Improving Statistical Sampling and Vegetation Monitoring the San Diego MSCP

2008 Final Report

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Executive Summary

San Diego's Multiple Species Conservation Program (MSCP) intends to conserve the diversity and function of the southwestern San Diego County ecosystem through preservation and adaptive management of habitat. Monitoring this large network of land is scientifically and logistically challenging as well as costly. The objective of this project is to evaluate the cost and accuracy of different sampling designs and field protocols for monitoring coastal sage scrub (CSS) and chaparral vegetation communities.

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

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

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

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

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INTRODUCTION

San Diego's Multiple Species Conservation Program (MSCP) intends to conserve the diversity and function of the southwestern San Diego County ecosystem through preservation and adaptive management of habitat. The MSCP also aims to conserve 85 specific "covered" species. The reserve system currently includes over 127,000 acres 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 wildlife agencies such as U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Game (CDFG), and U.S. Geological Survey.

Monitoring is a required element of all HCP and NCCP permits and is critical to assess whether large-scale multi-species programs are meeting their stated objectives (Atkinson, Trenham et al. 2004; Barrows, Swartz et al. 2005; Rahn, Doremus et al. 2006). San Diego's Multiple Species Conservation Program (Final MSCP Plan dated August 1998) describes two primary biological goals:

- Conserve the diversity and function of the ecosystem through the preservation and adaptive management of large blocks of interconnected habitat and smaller areas that support rare vegetation communities (e.g. vernal pools).
- Conserve specific species at levels that meet the take authorization issuance standards of the federal Endangered Species Act and California's Natural Community Conservation Planning Act.

These broad goals are discussed in more detail the final plan. The final plan identified several objectives for biological monitoring including inventories of biodiversity, documenting ecological trends, evaluating the effectiveness of management activities and providing new data on species populations (Larsen, Kinkaid et al. 2001; McDonald 2003; Legg and Nagy 2006). The wildlife agencies (USFWS and CDFG) are responsible for coordinating the monitoring program.

MONITORING ECOLOGICAL CHANGE

Monitoring to detect ecological change is an important component of many environmental and conservation programs. Developing effective monitoring programs for conservation plans is scientifically and logistically challenging (Fuller 1999; Atkinson, Trenham et al. 2004) and many monitoring programs have been criticized as naïve, inefficient, and in many cases, inadequate (NRC 1995; Legg and Nagy 2006; Rahn, Doremus et al. 2006). The science of ecological monitoring has improved in response to the criticism of earlier efforts (McDonald 2003; Atkinson, Trenham et al. 2004; Legg and Nagy 2006).

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

The sampling design must address several related questions.

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

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

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

The response design is defined as determining what to measure, count or observe (Stevens and Urquhart 2000). The response design is often more closely linked to the specific questions being asked (Larsen, Kinkaid et al. 2001). Common response designs for vegetation sampling include visual estimation (Sykes, Horrill et al. 1983; Mitchell, Bartling et al. 1988; Sawyer and Keeler-Wolf 1995; Carlsson, Bergfur et al. 2005, but see Klimes 2003; Podani 2006; Podani and Csonotos 2006), quadrats (Stohlgren, Bull et al. 1998; Keeley and Fotheringham 2005; Ringvall, Petersson et al. 2005; Archaux, Gosselin et al. 2006), transect or belt transect (Grant, Madden et al. 2004), or line-intersect (Floyd and Anderson 1987; Stevens and Urquhart 2000; Kercher, Frieswyk et al. 2003). There is tendency among statisticians to overlook the importance of the interaction between the sampling design and the response design. For example, Larsen et al (2001) note "we generally assume that response design issues have been dealt with responsibly, consistent with the organism or phenomenon under consideration …" (Page 1070). However, the choice of what to measure and how to measure it can have enormous impact on the sampling design.

PREVIOUS MONITORING EFFORTS

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 reviewed the existing San Diego MSCP Biological Monitoring Plan and its implementation and assessed the status of the program relative to the critical steps for monitoring program development identified by Atkinson et al. (2004; see Figure 1). 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).

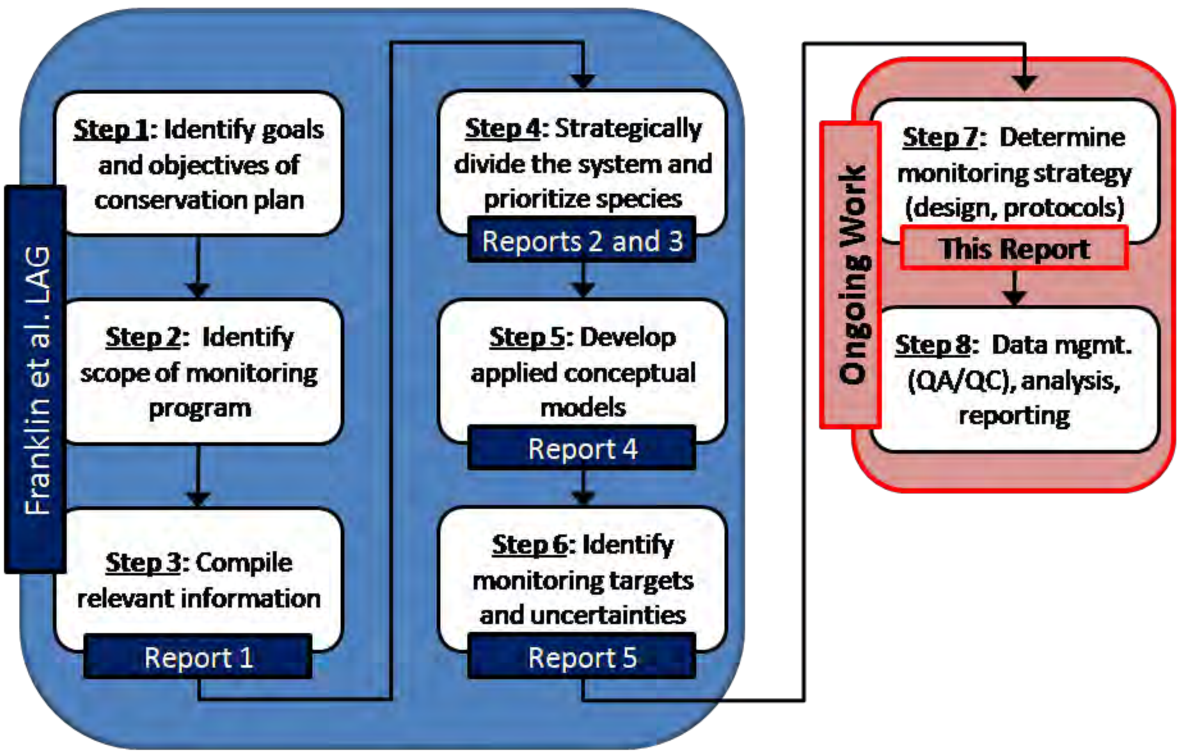

Figure 1: *Stepwise evaluation of the BMP based on the Atkinson et al. (2004) technical report. Steps 3 through 6 were implemented as part of the previous LAG to Franklin et al. (#P0450009). This report focuses on Step 7, determining monitoring strategy.*

Goals of this Project

The objective of this project is to evaluate the accuracy of different sampling designs and field protocols for monitoring Coastal Sage Scrub (CSS) and chaparral vegetation communities. In particular, we will refine our understanding of the relative strengths and weaknesses of alternative protocols as well as their cost. We also characterize spatial and temporal variability in order to provide guidance for developing and efficient sampling design.

This project builds on the Franklin, Regan and Deutschman LAG project funded by CDFG (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). This report follows and elaborates on ideas presented in two earlier reports submitted to CA DFG (Deutschman, Franklin, and Lewison - Agreement # P0685105; Deutschman – Agreement # P0782006).

This project was conducted concurrently with a project by the authors in Orange County, using the same techniques and with the same goals. In addition the authors collaborated with western Riverside's MSHCP monitoring program to sample the same vegetation types using the same techniques. For the final variance components analysis the data from all three projects is pooled to increase the sample size, as well as to address regional monitoring challenges. This report is structured to provide site specific reviews of the vegetation communities in San Diego County, but uses the data from the other two projects in the final variance components analysis. Information presented in the "CSS sites", "chaparral sites", "site visits" and "vegetation community" sections are for San Diego County only. Data from San Diego, Orange and Riverside Counties were analyzed together in the "Variance components analysis" section and helped us develop our conclusions and recommendations.

Field Sampling Design

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

Our primary goal this year was to get better spatial coverage across the San Diego County. Plots were selected using a stratified random design. Points were buffered to be located between 30m and 300m of an accessible road, and under a 35 percent slope. A great number more points were generated in order to provide back-up locations if any given point was deemed unsafe or inappropriate for work (re: wrong vegetation type) and for future monitoring. This year we sampled 13 (8 CSS and 5 chaparral) sites using a total of 70 plots throughout San Diego County (see

Figure 2 and Appendix A). Of the original 8 sentinel sites monitored in San Diego in 2007, 3 CSS and 1 chaparral burned in the October 2007 wildfires (Table 1).

Overall, 67 percent of our sites in San Diego County were new this year and these additional sites will provide an excellent opportunity to refine our understanding of spatial and methodological variability. In addition 23 percent of plots in San Diego were sampled by 2 teams, which will allow us to continue exploring team to team variability. Unfortunately, the distribution of the fire across the sentinel sites unbalanced our original experimental design in that more CSS plots were lost than chaparral plots. This will weaken the precision with which we can describe temporal change. Our field protocols were selected to capture a number of response variables, including the richness of the vegetation being sampled and the cover of different species and functional groups.

Coastal Sage 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

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. Our sentinel plots at Blue Sky burned in the 2007 wildfires.

Lake Hodges

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. Our sentinel plots at Lake Hodges burned in the 2007 wildfires.

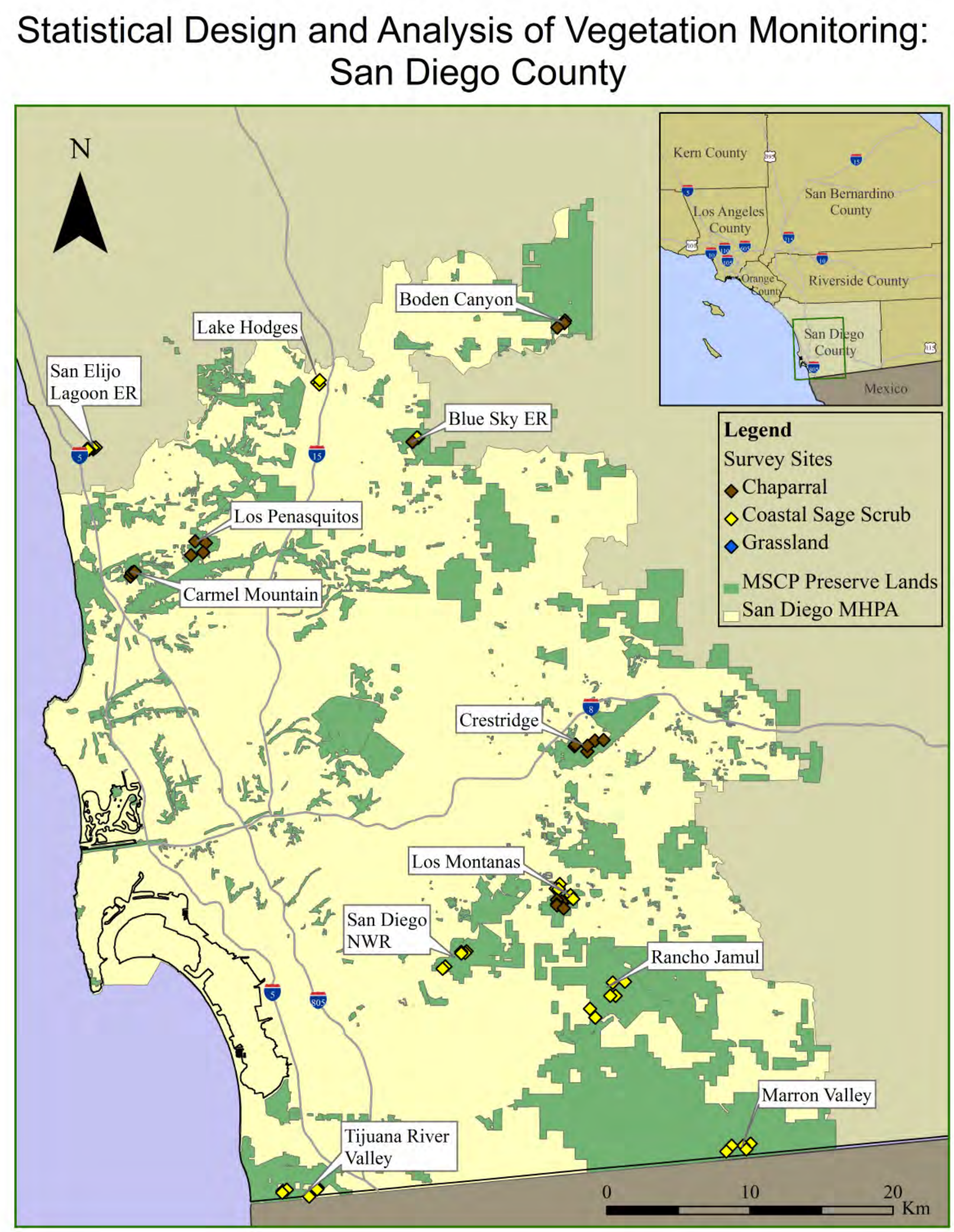

Figure 2: *Location of CSS and chaparral plots in San Diego County. Yellow diamonds mark the location of plots in CSS and olive diamonds mark the locations of chaparral plots.*

Vegetation Community and Site	New Plots	Sentinel Plots	Total Plots	Burned Plots	Double sampled
Coastal Sage Scrub	**32**	**12**	**44**	**25**	**9**
Blue Sky ER		3	**3**	3	
Lake Hodges		3	**3**	3	
Los Montanas, CSS	6		**6**		2
Marron Valley	4	3	**7**	7	
Rancho Jamul ER	6		**6**	6	3
San Diego NWR	6		**6**	6	
San Elijo Lagoon ER	7		**7**		2
Tijuana Estuary	3	3	**6**		2
Chaparral	**15**	**11**	**26**	**3**	**7**
Boden Canyon		3	**3**	3	
Carmel Mountain	4	2	**6**		2
Crestridge	3	3	**6**		2
Los Montanas, chaparral	4	3	**7**		3
Penasquitos	4		**4**		
Total:	**47**	**23**	**70**	**28**	**16**
Proportion	**67%**	**33%**		**40%**	**23%**

Table 1: *2008 site and plot breakdown. Almost all sentinel CSS plots were lost in the 2007 fires, and were replaced with other un-burned sites. Although the new sites provide a data for spatial and methodological variance components analysis, we did lose power to describe temporal variation*

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MARRON VALLEY

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. We have had significant safety issues at this site and we now sample the site only with larger groups of researchers.

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 high densities of this plant, as it is unclear what the effect of our methods could be on the larvae and its host plant.

The 2007 Harris fire burned into this area. Our sentinel plots were located on the edge of the published fire perimeter map, and it was unclear prior to our single site visit if they had burned. We decided to sample the site fully in 2008 (revisiting sentinel plots and establishing new plots), and found that the entire valley had burned.

Rancho Jamul Ecological Reserve

Rancho Jamul Ecological Reserve was acquired by the California Department of Fish and Game between 1998 and 2001 as a part of the San Diego MSCP. Rancho Jamul is located in south eastern San Diego County, and is spatially connected to the Otay Mountain Wilderness Area (BLM), Hollenbeck Canyon Wildlife Area (DFG) and the Sweetwater unit of the San Diego National Wildlife Refuge (USFWS), another of our new sampling sites this year.

Rancho Jamul contains CSS, chaparral and native grassland communities. The habitat quality of these communities may have been altered by the Otay Fire of 2003 and the subsequent Harris fire in 2007.

