
Calystegia macrostegia	Morning Glory	Vine	Native	Calmac
Cuscuta species	Dodder	Vine	Native	Cussp
Convolvulus arvensis	Bindweed	Vine	Non-native	Conarv
	Crassulaceae			
Crassula connata	Pygmyweed	Forb	Native	Cracon
Dudleya pulverulenta	Chalk-Leaf Dudleya	Forb	Native	Dudpuv
	Cucurbitaceae			
Marah macrocarpus	Wild Cucumber	Vine	Native	Marmac
	Cyperaceae			
Carex species	Sedge	Grass	Native	Carsp
	Ephedraceae			
Ephedra californica	Mormon Tea	Shrub	Native	Ephcal
	Ericaceae			
Xylococcus bicolor	Mission Manzanita	Shrub	Native	Xylbic
	Euphorbiaceae			
Chamaesyce albomarginata	Rattlesnake Spurge	Forb	Native	Chaalb
Chamaesyce mircomera	Sandmat	Forb	Native	Chamic
Chamaesyce polycarpa	Sandmat	Forb	Native	Chapol
Croton californicus	California Croton	Shrub	Native	Crocal
Eremocarpus setigerus	Dove Weed	Forb	Native	Ereset
Euphorbia misera	Cliff Spurge	Shrub	Native	Eupmis
Euphorbia peplus	Petty Spurge	Forb	Non-native	Euppep
Stillingia paucidentata	Stillingia	Shrub	Native	Stipau
	Fabaceae			
Lathyrus vestitus	Wild Pea	Forb	Native	Latves
Lotus scoparius	Deerweed	Shrub	Native	Lotsco
Lotus species	Lotus	Forb	Native	Lotsp
Lupinus bicolor	Miniature Lupine	Forb	Native	Lupbic
Pickeringia montana	Chaparral Pea	Shrub	Native	Picmon
Trifolium species	Clover	Forb	Native	Trisp
Vicia villosa	Winter Vetch	Forb	Non-native	Vicvil
	Fagaceae			
Quercus agrifolia	Coast Live Oak	Tree	Native	Queagr
Quercus berberidifolia	Scrub Oak	Shrub	Native	Queber
Quercus wislizenii	Scrub Live Oak	Shrub	Native	Quewis

Species	Common	Habit	Origin	Code
		Geraniaceae		
Erodium species	Filaree or Stork's Bill	Forb	Non-native	Erosp
Geranium californicum	California Geranium	Forb	Native	Gercal
		Grossulariaceae		
Ribes indecorum	Winter Current	Shrub	Native	Ribind
		Hyacinthaceae		
Chlorogalum species	Soap Plant	Forb	Native	Chlsp
		Lamiaceae		
Salvia apiana	White Sage	Shrub	Native	Salapi
Salvia columbariae	Chia	Forb	Native	Salcol
Salvia mellifera	Black Sage	Shrub	Native	Salmel
Trichostema lanatum	Woolly Blue Curls	Shrub	Native	Trilan
		Liliaceae		
Calochortus species	Mariposa Lily	Forb	Native	Calsp
		Malvacea		
Malacothamnus fasciculatus	Bushmallow	Shrub	Native	Malfas
		Melanthiaceae		
Zigadenus fremontii	Death Camas	Forb	Native	Zigfre
		Nyctaginaceae		
Mirabilis laevis	Wishbone Bush	Forb	Native	Mirlae
		Onagraceae		
Camissonia bistorta	California Sun Cup	Forb	Native	Cambis
Camissonia californica	California Primrose	Forb	Native	Camcal
Camissonia hirtella	Field Sun Cup	Forb	Native	Camhir
Clarkia purpurea	Wine-Cup Clarkia	Forb	Native	Clapur
		Orobanchaceae		
Castilleja affinis	Coast Paintbrush	Forb	Native	Casaff
Castilleja applegatei	Pine Paintbrush	Forb	Native	Casapp
Castilleja exserta	Purple Owl's Clover	Forb	Native	Casexs
Cordylanthus rigidus	Dark-Tip Bird's Beak	Forb	Native	Corrig
		Oxalidaceae		
Oxalis pes-caprae	Bermuda Buttercup	Forb	Non-native	Oxapes
		Paeoniaceae		
Paeonia californica	California Peony	Forb	Native	Paecal
		Papaveraceae		
Dicentra chrysantha	Golden Eardrops	Forb	Native	Dicchr
Eschscholzia californica	California Poppy	Forb	Native	Esccal
		Phrymaceae		
Keckiella antirrhinoides	Yellow Bush Penstemon	Shrub	Native	Kecant
Mimulus aurantiacus	Bush Monkeyflower	Shrub	Native	Mimaur
		Plantaginaceae		