San Diego National Wildlife Reserve: Los Montanas North

The Los Montanas section of SDNWR is administered as part of the San Diego MSCP (USFWS 2006). This site is located just north of SR-94, and is part of a large swath of open space in southeastern San Diego County that connects RJER, the Sweetwater unit of SDNWR, Hollenbeck Canyon, Marron Valley and the Otay Wilderness. This site was sampled for CSS for the first time in 2008. A large patch of chaparral south of the 94 was sampled last year. The chaparral site was referenced as "Los Montanas" in last year's reports. We now refer to the chaparral site as "Los Montanas South".

San Diego National Wildlife Reserve: Sweetwater Unit

The Sweetwater unit of SDNWR is located just south of Sweetwater Reservoir, and is managed by FWS as part of the San Diego MSCP. The Sweetwater unit burned in 2007 in the Harris fire. Like many of the sites in south eastern San Diego County Sweetwater is part of a large swath of open space administered and owned by a number of different entities.

San Elijo Lagoon Regional Park

The San Elijo Lagoon is one of the few remaining wetlands in southern California, and as such is critically important as a lay-over point for migratory birds. The regional park surrounds the Lagoon in north western San Diego County and provides recreational opportunities for the communities of Solana Beach and Encinitas. SERP is not included in the foot print of the San Diego MSCP, however, it was selected for monitoring because there is are few undeveloped CSS sites close to the coast in San Diego County.

Tijuana River Valley Regional Park

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* species, and *Rhamnus*.

Boden Canyon Ecological Reserve

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 footprint. 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. Boden Canyon was the only chaparral sentinel site that burned in 2007.

Carmel Mountain and Del Mar Mesa Preserve

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

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. Our plots at Crestridge are recovering from fire and have a diverse mix of early and mid-successional plants.

Los Penasquitos Canyon Preserve

Los Penasquitos Canyon Preserve is 4,000 acres jointly owned and administered by the city and county of San Diego (Diego). The canyon contains both CSS and Chaparral vegetation types in addition to various oak and sycamore riparian areas. For our purposes, plots were located on the northern slope and rim of the canyon park, approximately half way between the park entrance in the community of Rancho Penasquitos and Torrey Pines State Beach, where the river empties into a coastal Lagoon (the end of Park Village Rd.).

San Diego National Wildlife Refuge: Los Montanas South

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. The 2007 Harris fire burned near this site, but did not burn our sentinel plots.

Response Design and Field Protocols

Our field protocols were selected to capture a number of biologically relevant measures of habitat quality, including the richness of the vegetation being sampled and the cover of different species and functional groups. In 2007 we used a modified 0.1ha Keeley plot (Keeley and Fotheringham 2005) which included sub-plots for visual cover estimates. This year we eliminated visual cover sub-plots because they were of limited value at the scale we used them. We also reduced the length of the transect (from 100m to 50m) and the number of quadrats (from 20 to 10; See Figure 3).

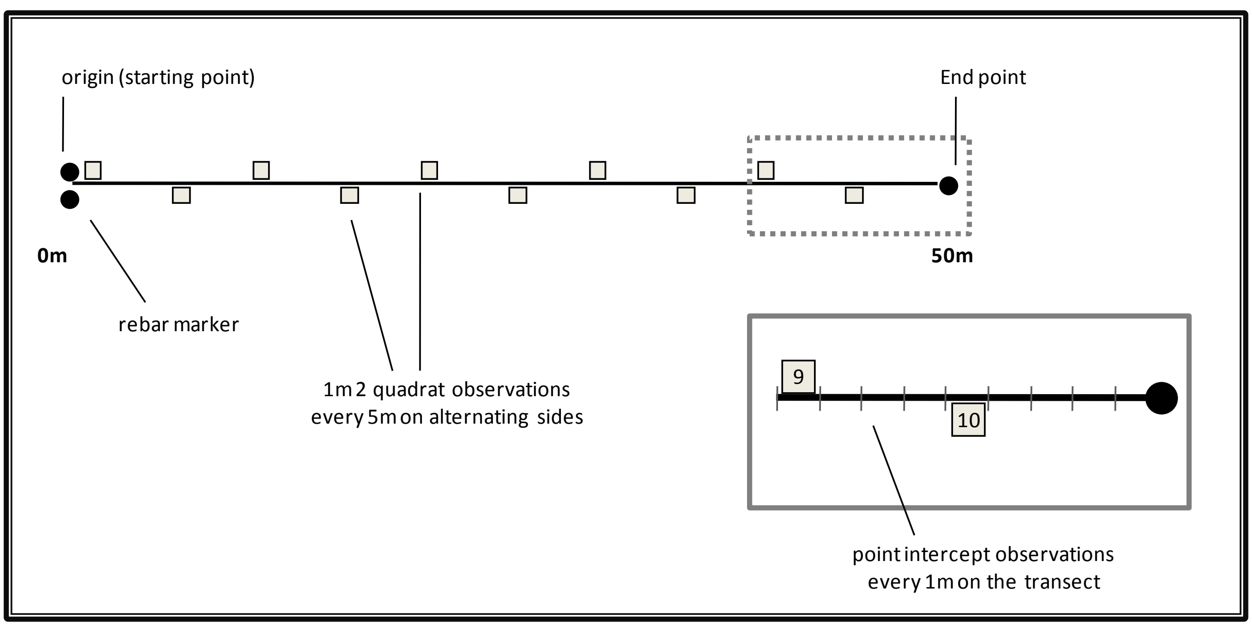

Figure 3: *Transect plot design. Each plot measured 50m in length. A single 50m point intercept transect took measurements every 1m, starting at 0m. Quadrats were read for percent cover every 5m starting at 0m.*

Point intercept sampling was used on the modified 50m transect with observations made every 1m starting at zero. Quadrats were read every five meters on alternating sides, starting on the left (Figure 3; Figure 4). This allowed us to compare the two different protocols at the same exact location. Both data collection protocols were used at every plot. In order to reduce learning bias, teams collected their data in a strict sequence. First, teams used point intercept transects. During transects, teams did not spend time looking for hidden or cryptic species except for those touching the pole. Second, teams placed the ten $1m^2$ quadrats on alternating sides of the transect, and tried to capture every species inside the quadrat frame.

Figure 4: *Implementation of the two protocols, point-intercept, and quadrats.*

Transects

Point intercept transects tend to under represent very uncommon species, but perform equally well when compared to line and other transect techniques in all other regards, and do so with significant time savings (Elzinga, Salzer et al. 2001). Of the many transect techniques available, we decided on point intercept because it minimizes decision making time by the field teams. During a point intercept transect the observer drops a dowel perpendicular to the meter tape at a predetermined distance (in our case every 1 meter). Each species and ground cover the dowel touches is recorded for that point (note that multiple species at one point can yield over 100% absolute cover). Absolute cover is calculated for this method by dividing the total number of hits for each species, by the total number of points on the transect. This technique also records ground cover, even when overgrown by canopy plants.

Quadrats

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

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

RESPONSE VARIABLES

Based on previous work conducted for the San Diego MSCP by Franklin et al. (Franklin 2006)and Deutschman et al. (Deutschman 2007), we selected four key types of response variables to perform our data analysis on: species richness, the cover of different plant functional groups (such as native shrubs and exotic forbs), the cover of individual species (e.g. *Eriogonum fasciculatum, Artemisia californica, Erodium botrys, Nassella pulchra*), and the cost (as estimated by hours worked). Species richness was a simple count of the number of species detected in each plot. Absolute cover estimates for functional groups and individual species were calculated by averaging the cover in each quadrat for the entire plot, and evaluated at the plot level. Absolute cover for transects was calculated by dividing the number of hits each functional group or species had on the transect by the total number of possible hits (e.g. by 50 for 50m transects). Relative cover, which is calculated and interpreted slightly differently, was not used for this study, but can easily be calculated from our baseline data set.

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

FIELD WORK PERFORMED

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

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

Site Visits

Training for all teams began on February 25th and was completed on March 1st (Table 2). Due to rain earlier in the season, sampling was possible in the southern portion of San Diego beginning in the first week of March. Visits to any given site were completed by most teams within a 1-week period in order to avoid minimize phenological change. The only exceptions to this were visits made to chaparral plots in Los Montanas and Carmel Mountain to increase our sample size two weeks after the first series of plot visits. These sites had a relatively small annual component when compared to most other sites, which limits the risk of misidentifying phenological changes. Where access permission permitted we tried to work from the south to the north of the county during the peak of the growing season at each site. Unburned sites were sampled prior to visiting burned sites regardless of latitude.

	March				April				May
	1	2	3	4	1	2	3	4	1
Training	A								
TJ	2 1 3								
LM-CSS	2 1	3							
LM-Chap		1 2	3		3				
CM		2 1 3		3					
MV				A					
PQ					2 3				
CR					1	2 3	2		
RJ						2	3 1		
SE							2 1 3		
LH								1	
BS									1
BC									1
SNWR									1 1

Table 2: *Schedule of site visits in 2008. Green boxes represent sampling days, numbers in the boxes represent the 3 different teams. "A" denotes all teams working in the same site at the same time for training or safety purposes. Sampling began the first week of March and ended during the first week of May. Unburned sites we given priority during the peak of the growing season*

Effort

Time spent in the field is an important constraint to consider when designing a vegetation monitoring program (Figure 5). Set-up time (plot selection, navigation to plot, permanent marking) is significant, but can be completed prior to the start of the field season given enough forward planning. While data entry time is also important to a monitoring effort, time spent entering data is more flexible in terms of scheduling and staff. In our time budgets, we assumed that the field day began when a field team left SDSU (or a designated meeting site) and traveled to the field site.

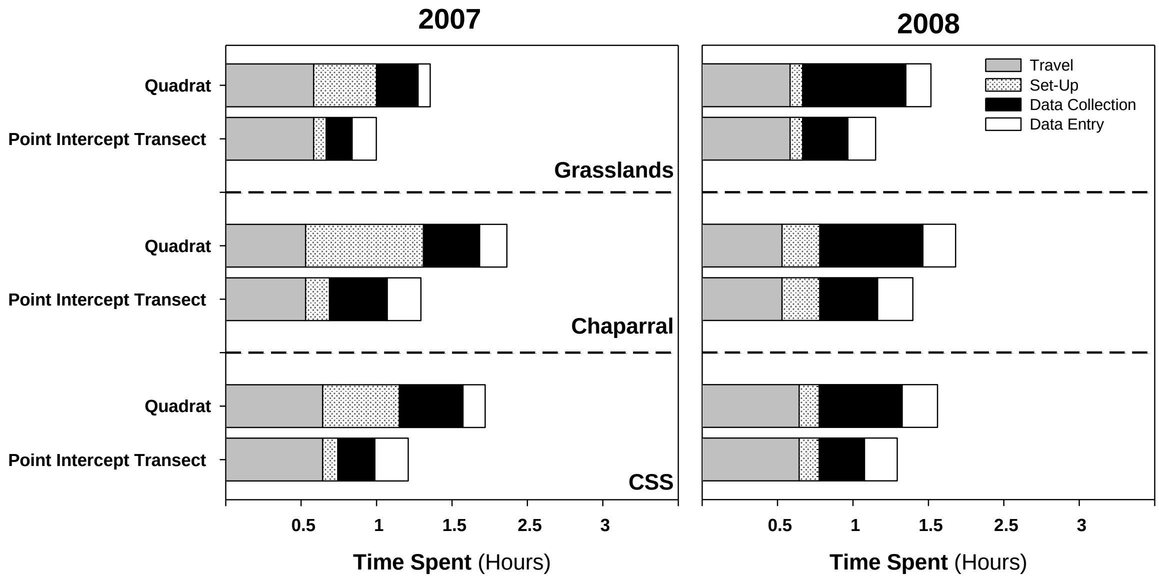

Figure 5: *Average time (hours) in unburned plots spent on two protocols (50m transects, and 10 quadrats). Quadrats were more time consuming in the field than point intercept transects.*

Last year we observed that point intercept transects were much faster than quadrats. This year that trend continued, although the difference between the two methods was less pronounced (Figure 5). Unexpectedly it took us much longer to cover 50m and 10 quadrats this year than it did to cover 100m and 20 quadrats last year. This is due to the tremendous increase in cover and diversity associated with this year's increased rainfall.

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

Field Data Collection

Last year we identified travel to sites and among plots as one factor limiting the number of plots readable in a day. This year we eliminated one method (visual cover), simplified plot set up to one linear transect, and halved the number of points for point intercept (50 vs. 100) and quadrats (10 vs. 20). Our expectation was to save a significant amount of time while acquiring close to the same amount of information. These time savings should have allowed us to sample more transects at each site.

This year we discovered another factor limiting the number of plots that could be sampled in a day - diversity. Last year was a relatively dry year, and sites had far fewer species than they did this year. This year we averaged about 20 minutes for every 50m point intercept transect, about 45 percent more time than last year (Figure 6).

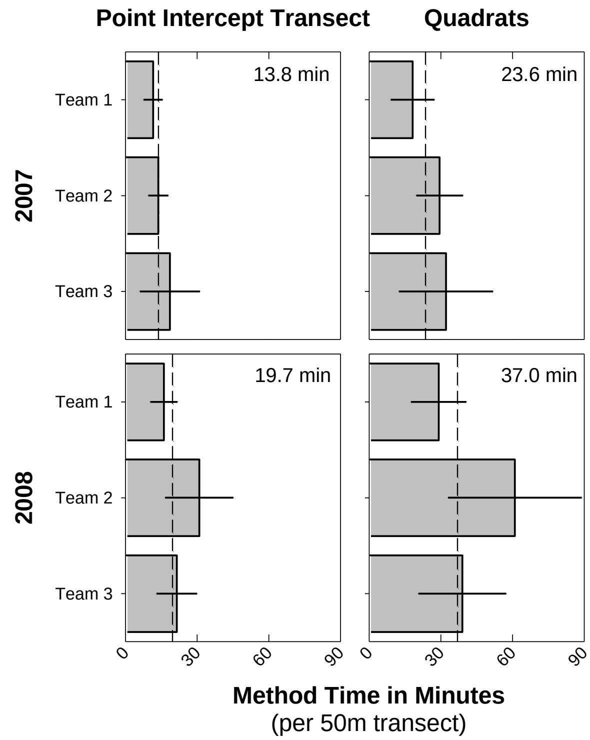

Figure 6: *Method times for primary teams compared. Team 1 had the same members in 2007 and 2008 and teams 2 and 3 had one returning member each from 2007.*

Quadrats were more affected by higher diversity going from about 24 minutes per 10 to 37 minutes per 10, a 56 percent difference. The increase in time for both methods, but especially quadrats, probably has to do with the time it takes not only to call out and record more species, but to find them. Teams were very careful when searching quadrats, and attempted to catch all species, even if they made up less than one percent cover. This process took some time, and had the potential to increase observer fatigue substantially as a result.

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

VEGETATION COMMUNITIES

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

Species Richness

This year we detected 214 (Table 3) species throughout the county. This figure is higher than 2007 when we identified 156 species. In San Diego CSS sites as a whole contained many more species than chaparral sites, although the average richness per plot was not significantly different (Table 3). There were more native forbs (101) than any other functional group in both CSS and chaparral. Non-native forbs were less rich as a group than native forbs.

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

In order to understand the source of this change we compared richness in 2007 to richness in 2008 at all unburned sites that were sampled in both years. In Figure 11, if the richness at a site was the same in both years, the value for that site would lie directly on the 1:1 line (dashed). Instead, all of the points lie well above the 1:1 line, indicating that richness was consistently greater in 2008 (Figure 7).

		Native			Non-native	
	All Species	Shrubs	Forbs	Grasses	Forbs	Grasses
All Sites	**214**	**48**	**101**	**9**	**31**	**13**
CSS Sites	**185**	**37**	**90**	**5**	**28**	**13**
Blue Sky (3 plots)	59	8	31	0	10	5
Lake Hodges (3 plots)	45	5	25	2	7	5
Los Montanas (6 plots)	70	11	39	1	8	4
Marron Valley (7 Plots)	73	11	33	2	14	8
Rancho Jamul (6 plots)	40	3	14	1	8	10
SDNWR (6 plots)	65	7	31	1	13	9
San Elijo (7 Plots)	72	12	39	3	9	4
Tijuana (6 plots)	81	23	32	0	15	7
Chaparral Sites	**144**	**32**	**71**	**6**	**18**	**8**
Boden Canyon (3 plots)	76	16	39	0	9	6
Carmel Mountain (6 plots)	56	12	25	4	10	3
Crestridge (6 Plots)	89	20	43	4	12	5
Los Montanas (7 plots)	74	18	38	1	7	5
Los Penasquitos (4 plots)	35	7	19	0	3	4

Table 3: *Species richness in San Diego County. Unburned plots in black, burned plots in dark red. Vegetation type and overall sums include both burned and unburned plots.*

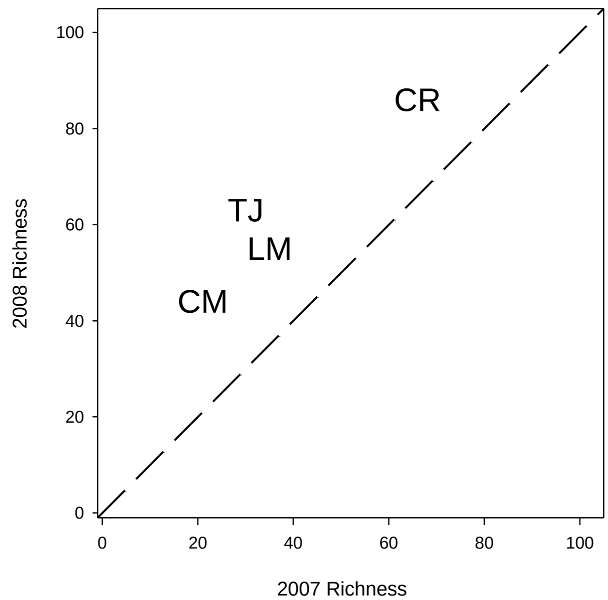

Figure 7: *Increased richness at unburned sites sampled in both 2007 and 2008. The 1:1 line is dashed. Points lying on the line indicate unchanged richness, points lying above the line indicate increased richness in 2008.*

This result demonstrates that the wildfires and our increased sampling effort were not completely responsible for the observed increase in richness. The year-to-year change in richness was almost certainly due to increased rainfall. It does not suggest that spatial extent and fire are unimportant, but does indicate that temporal variability in this system alone is on its own a major factor in vegetation dynamics. In order to see how different functional groups, with different life strategies, responded to interannual variability we regrouped the same data and summed species richness by functional group (Figure 8).

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

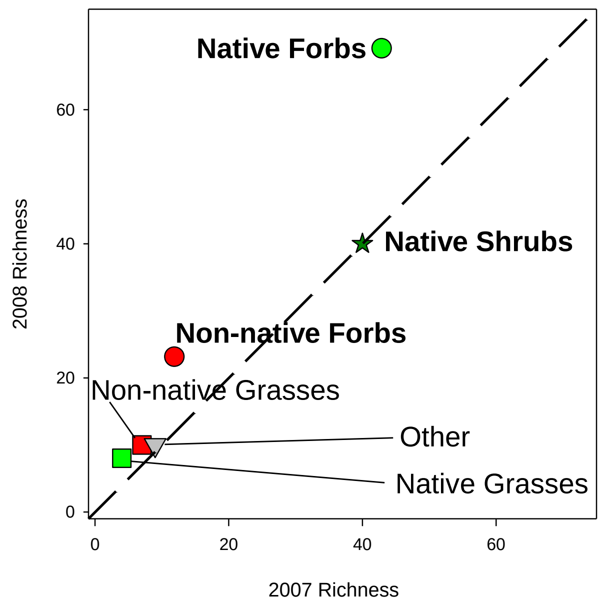

Figure 8: *Increased richness by functional group at unburned sites and plots which were sampled in both 2007 and 2008. The 1:1 line is dashed. Points lying on the line indicate unchanged richness, points lying above the line indicate increased richness in 2008.*

Species Distribution

Several species, like *Crassula connate*, *Bromus madritensis,* and *Erodium sp.* were widely distributed. These three species were found on more than 75% of our plots. *Artemisia californica* was the most prevalent shrub occurring in 61% of our plots. *Nassella* species were the most widely distributed native grass, but only occurred at 20% (14) of our plots.

In CSS, *Erodium* species were the most widely distributed species in both burned and unburned plots, occurring at 89% of the CSS plots. There was a similar pattern in *Bromus madritensis* which was the most widespread non native grass, occurring at 86% of plots. *Atremisia californica* was the most widespread shrub species in CSS, occurring at 75% of our CSS plots. *Cryptantha* species were the most widespread native herb species in unburned CSS plots occurring at 72% of sampled plots. In burned CSS plots, however, herbaceous *Lotus* species were the most prevalent native herb, occurring in 95% plots.

In chaparral several species were distributed across most (89%) of the plots including the native herbs *Crassula connata, Cryptantha* species, and *Dichelostemma capitatum* and the native shrub *Adenostoma fasciculatum*. *Hypochaeris glabra* was the most widespread non-native herb occurring in 77% of chaparral plots. There did not appear to be any shifts in the distribution of species between burned and unburned chaparral species, however, we only had three plots at Boden Canyon as examples of burned chaparral.

Chaparral had several species that were widely distributed across the same number of plots, while CSS did not seem to have that degree of internal consistency. This observation could hint at the role that spatial scale plays for each of the two vegetation communities. It might also be an artifact of having fewer CSS plots than chaparral plots.

DOMINANT SPECIES

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

In order to make realistic comparisons from year to year we have excluded burned sites from this analysis, and plots that were sampled for the first time this year. This allows us to make comparisons across years without confounding our results with the effect of fire or widened spatial extent. Note that the sample is heavily weighted toward chaparral plots since we lost many CSS plots in the 2007 fires.

There was a dramatic increase in the cover of herbaceous (both forbs and grasses) species from 2007 to 2008 (Figure 9). Native and non-native forb species showed a particularly dramatic increase in cover. For example the native herbs *Crassula connata* and *Pterostegia drymaroides* were observed at trace amounts (>0.01%) in 2007, but occurred at high average cover in 2008. There were also similar increases in the cover of non-native forbs. The non-native grass, *Bromus madritensis,* was present in appreciable amounts in 2007, but increased its cover by greater than 60% in 2008. Shrub species maintained their cover and rank order in terms of dominance form 2007-2008.

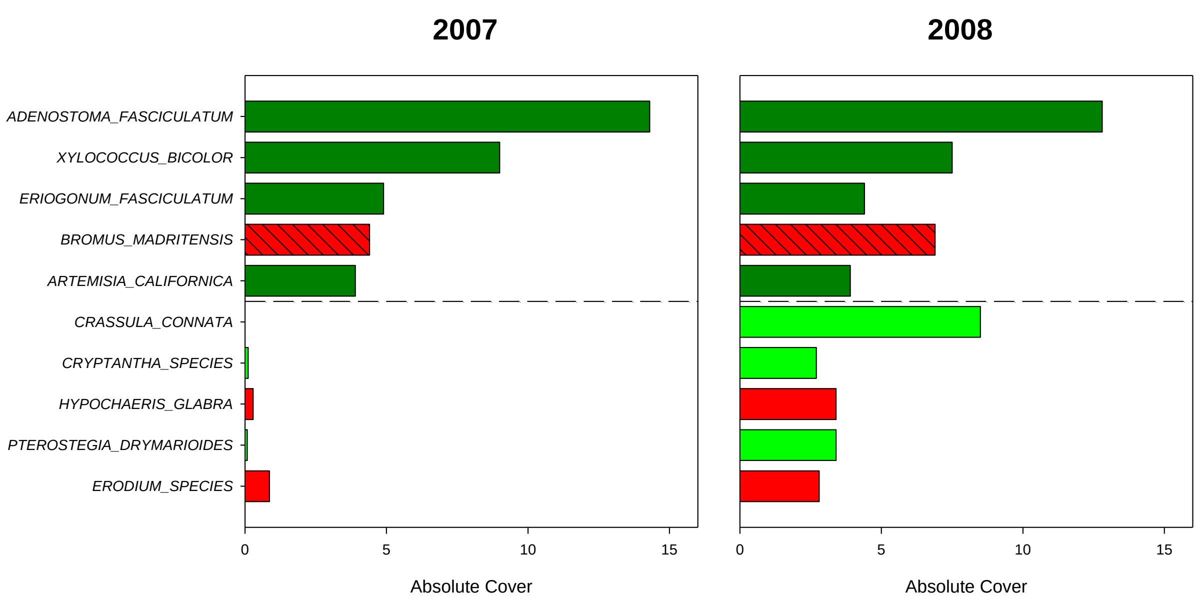

Figure 9: *Increased absolute cover of dominant species at unburned sites and plots which were sampled in both 2007 and 2008. Dashed line represents the division between species that were selected because they were dominant in both years and species that were dominant only in 2008. Dark green bars are native shrub species, light green bars are native forbs. Red bars are non-native forbs and red bars with a cross hatch are non-native grasses.*

Coastal Sage Scrub

We were only able to look at year to year changes in CSS at the three initial plots at the Tijuana River Valley Regional Park site since all other CSS sites from 2007 burned. The dominant shrub species (*Artemisia californica*, *Eriogonum fasciculatum, Lotus scoparius and Salvia apiana*) maintained about the same cover and rank order between 2007 and 2008 (Figure 10). *Lotus scoparius* exhibited a modest decrease in cover. This may be due to mortality as unlike the other shrub species, *Lotus scoparius* has a mean life span of two years. Change in cover from year to year could be a result of plants dying off and recruiting more rapidly than other shrubs. Alternatively the difference could simply be experimental error introduced by slight variations in transect placement as this species tends to be smaller than other CSS shrubs. The same is true for a small but apparent increase in the native shrub *Salvia apiana*. In this case the increase is probably attributable to relocation error, or, by new flowering stocks which extend well past the shrub canopy.

Last year no single native forb was dominant, however in 2008 *Crassula connata, Camissonia sp,* and *Daucus pusillus,* occurred as dominant species with high cover. The non-native forb *Erodium* species and the non-native grass *Bromus madritensis* were both detected last year at low cover, and increased two to four fold in 2008 (Figure 10). The non-native grass *Vulpia myuros* was not detected last year but contributed about 5% cover this year.

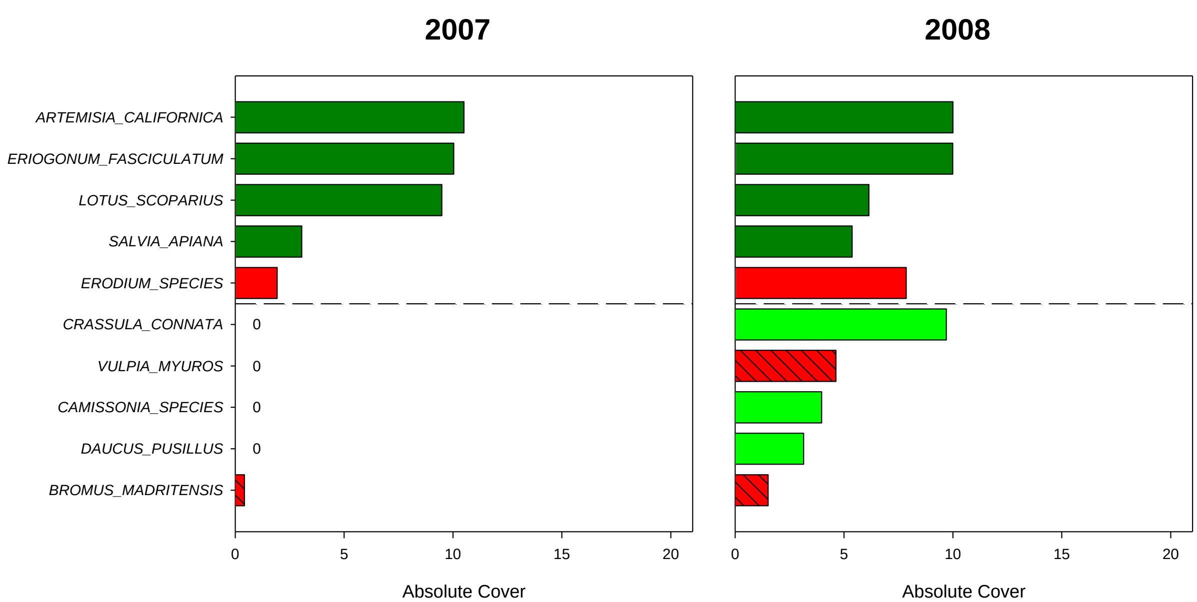

Figure 10: *Increased absolute cover of dominant CSS (Tijuana River Valley Regional Park only) species at unburned sites and plots which were sampled in both 2007 and 2008. Colors and bar shading as in previous figure.*

The cover of species at different plots inside the Tijuana River Valley site varied dramatically. While the cover of *Artemisia californica* did not change dramatically from 2007 to 2008, it ranged from almost thirty percent in plot 1 to totally absent in plot 3 (Figure 11). The native herb *Crassula connata* varied most dramatically by year (as it was totally absent in 2007), but still showed a large range of cover between plots in 2008. *Erodium* species varied in cover both by year and by plot. Plot 2 had the highest *Erodium* cover in both years, and saw the smallest year to year change. Plot 3 showed the largest change in *Erodium* cover, and plot one saw a small amount of *Erodium* appear although it had not been there in 2007.

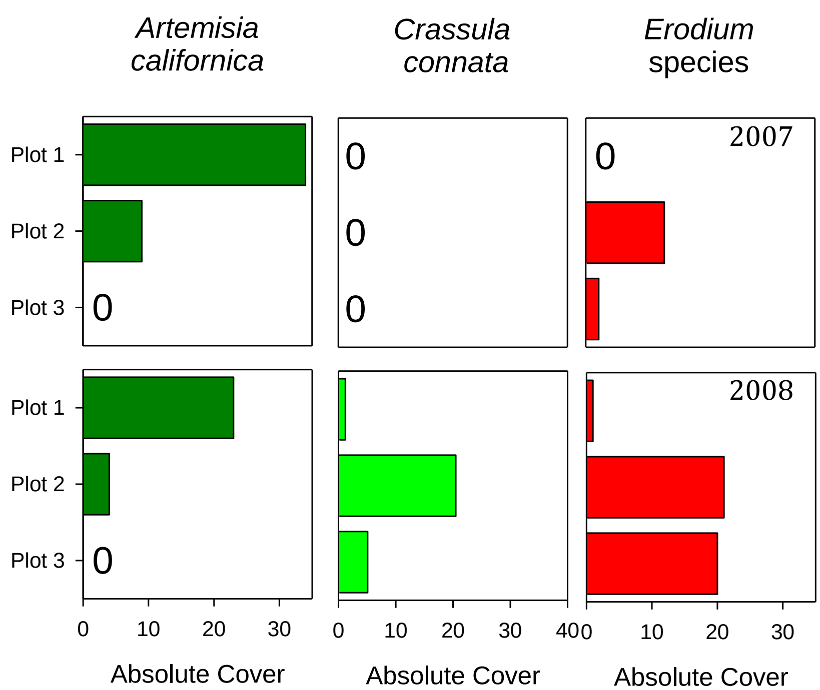

Figure 11: *different cover of dominant CSS (Tijuana River Valley Regional Park only) species at plots which were sampled in 2007 and 2008. Colors and bar shading as in previous figures.*

Chaparral Species

We sampled three sites (11 plots total) in both years. As seen in the CSS plots, the cover of dominant native shrub species (*Adenostoma fasciculatum, Xylococcus bicolor, Malosma laurina, Eriogonum fasciculatum* and *Salvia mellifera)* were fairly consistent. Native herbs (*Crassula connata, Pterostegia drymaroides, and Cryptantha* species) which had occurred at trace amounts in 2007 increased dramatically, often by one or two orders of magnitude (Figure 12). The non-native grass *Bromus madritensis* increased by 60% from 2007 to 2008.