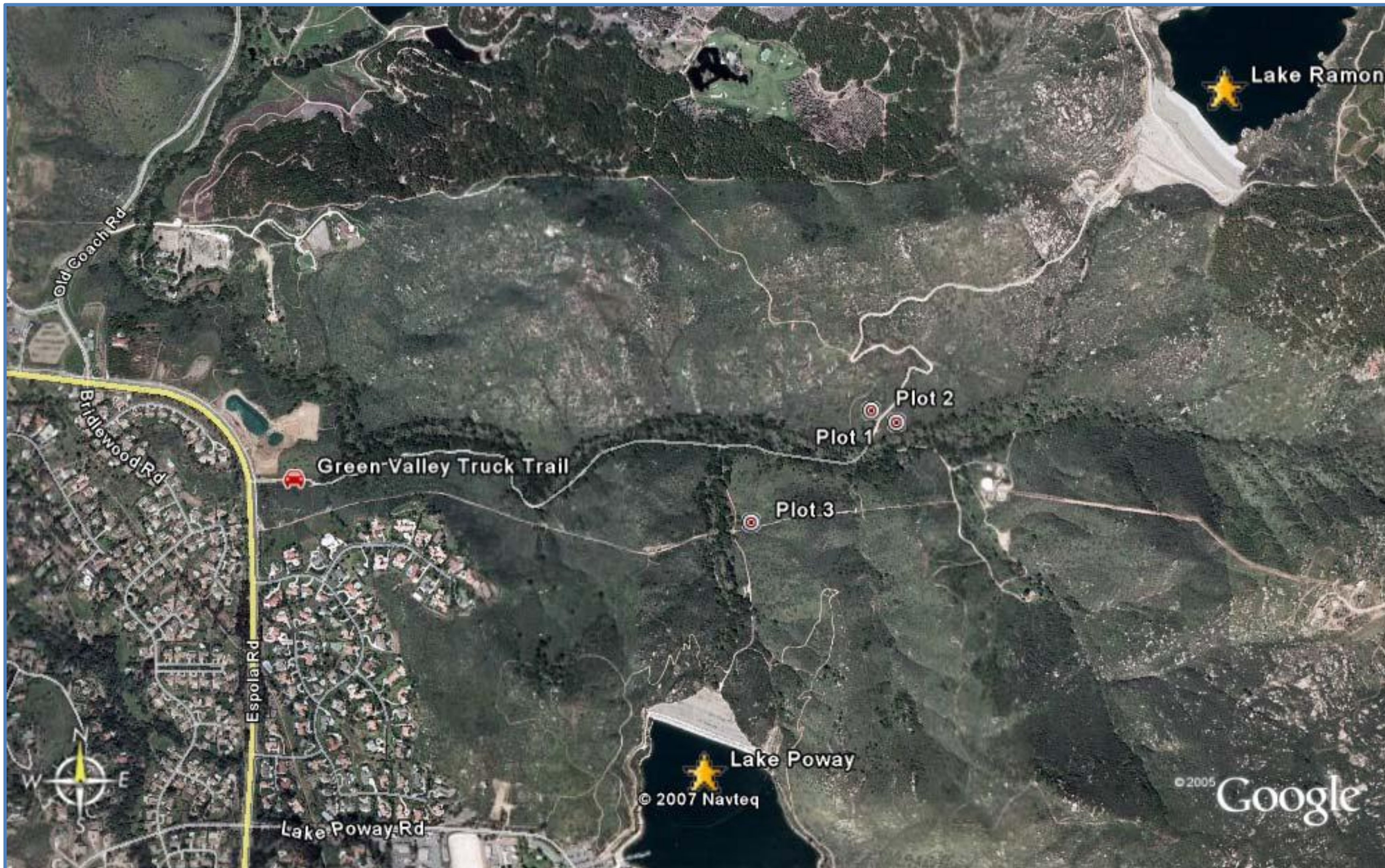
Species	Common	Habit	Origin	Code
Plantago erecta	California Plantain	Forb	Native	Plaere
		Poaceae		
Agrostis exarata	Bent Grass	Grass	Native	Agrexa
Aristida purpurea	Three-Awn	Grass	Native	Aripur
Avena species	Wild Oats	Grass	Non-native	Avesp
Brachypodium distachyon	Purple False-Brome	Grass	Non-native	Bradis
Bromus diandrus	Ripgut Brome	Grass	Non-native	Brodia
Bromus hordeaceus	Soft Chess Brome	Grass	Non-native	Brohor
Bromus madritensis	Red Foxtail Brome	Grass	Non-native	Bromad
Cynodon dactylon	Bermuda Grass	Grass	Non-native	Cyndac
Distichlis spicata	Saltgrass	Grass	Native	Disspi
Gastridium ventricosum	Nitgrass	Grass	Non-native	Gasven
Hordeum murinum	Glaucous Barley	Grass	Non-native	Hormur
Lamarckia aurea	Toothbrush Grass	Grass	Non-native	Lamaur
Melica imperfecta	Coast Melic	Grass	Native	Melimp
Muhlenbergia rigens	Deergrass	Grass	Native	Muhrig
Nassella species	Needlegrass	Grass	Native	Nassp
Vulpia myuros	Rat-Tail Fescue	Grass	Non-native	Vulmyu
		Polemoniaceae		
Linanthus dianthiflorus	Ground Pink	Forb	Native	Lindia
		Polygonaceae		
Chorizanthe fimbriata	Fringed Spineflower	Forb	Native	Chofim
Eriogonum fasciculatum	California Buckwheat	Shrub	Native	Erifas
Pterostegia drymarioides	Granny's Hairnet	Forb	Native	Ptedry
		Portulacaceae		
Claytonia perfoliata	Miner's Lettuce	Forb	Native	Claper
		Primulaceae		
Anagallis arvensis	Scarlet Pimpernel	Forb	Non-native	Anaarv
		Pteridaceae		
Pellaea andromedifolia	Coffee Fern	Forb	Native	Peland
Pellaea mucronata	Bird's Foot Fern	Forb	Native	Pelmuc
Pentagramma triangularis	Silverback Fern	Forb	Native	Pentri
		Ranunculaceae		
Thalictrum fendleri	Meadowrue	Forb	Native	Thafen
		Rhamnaceae		
Ceanothus crassifolius	Thick-Leaf Ceanothus	Shrub	Native	Ceacra
Ceanothus leucodermis	Chaparral Whitethorn	Shrub	Native	Cealeu
Ceanothus tomentosus	Ramona Lilac	Shrub	Native	Ceatom
Ceanothus verrucosus	Warty-Stem Ceanothus	Shrub	Native	Ceaver
Rhamnus crocea	Spiny Redberry	Shrub	Native	Rhacro
Rhamnus ilicifolia	Holly-Leaf Redberry	Shrub	Native	Rhaili