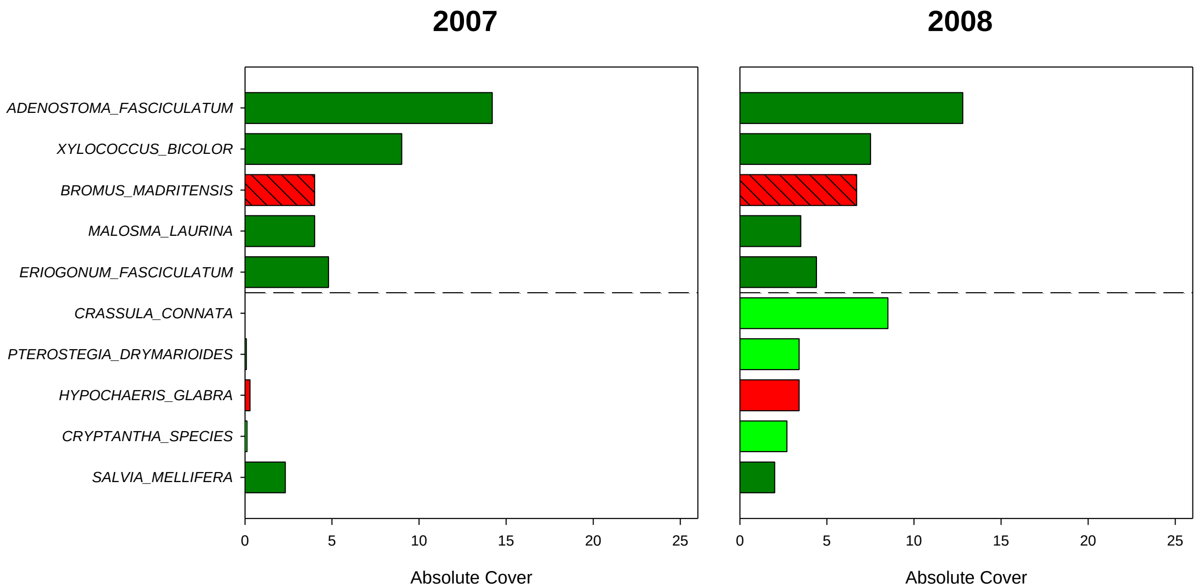

Figure 12: *Increased absolute cover of dominant chaparral (Los Montanas, Carmel Mountain and Crestridge) species at unburned sites and plots which were sampled in both 2007 and 2008. Colors and bar shading as in previous figures.*

The average absolute cover of different plant species varied from site to site in the chaparral (Figure 13). *Adenostoma fasciculatum* consistently had higher cover than most other shrub species, but by varying degrees. At Carmel Mountain *Adenostoma fasciculatum* was the clear dominant shrub. At Crestridge the proportions of *Adenostoma fasciculatum* and *Xylococcus bicolor* were approximately the same, but at overall shrub cover was low due to the 2003 Cedar Fire. At Los Montanas, *Adenostoma fasciculatum* and *Xylococcus bicolor* were codominants. The native shrub *Salvia mellifera* was only detected at Carmel Mountain.

Herbaceous species also varied from site to site, as well as year to year (Figure 12). In 2007 the dominant non-native plant was the grass *Bromus madritensis*. At Crestridge this non-native grass had higher cover than any other plant. In 2008 *Bromus madritensis* increased in absolute cover at Crestridge and was detected at Carmel Mountain and Los Montanas, but at lower levels. Crestridge also had the only appreciable amount of the non-native herb *Hypochaeris glabra,* and trace amounts of native herbs. The cover of native herbs increased dramatically in 2008 at Crestridge, and species that had not been detected previously appeared in the other two chaparral sites, sometimes at higher cover than observed at Crestridge. As expected, chaparral plots generally had lower cover of forbs and grasses than the CSS plots.

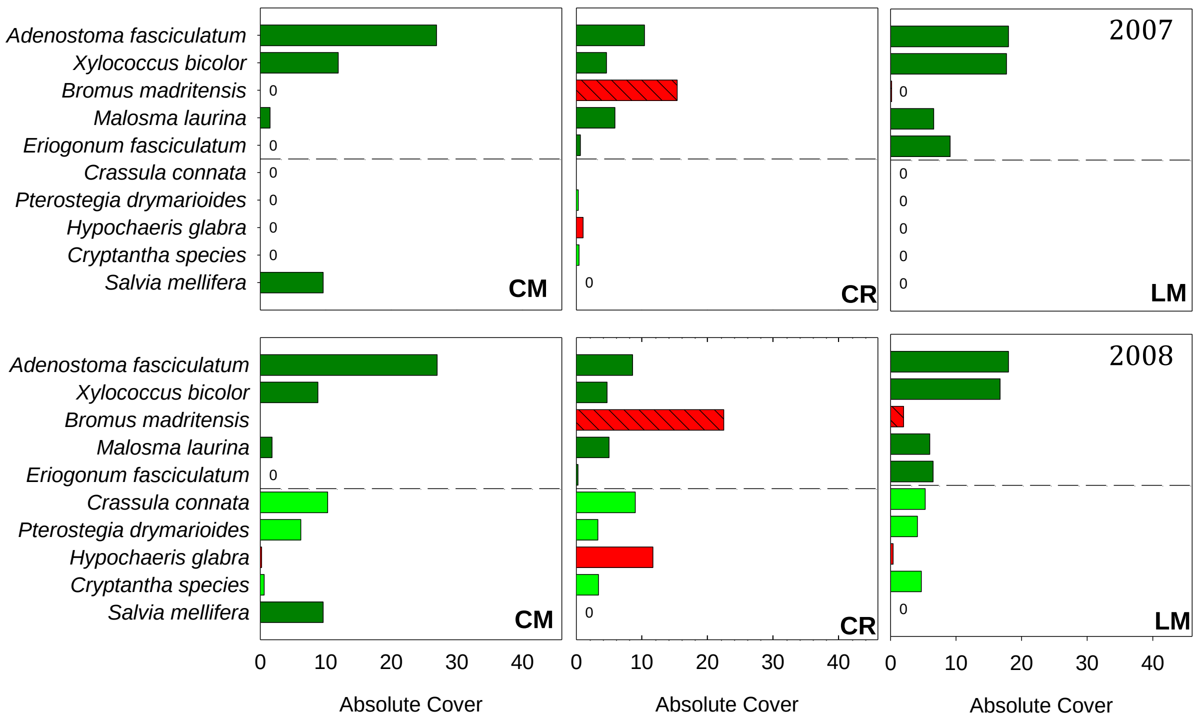

Figure 13: *Dominant species differed at different chaparral sites (Los Montanas, Carmel Mountain and Crestridge. Colors and bar shading as in previous figures.*

In addition to year to year and site to site variability, there was often a great deal of plot to plot variability in the cover of some species. *Adenostoma fasciculatum* cover (like other shrubs) did not vary by year (Figure 12), but did vary by site (Figure 13) and plot (Figure 14). *Cyptantha* species, like most native herbs, varied dramatically by year, site and plot (Figure 14). The non-native grass *Bromus madritensis* showed moderate year to year variability. *Bromus madritensis* was variable among sites, but less so at the plot level.

FUNCTIONAL GROUP COVER

The aggregate cover for each functional group was calculated by summing the cover of all the species in that functional group by plot. Combining species into functional groups avoids analysis problems with rare, small and infrequent species. Coarsening the data by functional group supports the major patterns we saw at the species level (Figure 15). Shrub cover varied among plots, but was similar in 2007 and 2008. Native forbs and grasses were all but absent in 2007. They were more common in 2008, with native forb cover far exceeding native grass cover. Exotic forbs and grasses were patchy in 2007 and more ubiquitous in 2008. Non-native grasses tended to vary at the site level but not at the finer scale.

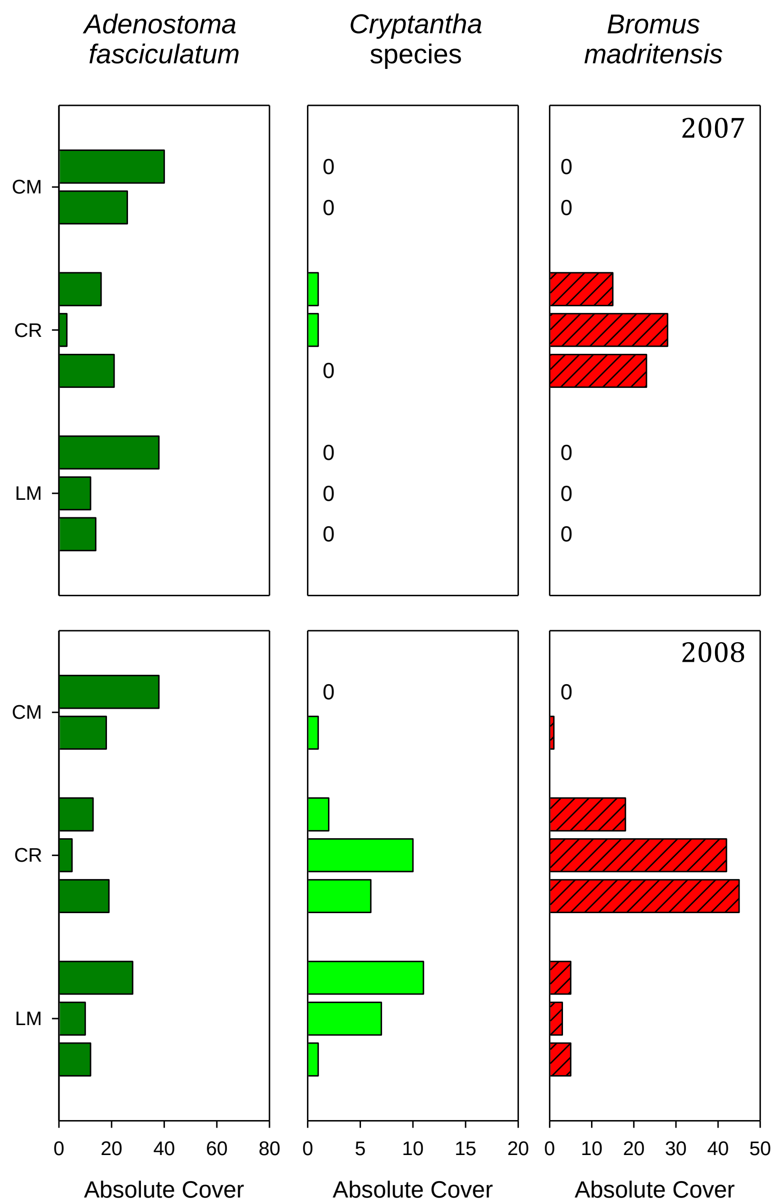

Figure 14: *Different cover of dominant chaparral species at sites and plots which were sampled in 2007 and 2008. Colors and bar shading as in previous figures.*

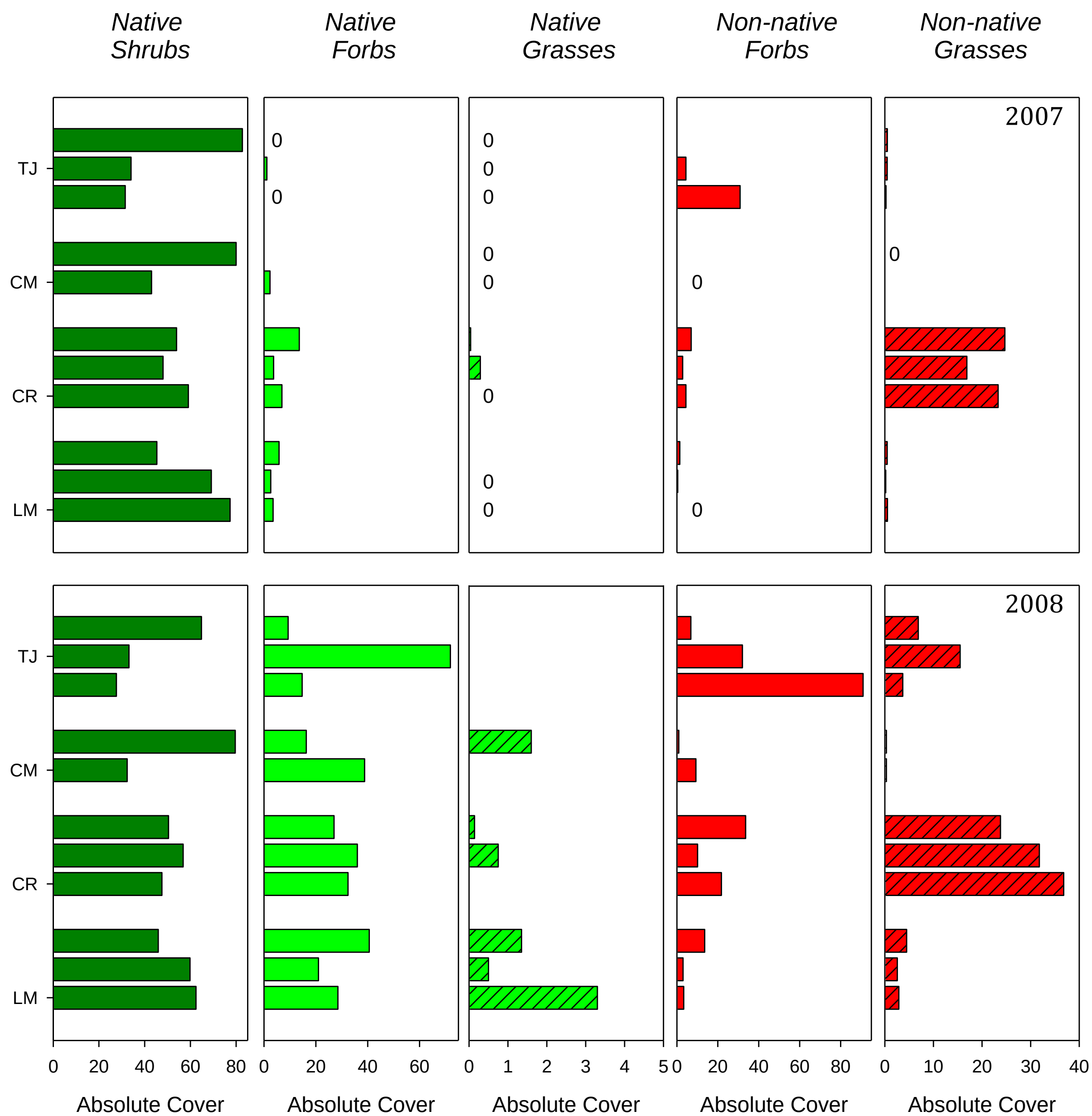

Figure 15: *Cover of functional groups at sites and plots which were sampled in 2007 and 2008. Note the scale on the X axis (cover) varies among functional groups. In particular, native grass cover was quite low.*

VARIANCE COMPONENTS ANALYSIS

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

SOURCES OF VARIATION

The variance components analysis that we present has three major sources of variation: temporal (interannual), spatial and methodological (Figure 16). Spatial variation includes three nested levels: vegetation community, site and plot. Methodological variation includes two levels: protocol (quadrat vs. point intercept) and team.

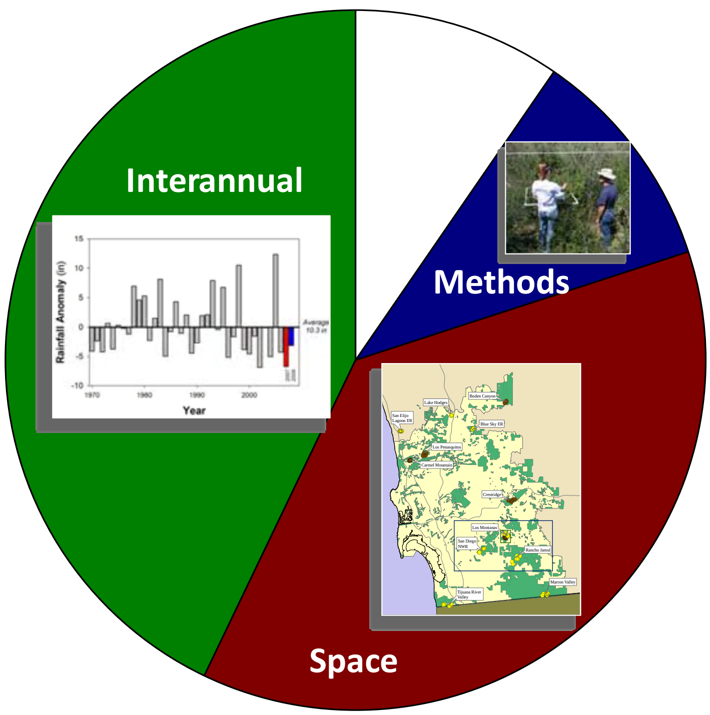

Figure 16: *Major sources of variation. The green slice represents interannual variability, the red slice represents spatial variability, the blue slice represents methodological variability and the white slice represents the remainder (unexplained) variation.*

INTERANNUAL VARIABILITY

We quantified interannual variability using data from plots sampled in 2007 and 2008 that were also not burned in 2007. This allows us to look at interannual variability without confounding the effect of fire. Given the importance of water on the California landscape, our interannual component is probably closely linked to rainfall. 2007 was one of the driest years southern California has experienced since 1970, second only to 2003 (Figure20). Both of these years saw major fires and unusually low germination rates. 2008, while still below average, was by comparison a relatively wet year.

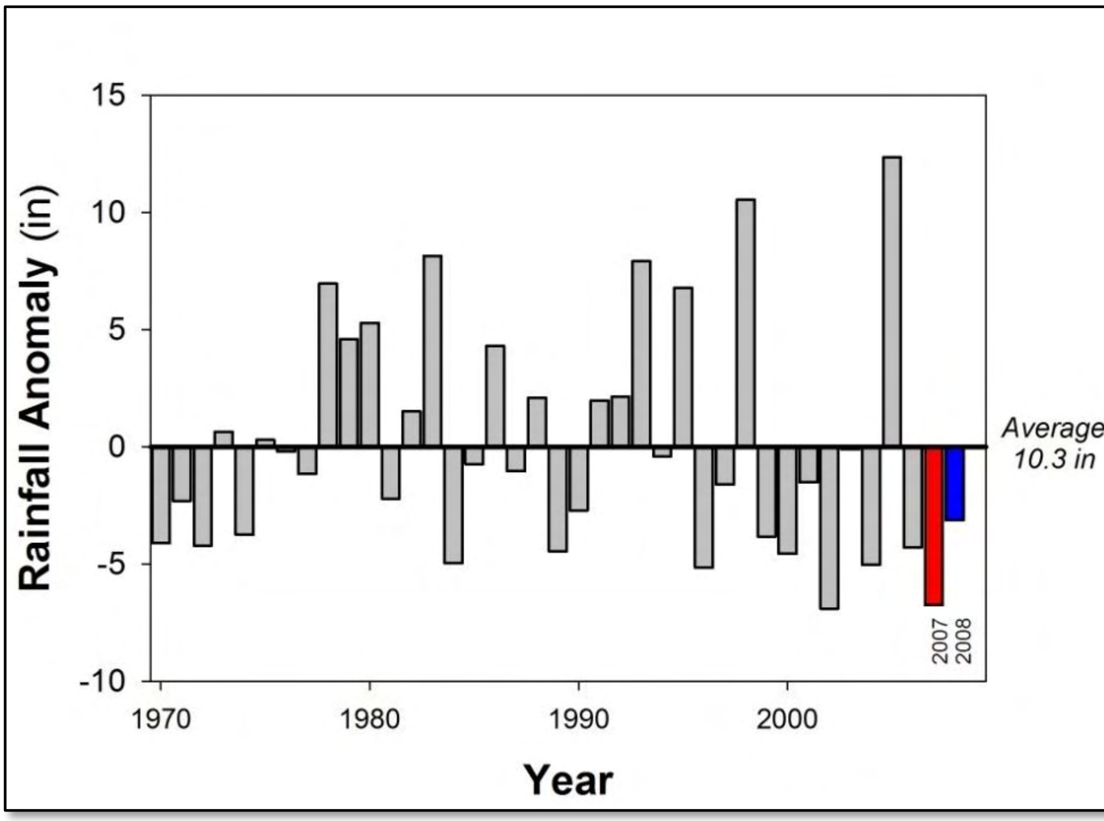

Figure 17: *Rainfall Anomaly from 1970 to 2008 in inches. 2007 was a very dry year in comparison to 2008.*

Spatial Variability

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

Spatial variability was described in three nested levels. The first (and most coarse) level was the vegetation community. Sites were nested within each vegetation community, and plots were nested within sites (Figure 18). It is important to recognize that these levels are a necessary simplification designed to reflect processes which likely vary across a continuous gradient. These three levels help provide a robust sampling design and allow us insight into processes happening at scales ranging from a square meter to tens of kilometers.

We distinguished between CSS and chaparral communities using fairly coarse characteristic traits and species as defined by the literature and described in the "Field Sampling Design" section. We did not break these vegetation communities up further (e.g. chamise chaparral V. southern mixed chaparral or Diegan CSS V. Riversidian CSS). Sites were nested within each vegetation community, and plots were nested within sites. Sites were defined as sections of conservation lands that tended to be contiguous. Generally speaking different reserves were considered different sites. In general sites were separated by developed land use, major roads and highways, long distances or any combination of those factors. Plots were defined as the actual point locations where we took data. Plots were located using a stratified semi-random design as discussed in the "Field Sampling Design" section.

Methodological Variability

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

We considered two sources of methodological variability: method (field protocol) and team. These two factors do not nest inside each other, but are crossed (fully factorial) because every team used both protocols at every plot they visited (Figure22). For our purposes we entered method first in the model as the methodological decision is generally made independently of hiring team members. This detail is minor, and did not have a dramatic effect on our results.

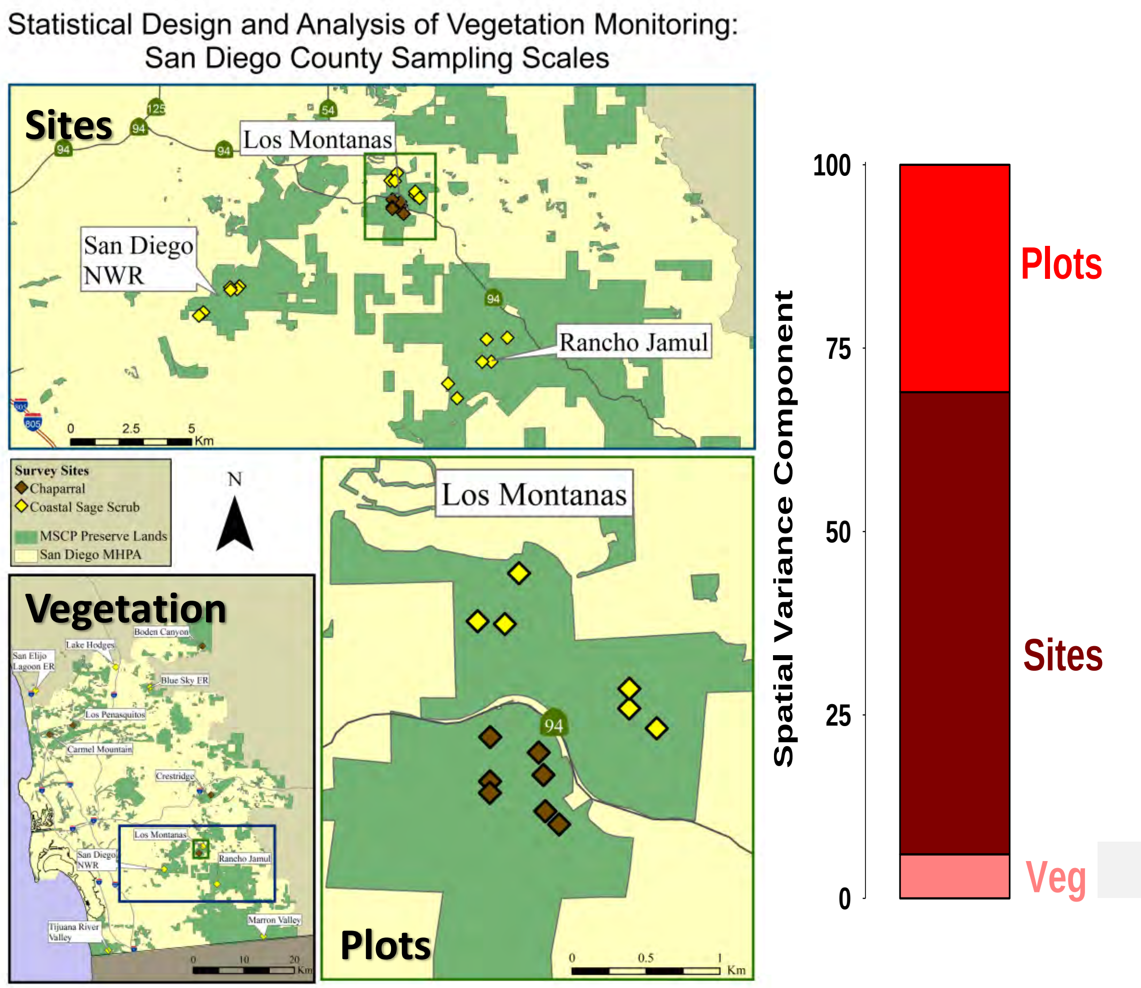

Figure 18: *Different spatial scales used in the variance components analysis. Vegetation communities are differentiated between CSS in yellow and chaparral in dark green. Sites were designated as different reserves that were not contiguous with each other. Plots were the actual point locations where sampling occurred.*

Figure 19: *Different teams and different protocols. Every team used both protocols at every plot they visited. Right: Dr. Marie Meroe and Dr. Janet Franklin using point intercept. Left: Marguerite Mauritz and Christina Brunette using reading quadrats.*

VARIANCE COMPONENTS ILLUSTRATED

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

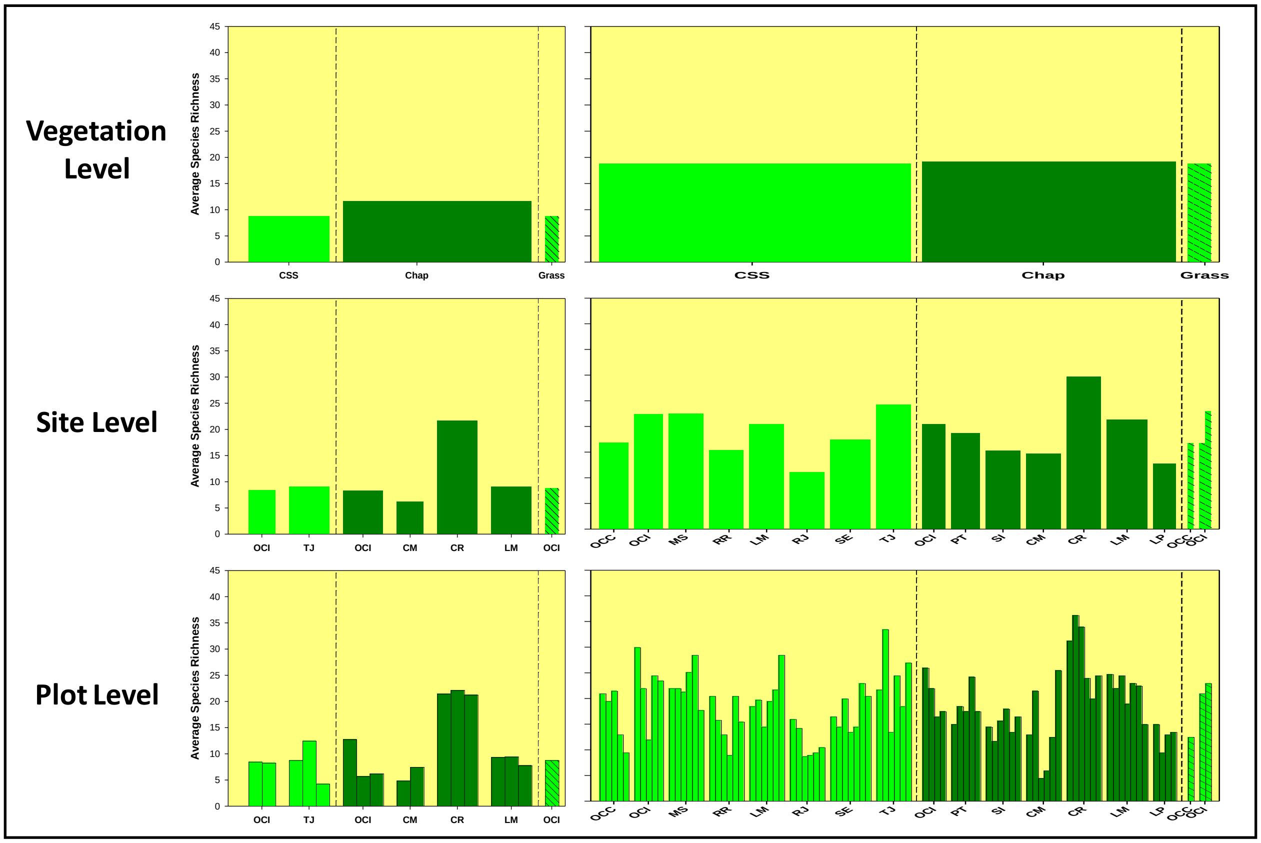

Figure 20: *The interannual and spatial variance components illustrated for species richness. Light green bars are CSS, dark green bars are chaparral and light green bars with hatch marks are grasslands. Unburned plots measured in 2007 (left column) and 2008 (right column) were used to estimate the interannual variability and all unburned plots in 2008 (left column) were used to estimate the spatial variance components.*

Figure 20 presents species richness averaged across teams and methods. In Figure 21, we show the same average values, however the top segment contrasts the richness values detected by the two different protocols. Quadrats (indicated by squares) typically captured more species than the point intercept technique (crossed diamonds), with method accounting for 10% of the variation in richness data. Different teams (indicated by different shapes and colors, Figure 21, bottom section) tended to capture about the same average richness in each plot. Team only accounted for 1% of the variation in richness data.