Species	Common	Habit	Origin	Code
	Rosaceae			
Adenostoma fasciculatum	Chamise	Shrub	Native	Adefas
Cercocarpus minutiflorus	Mountain Mahogany	Shrub	Native	Cermin
Heteromeles arbutifolia	Toyon Berry	Shrub	Native	Hetarb
	Rubiaceae			
Galium angustifolium	Narrow-Leaf Bedstraw	Forb	Native	Galang
Galium aparine	Common Bedstraw	Forb	Non-native	Galapa
Galium californicum	El Dorado Bedstraw	Forb	Native	Galcal
Galium nuttallii	San Diego Bedstraw	Forb	Native	Galnut
	Rutaceae			
Cneoridium dumosum	Spice Bush	Shrub	Native	Cnedum
	Selaginellaceae			
Selaginella bigelovii	Bigelow Spike-Moss	Forb	Native	Selbig
Selaginella cinerascens	Ashy Spike-Moss	Forb	Native	Selcin
	Simmondsiaceae			
Simmondsia chinensis	Jojoba	Shrub	Native	Simchi
	Solanaceae			
Lycium andersonii	Box Thorn	Shrub	Native	Lycand
Solanum parishii	Parish Nightshade	Forb	Native	Solpar
	Themidaceae			
Dichelostemma capitatum	Blue Dicks	Forb	Native	Diccap
Muilla maritima	Common Muilla	Forb	Native	Muimar
	Violaceae			
Viola species	Violet	Forb	Native	Viosp

APPENDIX 6: SITE MAPS AND COORDINATES

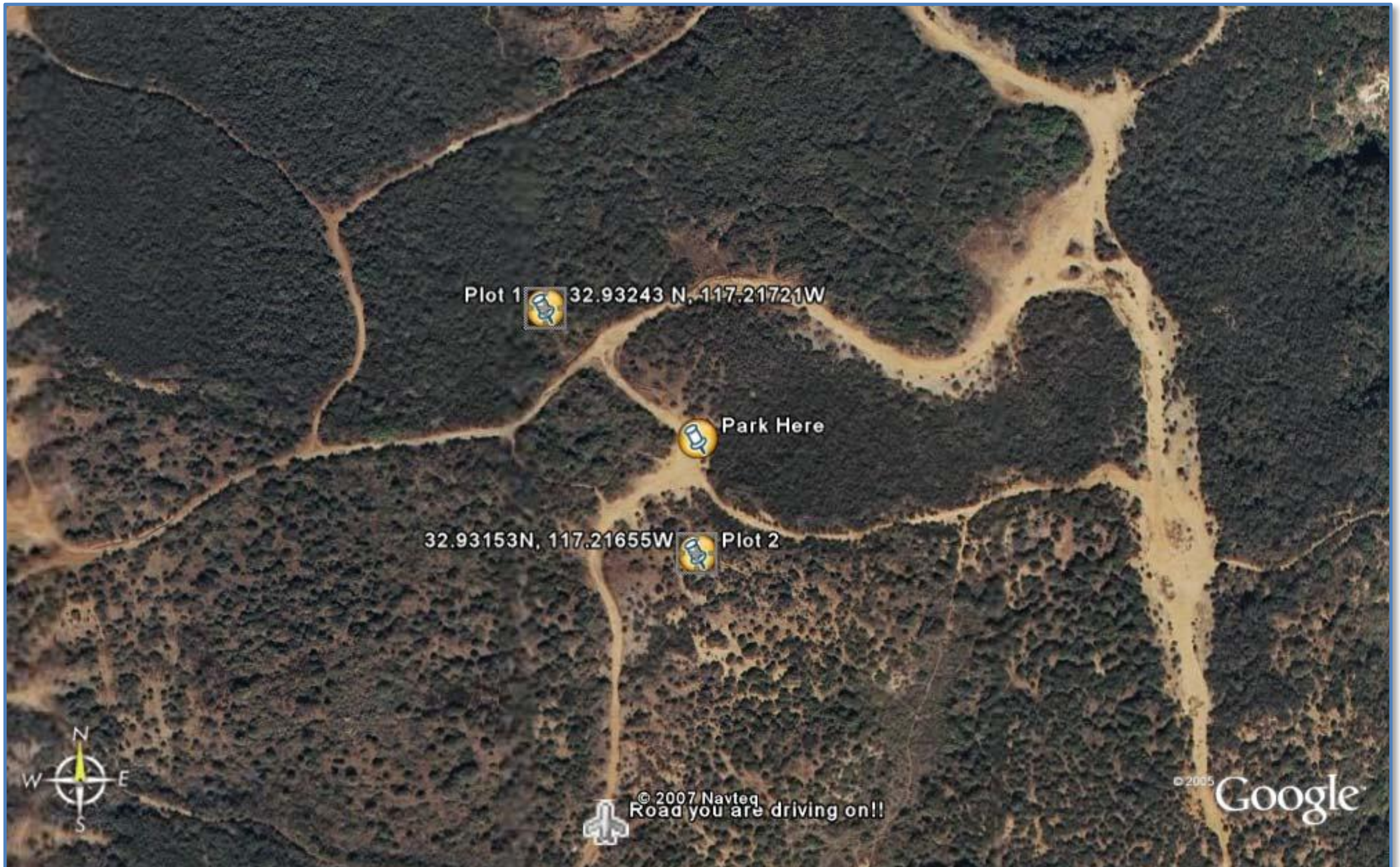
Site	Plot	Lat N	Lon W	Elevation
Blue Sky	1	33.01720	117.00500	220 m
	2	33.01749	117.00575	221 m
	3	33.01475	117.00927	222 m
Boden Canyon	1	33.09172	116.89569	231 m
	2	33.09017	116.89610	248 m
	3	33.08739	116.90470	261 m
Carmel Mountain	1	32.93243	117.21721	127 m
	2	32.93153	117.21655	123 m
Crestridge	1	32.82380	116.88672	350 m
	2	32.82056	116.87711	407 m
	3	32.82742	116.87166	451 m
Lake Hodges	1	33.05178	117.08072	120 m
	2	33.05042	117.07922	112 m
	3	33.05310	117.07887	129 m
Los Montanas	1	32.72608	116.89550	242 m
	2	32.72472	116.89515	276 m
	3	32.72250	116.89500	234 m
Marron Valley	1	32.57378	116.75388	175 m
	2	32.56688	116.75832	192 m
	3	32.57304	116.75921	172 m
Tijuana River	1	32.54420	117.07583	30 m
	2	32.54221	117.10162	74 m
	3	32.54371	117.09886	93 m