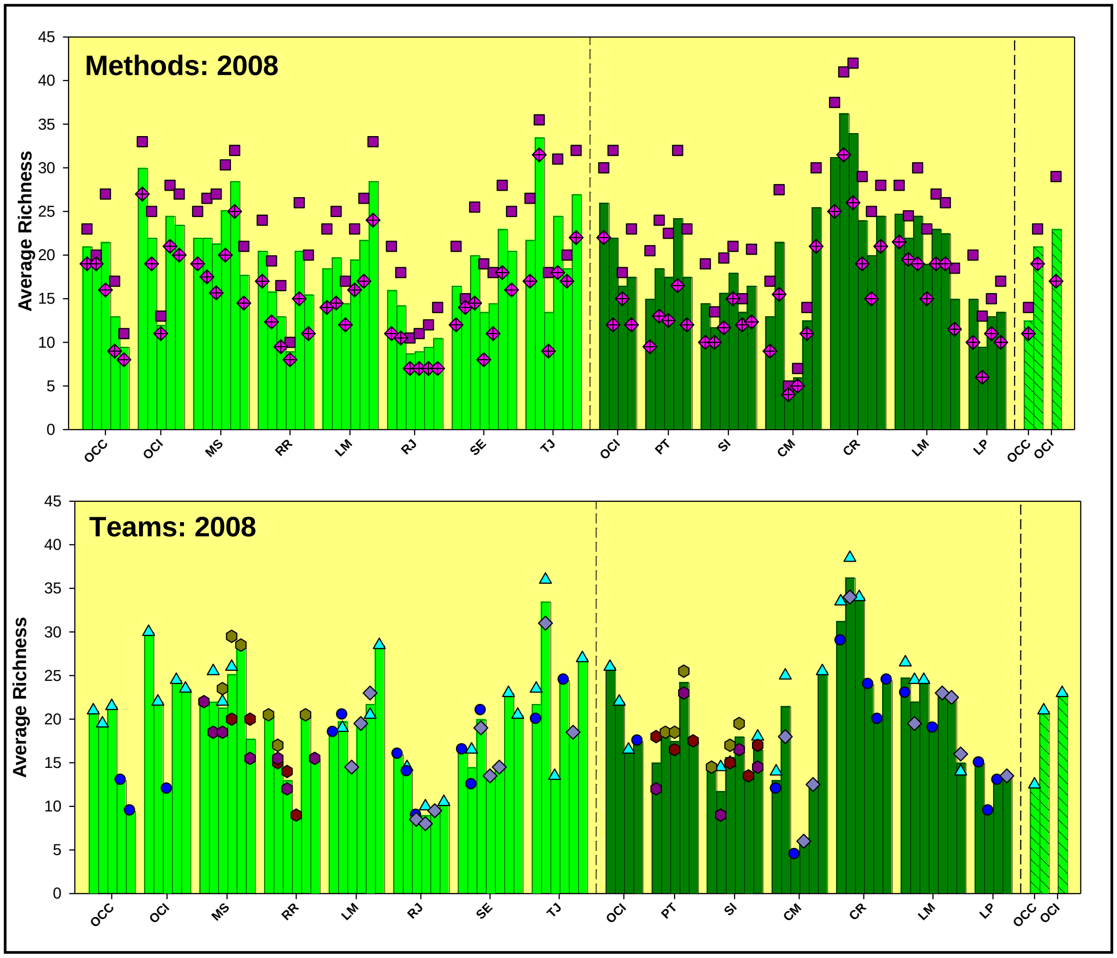

Figure 21: *The methodological variance components illustrated for species richness. Light green bars are CSS, dark green bars are chaparral and light green bars with hatch marks are grasslands. Methods are illustrated in the top row (squares are quadrats, diamonds with cross hatch are point intercept). Teams are compared in the bottom row, and are differentiated by different combinations of shapes and colors.*

These results are interesting but do not address which of the levels we identified can be controlled by the monitoring and sampling designs, and how to control for variability in a monitoring program. Figure 22 breaks down the major sources of variation (interannual, spatial and methodological) in a pie chart, and then shows the relative contribution of each level of spatial and methodological variability as a percentage of the major category. Interannual variability will affect the periodicity of sampling efforts, but beyond planning revisits there is little we can do to reduce inter annual variability (Figure 22, green section of pie chart). We are able to control our spatial coverage. Considering the relative contribution of vegetation community, sites and plots to the entire spatial component we know that planning on visiting many sites and several plots per site will be appropriate (Figure 22, red section of pie chart and center bar graph). Although methodology did not contribute the largest slice of the pie in Figure 22 (blue), it is one thing we can readily adjust about our response design. We see that the majority of that variability is accounted for by method (dark blue section of right bar chart), and are able to conclude that it is important to select the correct protocol for sampling richness, in this case quadrats. It should be noted that this particular conclusion is contingent on teams having the same amount of experience as the teams we used for this study.

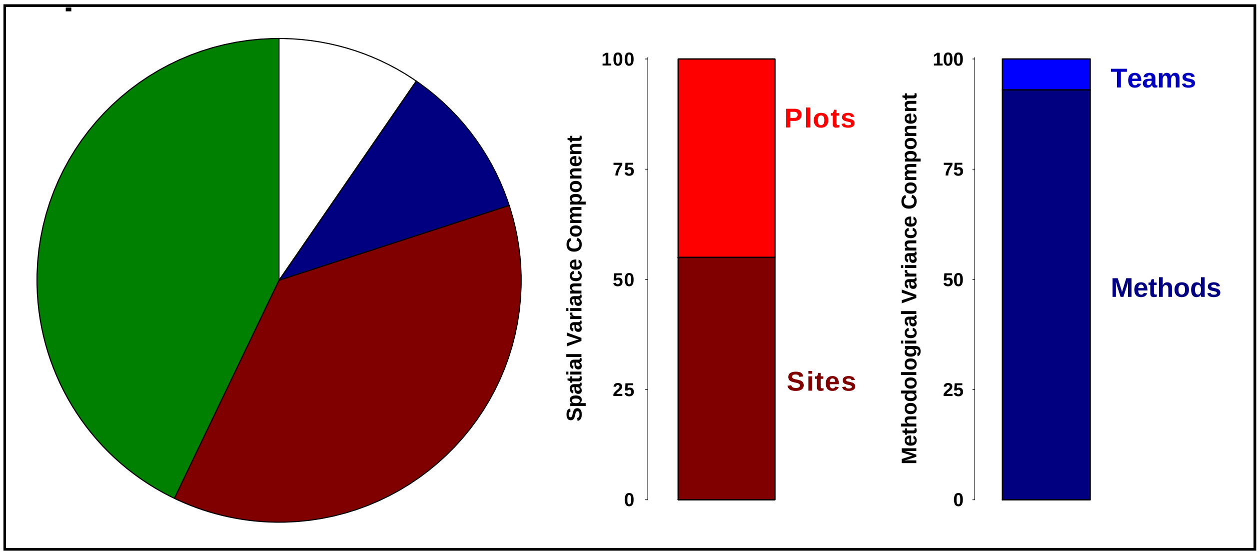

Figure 22: *The major sources of variation in species richness data. The pie chart shows the major components: interannual variability (green), spatial variability (red), and methodological variability (blue). Spatial variability and methodological variability are further broken down in bar charts to the left, which show the relative contribution of each level (pink is vegetation community, dark red is sites, red is plots, dark blue is methods and light blue is teams). Not that vegetation community contributed so little variation to species richness that it does not appear in the spatial (center, red) bar graph.*

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

Full Analysis

Several suites of variables were analyzed using variance components. In addition to species richness (previous section) we also analyzed the variance decomposition of the major functional groups: native shrubs, native herbs, native grasses, non-native forbs and non-native grasses. In addition we analyzed several example species from each functional group individually. Example species were selected because they were either prevalent at many sites or dominant in terms of cover. 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. In theory, similar analyses can be performed on all plant species, however many would be too rare for the analysis to be meaningful. Presentation of such an analysis would be cumbersome and provide little additional information. The variance decomposition values for each of the selected group is given in Table 4.

	Year	Veg	Site	Plot	Meth	Team	Unexplained
Native Shrubs	**0.5**	**4.2**	**42.0**	**20.7**	**15.8**	**3.6**	**13.2**
Adenostoma fasciculatum	0.2	21.0	36.5	35.0	1.3	0.8	5.2
Artemisia californica	0.0	9.6	31.7	46.9	1.1	0.2	10.5
Nassella species	0.0	29.2	36.5	23.3	1.6	0.2	9.2
Xylococcus bicolor	0.1	9.9	30.5	51.9	0.7	0.8	6.1
Eriogonum fasciculatum	0.0	11.8	35.1	45.9	0.8	0.1	6.2
Salvia melifera	0.0	0.8	29.5	63.1	0.6	0.3	5.7
Native Forbs	**40.3**	**0.5**	**10.6**	**17.7**	**9.5**	**0.2**	**21.2**
Crassula connata	23.5	0.6	17.3	26.6	4.6	0.1	27.3
Cryptantha species	27.3	0.8	6.7	32.5	3.5	0.8	28.4
Pterostegia drymariodes	20.8	0.6	30.8	27.4	2.1	0.0	18.3
Dichelostemma capitatum	12.3	16.5	4.7	23.9	2.7	1.5	38.4
Lotus species	10.7	1.7	22.0	34.9	2.3	0.2	28.2
Daucus pusillus	7.2	0.4	15.8	40.4	2.9	0.4	32.9
Non-Native Grasses	**6.8**	**11.1**	**30.2**	**22.5**	**8.3**	**0.6**	**20.4**
Avena species	0.1	3.7	42.5	15.0	3.5	0.3	34.9
Bromus madritensis	3.9	0.9	39.8	32.7	5.5	0.6	16.6
Bromus diandrus	0.6	12.3	4.3	12.1	5.9	1.6	63.1
Bromus hordeaceus	0.2	1.0	18.0	22.1	5.7	1.1	51.9
Non-Native Forbs	**17.1**	**15.3**	**22.3**	**21.7**	**6.6**	**0.3**	**16.7**
Erodium species	7.7	8.1	25.7	14.8	5.3	0.6	37.8
Brassica nigra	5.3	15.4	8.5	25.6	6.3	0.0	38.9
Hirschfeldia incana	7.0	0.4	28.4	44.4	1.2	0.1	18.5
Anagalis arvensis	5.8	0.6	8.7	28.3	2.1	0.0	54.5
Centaurea melitensis	11.4	1.9	16.3	33.1	1.8	4.8	30.7
Silene gallica	5.1	1.9	14.7	42.4	0.2	0.1	35.5
Species richness	**42.9**	**0.1**	**20.3**	**16.7**	**9.6**	**0.8**	**9.6**

Table 4: *Variance decomposition for selected groups. Cells are shaded from light to dark based on the percentage of variability in each cell. Ranking for shading was performed within each major source of variability. Also see Figure 23*

All of the groups and species selected for individual analysis varied across space. The spatial component was different for each group, but generally the site and plot levels were more important than vegetation community (Table 4, Figure 23). This is likely because each group lives on a slightly different spatial scale, and with a different degree of selectivity for different habitat types and because we are representing a continuum of using three chosen levels.

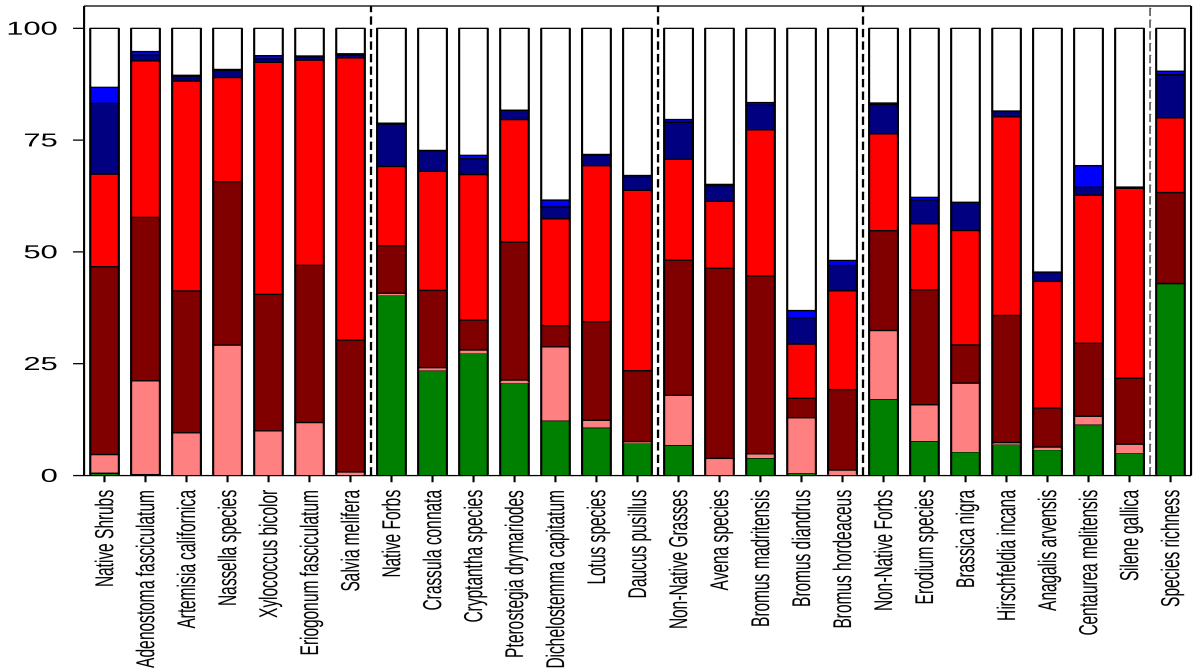

Figure 23: *Full variance decomposition of selected groups (see table 5 for values). Stacked bars represent interannual (green), vegetation community (pink), site (dark red), plot (red), methodological (dark blue) and team to team (blue) variability. The white section of the bar represents the proportion of variance unexplained by the model. Note: all levels are represented for all groups—where bars of some colors are not visible it is because their magnitude is too small to see.*

The species selected for individual analysis fell roughly into three groups: spatial responders, temporal responders, and mixed responders. Spatial responders were defined as species or groups that responded strongly to space to the exclusion of all other factors. For example *Nassella* species(Figure 23 middle column), occurred in the highest density in grasslands but was also scattered throughout the other two vegetation types at much lower levels. In comparison *Salvia mellifera* (Figure 23) tended to occur in both CSS and chaparral, but tended to prefer some plots over others. *Xylococcus bicolor* (Figure 23) had a larger team to team component than any of the other native perennial species (perhaps because it exists as a co-dominant where it occurs and either doesn't get spotted or isn't correctly identified), but the overall effect of methodology was so small as to make this issue negligible. Temporal factors don't effect these species as much because they tend to be slow growers, and methodological factors probably effect them less because they are easy to identify and hard to miss.

Temporal responders were defined as species that showed a large interannual component relative to other components of variance. While space was still a large contributor to the model for temporal responders, the annual component was large enough to suggest that not considering temporal variation would lead to egregious design mistakes and misinterpretation of data. Most native and non-native forb species were strong annual responders (Figure 23). For example, *Crypthanta* species showed greater than 27% of their variation in the temporal factor (Figure 23).

Cryptantha species also occurred at high densities in some plots, and not at all in others regardless of vegetation community. *Dichelostemma capitatum* showed less interannual variability than some of the other example native annuals, however had a spatial component similar to the other temporal responders with a larger unexplained component (Figure 23).

Mixed responders are a troublesome group that fit together in several general ways—often more about how they differ from the other groups than similarities between them. The models for mixed responders tend to explain less than 60% of the variation in cover data for the specific species (Figure 23). In addition to being moderately spatial they usually contain some interannual variability, and often have slightly higher degrees of methodological variability than members of the other groups. This suggests that some of the unexplained variation may be contained in interaction terms that were not included in the model. Such interactions could be team and year, team and plot or team and method. Three of four non-native grasses analyzed were mixed responders. For example, the model for *Bromus diandrus* left the majority of the variation unexplained (63%). The variation that was explained from the model was distributed more evenly between all the factors than other groups. Of all the selected example species it had the largest methodological component at 6%.

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

DISCUSSION

Sampling was conducted by three teams at 70 plots in San Diego County, located in 13 spatially distinct sites. Sixteen of those plots were sampled by two or more field teams to evaluate the magnitude of team-to-team bias. Teams had at least 1 member that had a field season of experience and 1 semester of a college level plant taxonomy course. All sampling was conducted between the first week of March and the first week of May. Field protocols (the response design) were modified for 2008 based on the results from the previous year's results.

We evaluated two response design's (point intercept transects and quadrats) for precision and efficiency. Due to higher rainfall this year (therefore cover and richness) field work took about twice as long as it did in 2007. Point intersect transects were faster than quadrats (20 minutes vs. 40 minutes) and returned precise (repeatable across teams) cover estimates, but fell short when evaluating species richness. We found that quadrats systematically under estimated cover values, but also captured higher richness values.

This year we observed 218 species in San Diego County, up from 156 in 2007. Herbaceous cover and diversity was up, although shrub cover either stayed the same or went down a small amount in unburned plots. This increase in richness holds true when new sites and plots are eliminated from the analysis. The most influential group contributing to the increase of richness was native forbs. We expected to see more observer bias as teams struggled to identify and quantify species they had not encountered last year, but this turned out not to be the case. Teams performed about equally for both cover and richness estimates, which we attribute to an enhanced training period. We did see a striking difference between the two protocols. Other functional groups, such as non-native grasses and forbs, which both increased in richness but by a smaller margin, may have seen a smaller change because successful non-native species tend to be robust generalists that tend toward monotypic assemblages.

Adenostoma fasciculatum was the dominant shrub at most chaparral sites, but was sometimes co-dominant with *Xylococcus bicolor*. *Artemisia californica* was the most prevalent native shrub in the CSS and was co-dominant with *Eriogonium fasciculatum* at our single unburned CSS site in San Diego, the Tijuana River Valley. Raw cover values demonstrated a high degree of spatial variability in shrubs at the vegetation community, site and plot levels.

Bromus madritensis was the most ubiquitous non-native species throughout San Diego County, occurring in a majority of plots, often at significant cover. Non-native forbs in the genus *Erodium* were almost as widespread, and found at high cover in CSS plots.

Herbs, particularly native forbs, also showed strong spatial variability, in addition to a major temporal aspect. Our analysis of interannual variability may be biased toward chaparral sites since we had to use unburned sites and 3 of 4 CSS sites were burned in 2007. Despite this limitation we saw dramatic and coherent increases in the richness and cover of herbaceous species from 2007 to 2008.

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

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

Different species can be broken out into rough groups of spatial responders, temporal responders and mixed responders depending on how influential different components are. Most shrubs are spatial responders, with a miniscule amount of temporal and methodological variability. Most native forbs are temporal responders, which respond strongly to year in addition to spatial factors.

Functional groups as variables tend to be mixed and have a large component associated with method due to compound estimation error in quadrats.

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

CONCLUSIONS:

Stevens and Urquhart (2000) distinguish two conceptually separate and distinct aspects of monitoring (see also Larsen, Kinkaid et al. 2001). They refer to **"sampling design"** as the process of specifying where to select population units or points. The other aspect is the "**response design"** defined as the process of deciding what to measure and how to measure it. This separation of the selection of sampling units (sampling design) from the process of measuring attributes of the selected units (response design) helps clarify the different aspects of monitoring (Larsen, Kinkaid et al. 2001). The objective of this project was to evaluate the precision and accuracy of different sampling and response designs, to identify the levels where natural variability was most influential and to minimize methodological variability. This information will help scientists and land managers make decisions about how to allocate their effort across the sampling and response designs of a monitoring project based on their specific needs and questions.

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

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

In southern California semi-arid shrublands allocating a significant amount of effort to spatial coverage is probably appropriate for most response variables (Table 6). We have found that a large number of plots are necessary to assess different sites inside a conservation plan, and that many sites need to be visited to assess the status of the reserve system.

Some response variables change dramatically across years, while others do not. The periodicity with which a variable should be monitored is inherently tied to its life cycle. Native forbs, for example, should be monitored yearly. However, a monitoring project most interested in shrub cover would likely be well served by a monitoring cycle of 5 years (Table 6).

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

Quadrats and point intercept protocols have opposite strengths for different response variables. Transects provide the most accurate and precise estimates of cover for individual species and functional groups (Table 5). Quadrats provide more information on richness and presence of uncommon or small species, but systematically underestimate cover. In some cases the sampling and response designs we tested will not be adequate to address the monitoring objective—for example, populations of rare plant species or small and patchy species.

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

Table 5: *General recommendations for sampling and response designs for example objectives.*

Further Study and Recommendations

It remains difficult to estimate the cost of monitoring. Due to the extreme drought in 2007 our baseline data may represent the arid extreme in southern California, but is not adequate on its own as baseline data. The time and cost it took to complete monitoring this year was higher than we originally estimated due to dramatically increased richness and herbaceous cover. The region received higher rainfall in 2008 than 2007, but was still well under average. Climactic factors in San Diego County are wide and varied, and we have yet to conduct monitoring over a particularly wet year, or a year with extremely early or late rainfall. Given the size of the interannual variation we observed for some groups, more data is needed to evaluate components of a comprehensive monitoring program will take longer. As a result we recommend continuing similar sampling in 2009 and 2010.

Several subsequent years are required to recover from the loss of three-quarters of our initial CSS sites from the 2007 fires, which led to a sample in which chaparral was over-represented. Post fire monitoring is important, and as a regular phenomena should be considered inside a monitoring program, but post fire monitoring is a long term issue that we are just beginning to address. In 2007 we took data that would become a spatially explicit "snapshot" of pre-fire vegetation. This spring (2008) we collected data to provide us a "snapshot" the spring after fire. As fire makes habitat more prone to invasion and erosion, we recommend resting these plots for 1-2 years after fire to allow natural regeneration to continue. In 2010 or 2011, we recommend taking another "snapshot" to begin exploring methods for best monitoring post-fire.

Our work clearly shows that monitoring methods must be tailored for their specific monitoring goals. As San Diego's Biological Monitoring Program is somewhat vague in regards to habitat and ecosystem health we recommend a revision of the goals and objectives of this plan by invested parties. The results of this discussion should yield explicitly stated objectives that are tied to specific and quantifiable parameters, bench-marks or trigger points. Objectives should also be tied to a relevant spatial scale or set of scales. For example, if the objective is to monitor trends in ecosystem health appropriate parameters could be native shrub cover at a site, or richness per hectare. Properly constructed objects inclusive of spatial scares and parameters will naturally suggest both sampling and response designs based on the work currently being carried out.

To prepare for and guide this discussion, it is also recommended that an additional review of the literature on the biological monitoring program to date is compiled as a brief white paper. This document would review the work done by McEachern et al., Franklin et al., Deutschman et al. and other relevant work. The goal of the document would be identify areas of inadequate detail in the original biological monitoring plan, and suggest tractable and relevant parameters and spatial scales to inform those objectives. If structured properly, this document will provide the context for overhauling the biological monitoring program.

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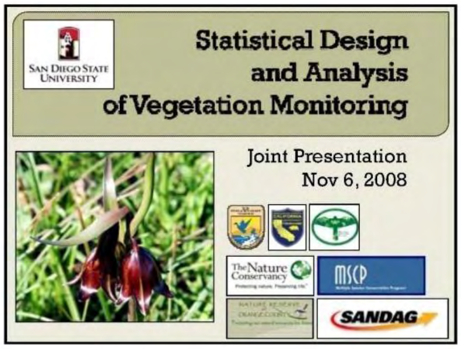
APPENDIX 1: NOVEMBER 2008 FINAL PRESENTATION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Statistical Design
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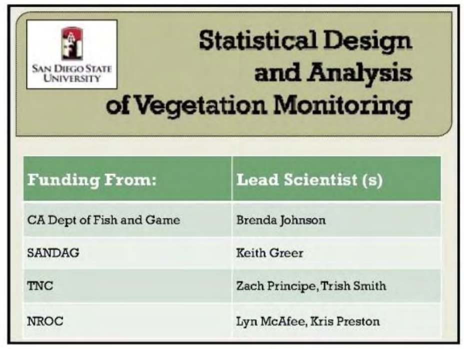
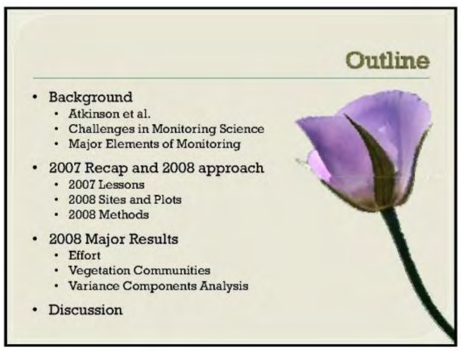
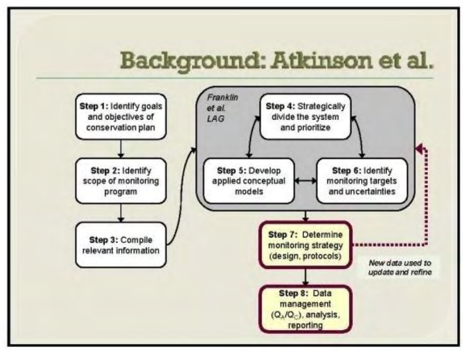
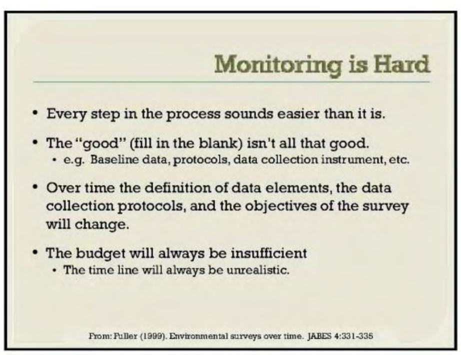
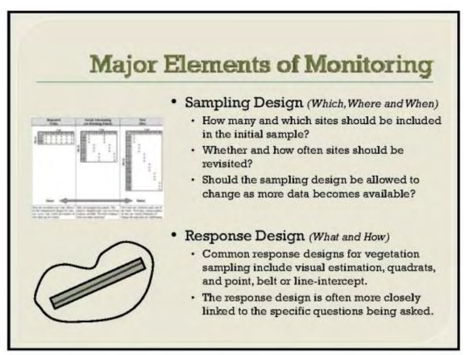
of Vegetation Monitoring
Joint Presentation
Nov 6, 2008
The Nature Conservancy
MSCP
SANDAG


SAN DIEGO STATE UNIVERSITY
Statistical Design
and Analysis
of Vegetation Monitoring
Funding From: | Lead Scientist (s)
CA Dept of Fish and Game | Brenda Johnson
SANDAG | Keith Greer
TNC | Zach Principe, Trish Smith
NROC | Lyn McAfee, Kris Preston

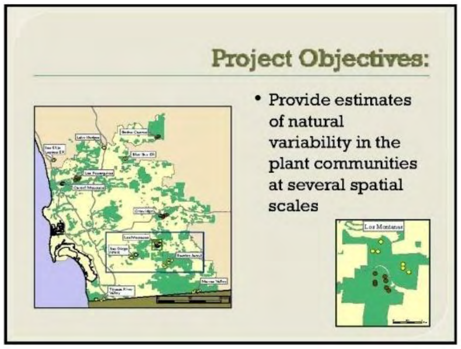

Outline
• Background
• Atkinson et al.
• Challenges in Monitoring Science
• Major Elements of Monitoring
• 2007 Recap and 2008 approach
• 2007 Lessons
• 2008 Sites and Plots
• 2008 Methods
• 2008 Major Results
• Effort
• Vegetation Communities
• Variance Components Analysis
• Discussion

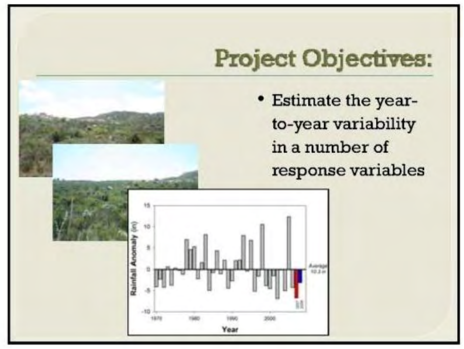

Background: Atkinson et al.
Step 1: Identify goals and objectives of conservation plan
Step 2: Identify scope of monitoring program
Step 3: Compile relevant information
Franklin et al. LAG
Step 4: Strategically divide the system and prioritize
Step 5: Develop applied conceptual models
Step 6: Identify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

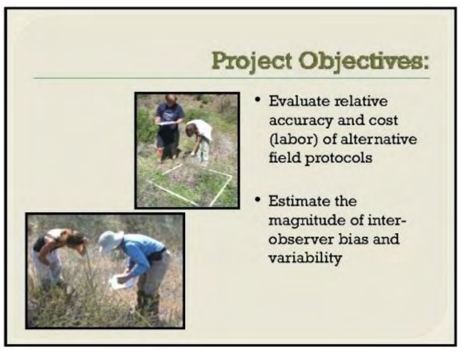

Monitoring is Hard
• Every step in the process sounds easier than it is.
• The "good" (fill in the blank) isn't all that good.
• e.g. Baseline data, protocols, data collection instrument, etc.
• Over time the definition of data elements, the data collection protocols, and the objectives of the survey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

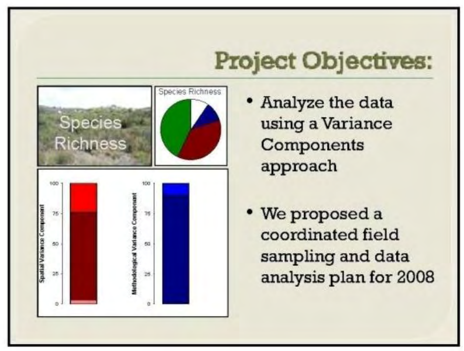

Major Elements of Monitoring
• Sampling Design (Which, Where and When)
• How many and which sites should be included in the initial sample?
• Whether and how often sites should be revisited?
• Should the sampling design be allowed to change as more data becomes available?
• Response Design (What and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

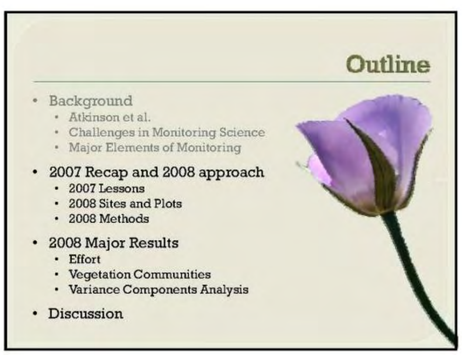
Deutschman et al. Monitoring Presentation – *November 6, 2008*

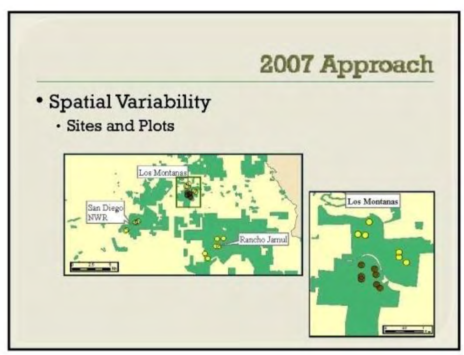


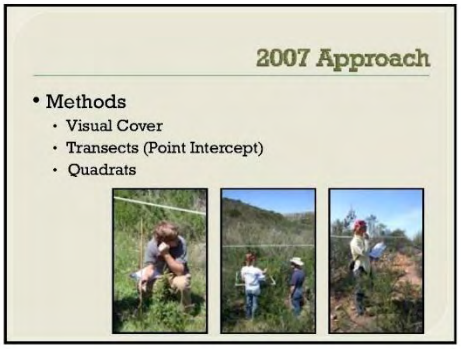


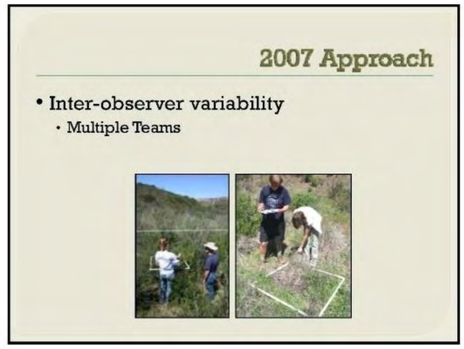


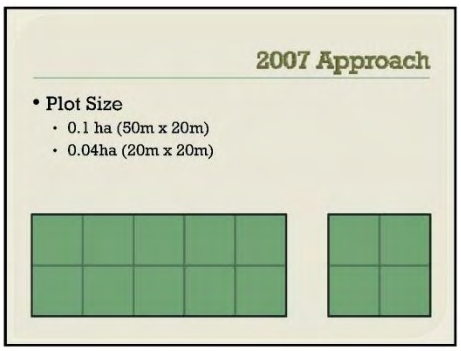


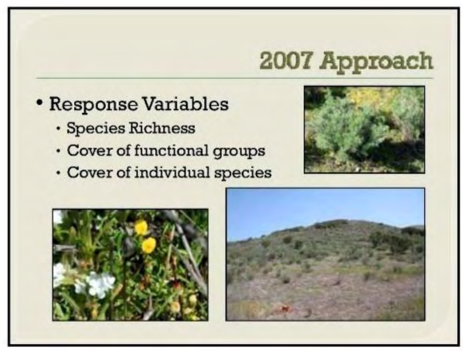





2007 Approach
• Methods
• Visual Cover
• Transects (Point Intercept)
• Quadrats


2007 Approach
• Inter-observer variability
• Multiple Teams

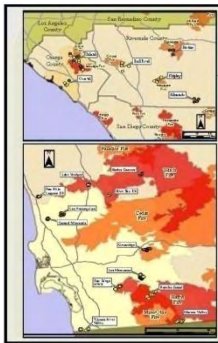

2007 Approach
• Plot Size
• 0.1 ha (50m x 20m)
• 0.04ha (20m x 20m)


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


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


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

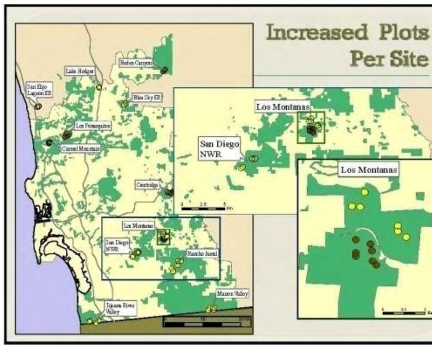
2007 Fire Impacts



- Several 2007 sites burned in the October wildfires.