Blue Sky Ecological Reserve:

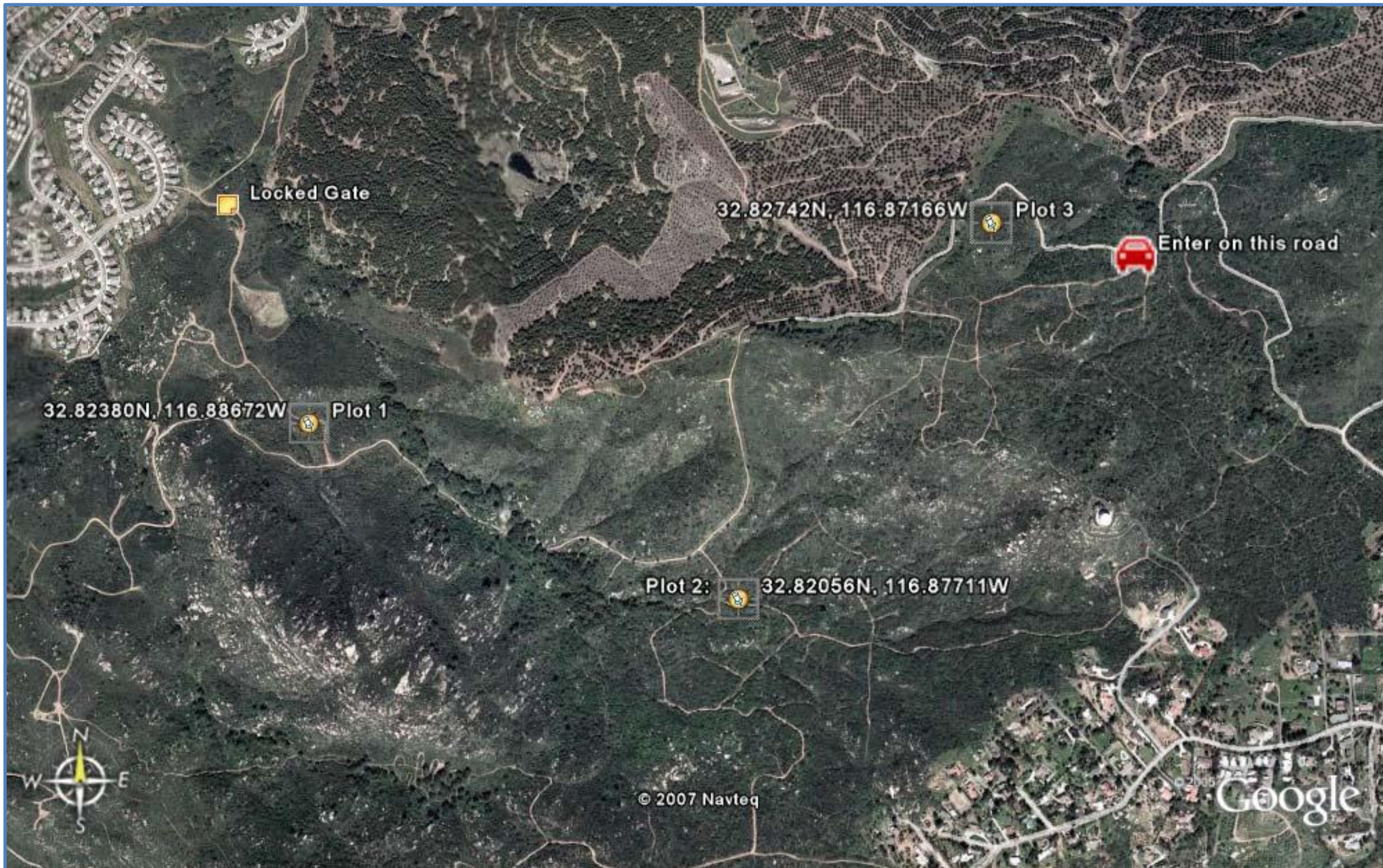


Boden Canyon:

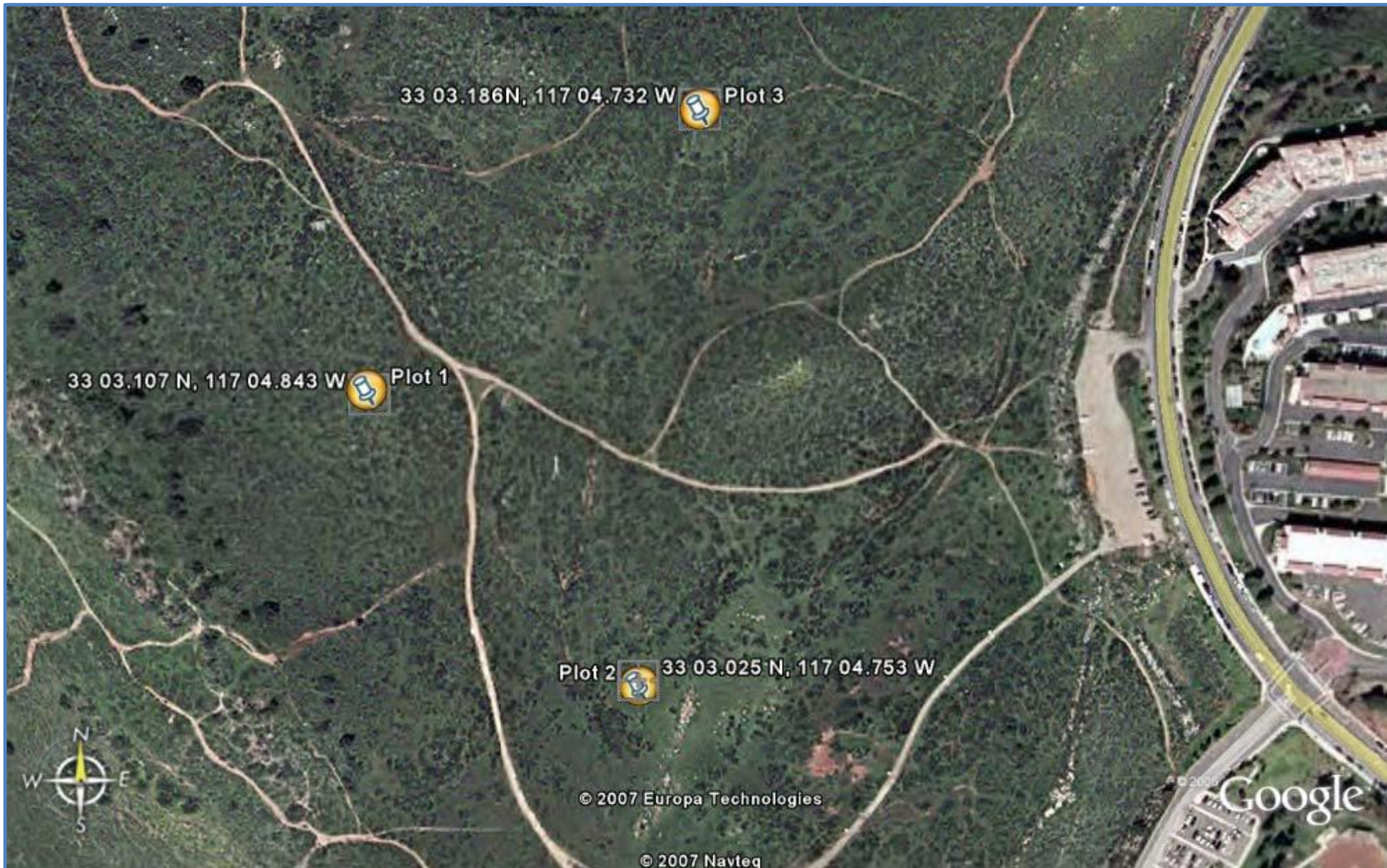
Carmel Mountain:



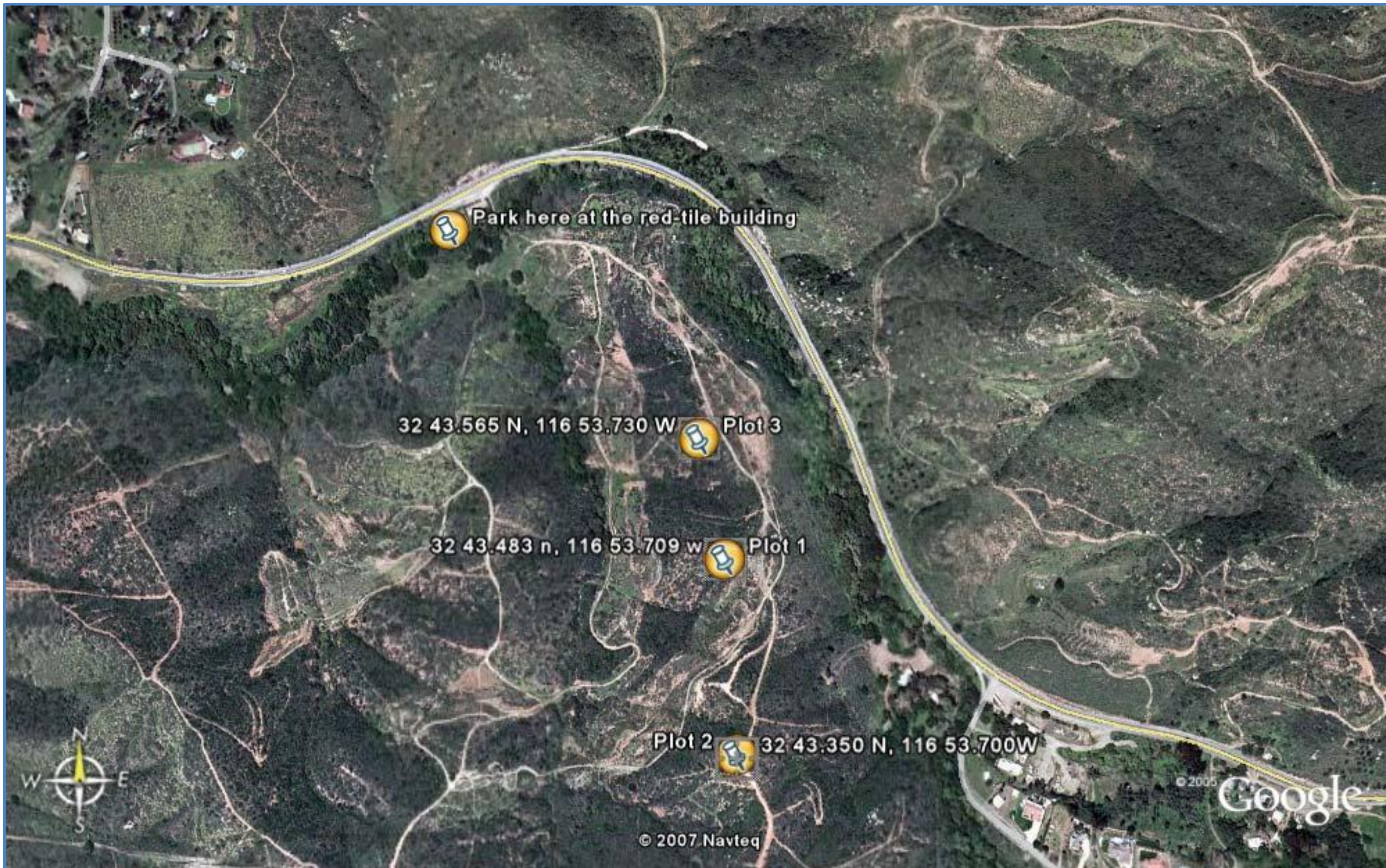
Crestridge:


Locked Gate
32.82742N, 116.87166W
Plot 3
Enter on this road
32.82380N, 116.88672W
Plot 1
Plot 2:
32.82056N, 116.87711W
N
W
E
S
© 2007 Navteq
Google

Lake Hodges:

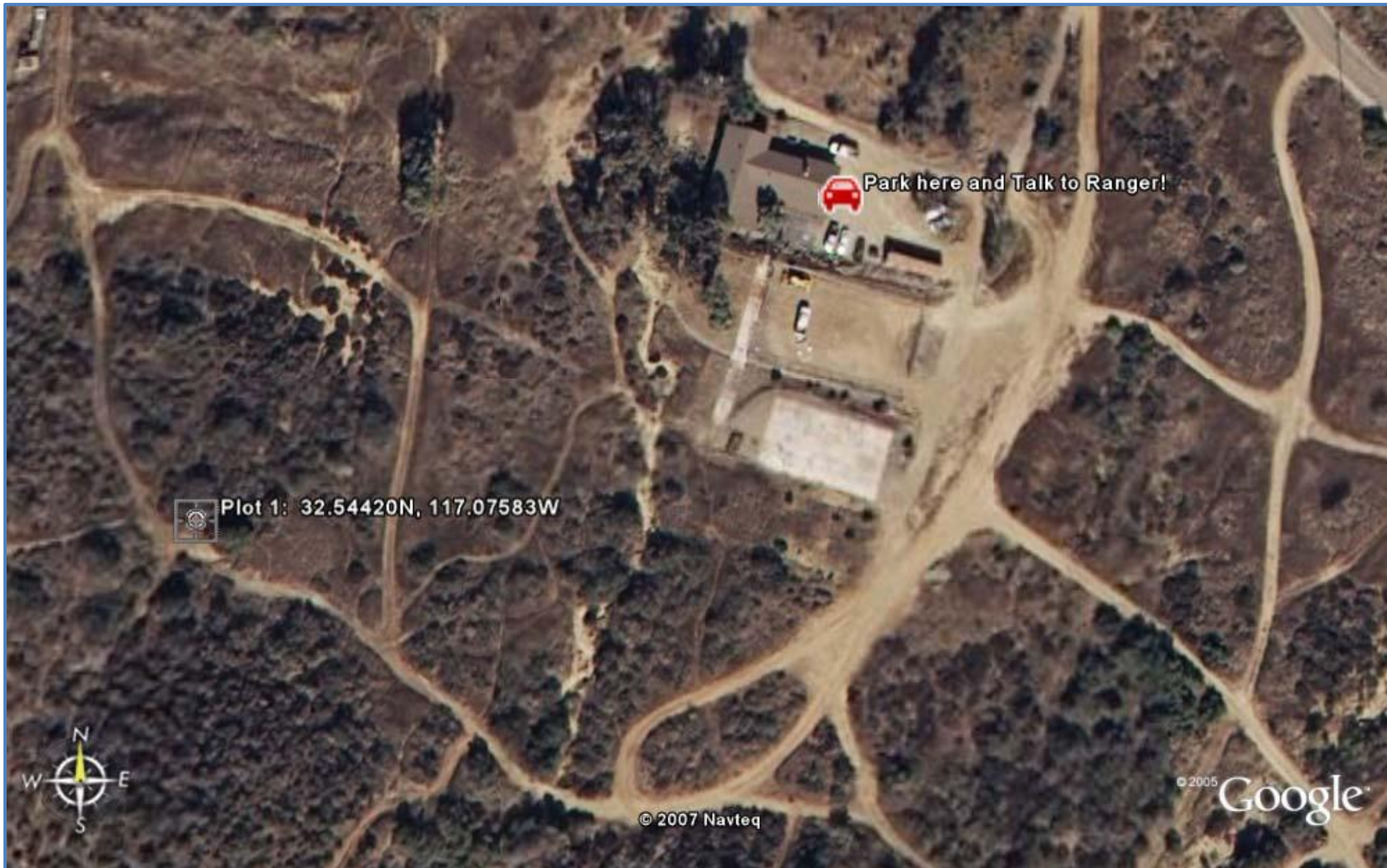

33 03.186N, 117 04.732 W
Plot 3
33 03.107 N, 117 04.843 W
Plot 1
Plot 2
33 03.025 N, 117 04.753 W
© 2007 Europa Technologies
© 2007 Navteq
Google

Los Montanas:

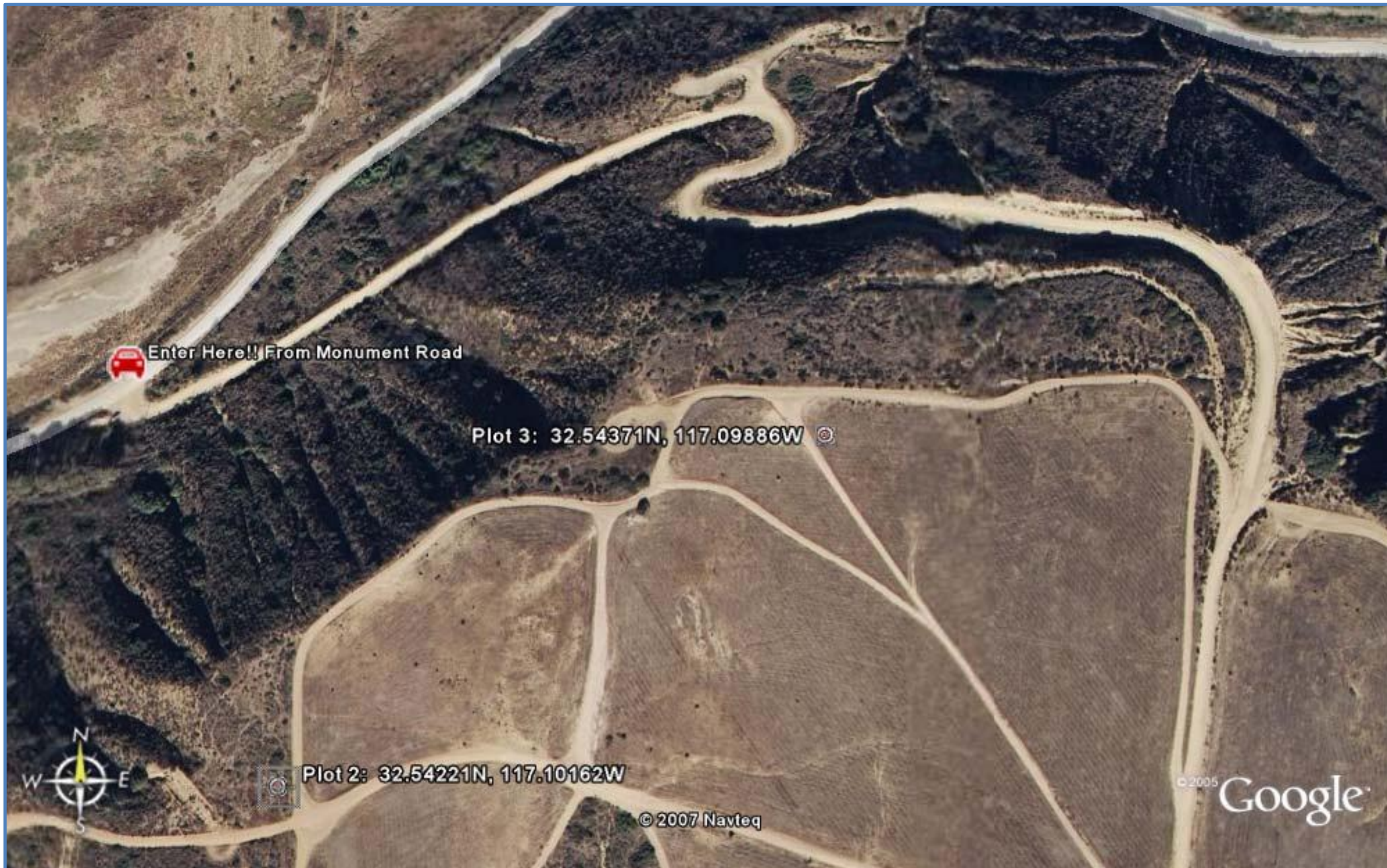


Marron Valley

Tijuana River (Valley):



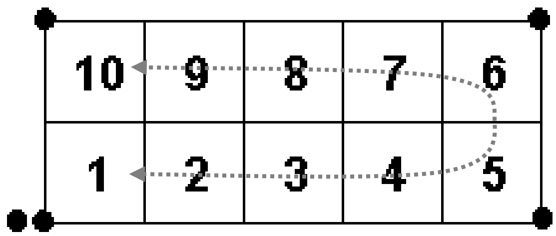
Tijuana River (Goat Mesa):



APPENDIX 7: DATA SHEETS

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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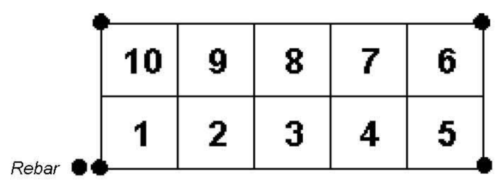
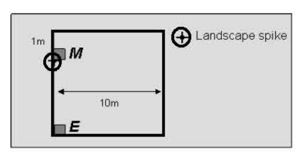
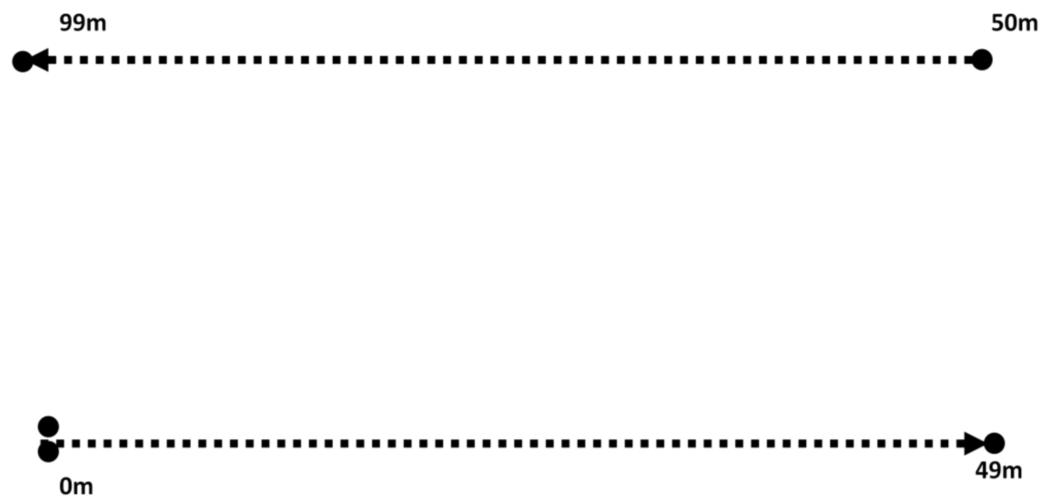




Point Intercept Transect Data Sheets:

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	

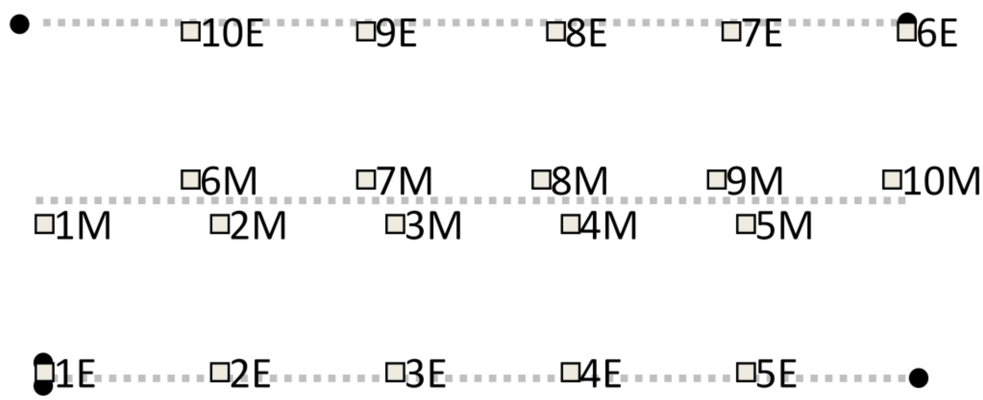
Transect 2

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

E

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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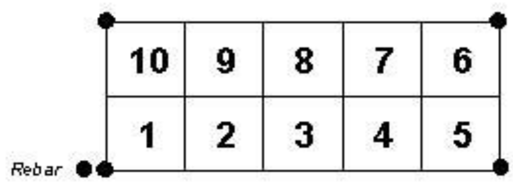

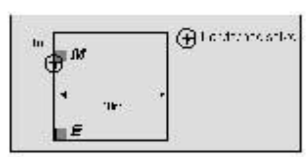

Quadrats

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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