	2007	2008	% Lost
CSS	15	5	-66%
Chaparral	14	11	-20%
Grassland	2	1	-50%

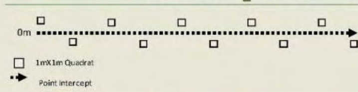
Increased Plots Per Site



2008 Response Design

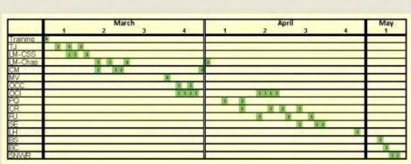
Method:	(1) Point Intercept	(2) Quadrat
Speed	Fast	Slow
Species	Large and Small	Small and Rare
Notes	Bad for rare or dispersed species	Best for small plants, not great for large

2008 Response Design



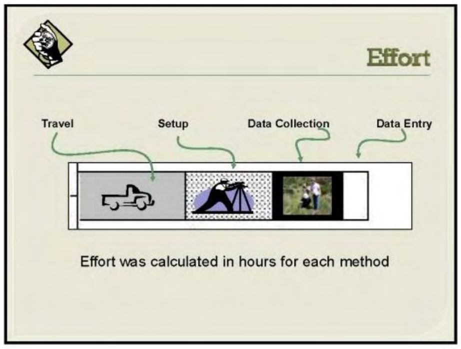
Change in Protocol	Expected Effect
Single Vector (Tape)	*Reduced set-up time*
Fewer points	*Reduced PI field and data entry time*
Fewer quadrats	*Reduced QD field and data entry time*
No visual cover	*Reduced time spent overall at the plot*
Total Desired Effect	**More plots per field day (at a site)**

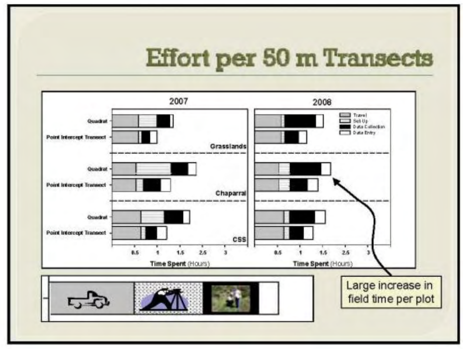
Field Schedule 2008

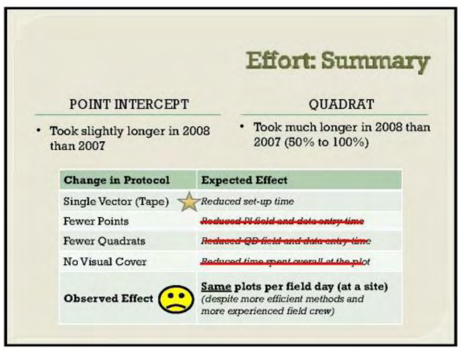


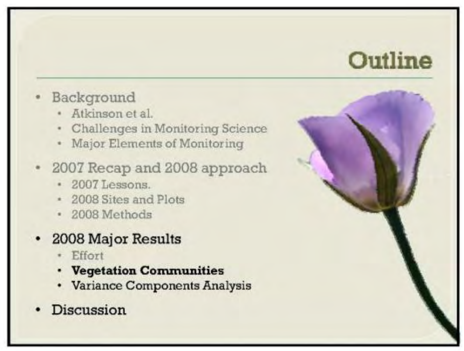
Outline

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


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


Effort per 50 m Transects
2007
2008
Grasslands
Chaparral
CSS
Time Spent (Hours)
Large increase in field time per plot


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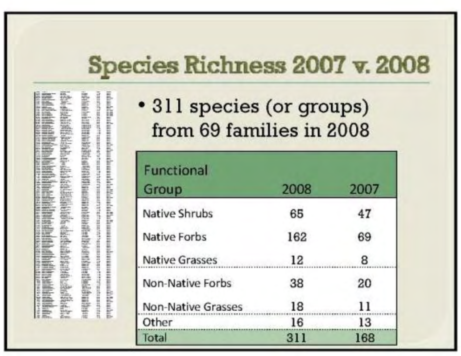
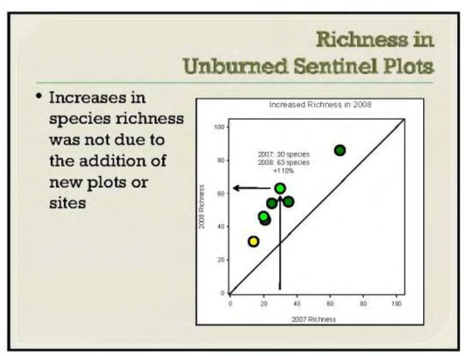
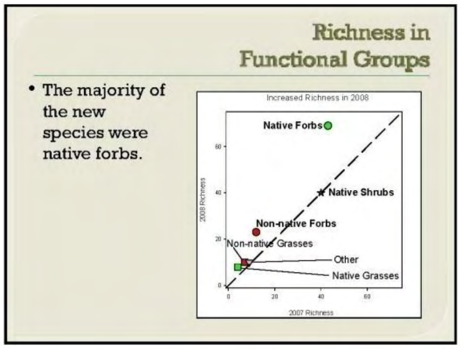
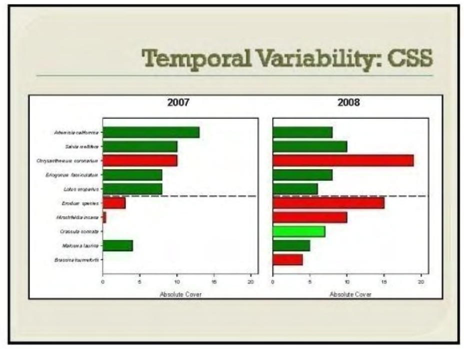
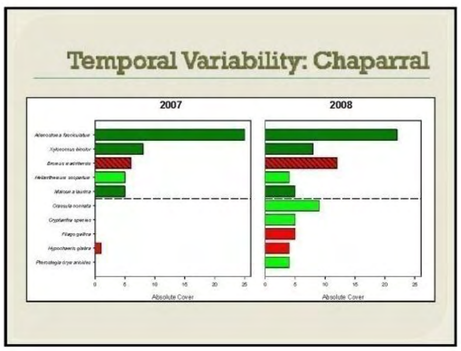
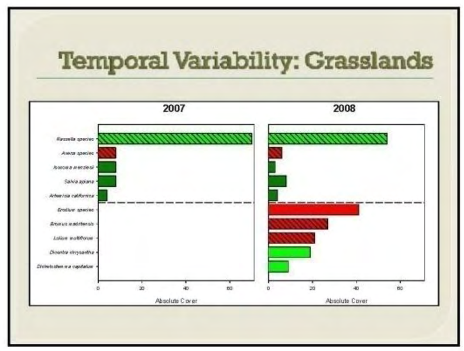

Species Richness 2007 v. 2008
• 311 species (or groups) from 69 families in 2008
Functional Group
2008
2007
Native Shrubs 65 47
Native Forbs 162 69
Native Grasses 12 8
Non-Native Forbs 38 20
Non-Native Grasses 18 11
Other 16 13
Total 311 168

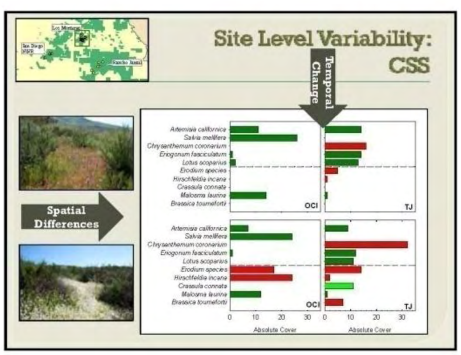

Richness in Unburned Sentinel Plots
• Increases in species richness was not due to the addition of new plots or sites
Increased Richness in 2008
2007: 30 species
2008: 63 species
+110%
2008 Richness
2007 Richness

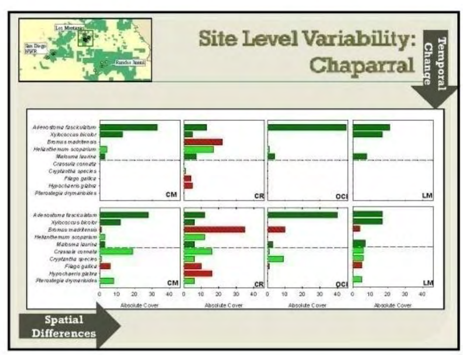

Richness in
Functional Groups
• The majority of the new species were native forbs.
Increased Richness in 2008
Native Forbs
Native Shrubs
Non-native Forbs
Non-native Grasses
Other
Native Grasses
2008 Richness
2007 Richness

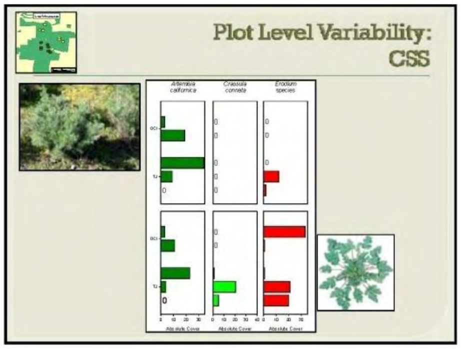

Temporal Variability: CSS
2007
2008
Absolute Cover

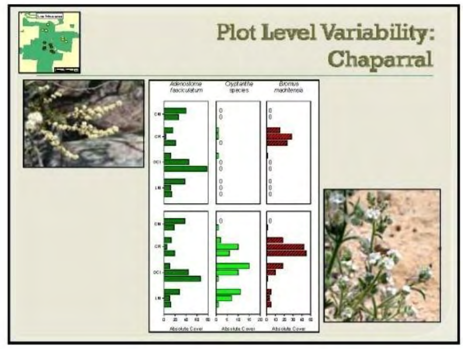

Temporal Variability: Chaparral
2007
2008
Absolute Cover

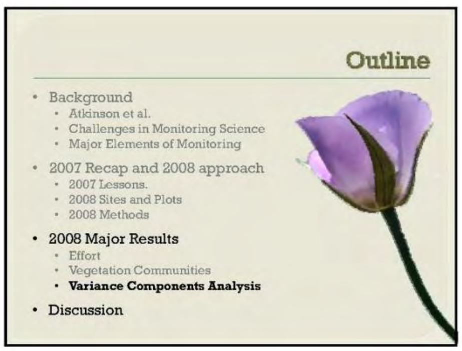

Temporal Variability: Grasslands
2007
2008
Absolute Cover


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


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


Plot Level Variability:
CSS


Plot Level Variability:
Chaparral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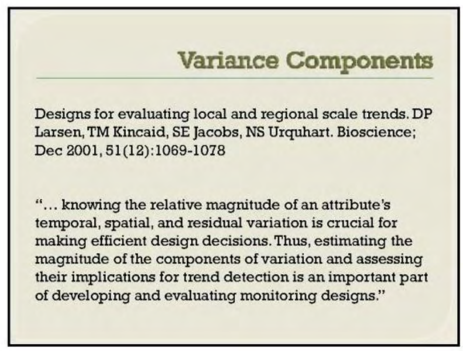
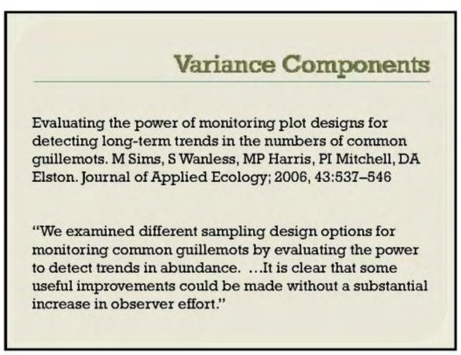
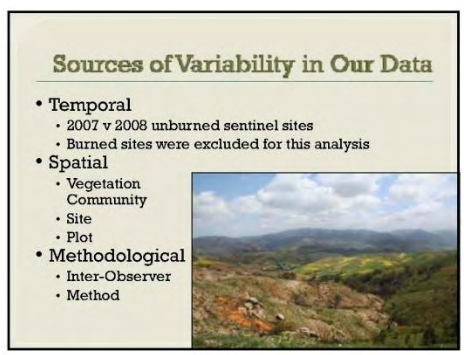
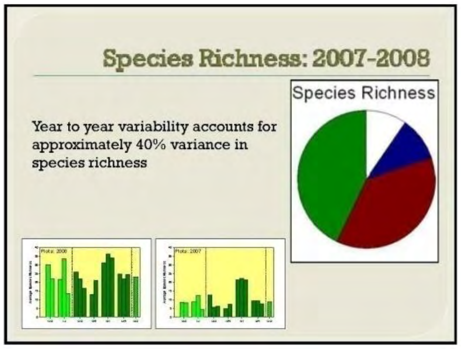
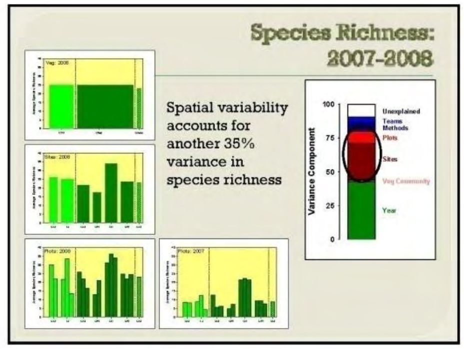
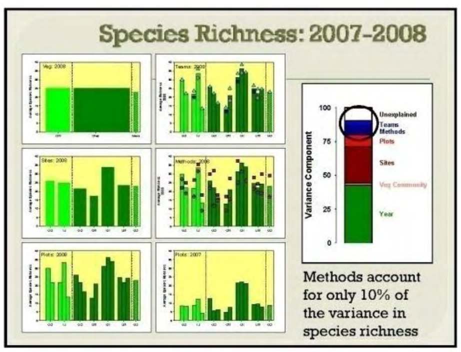

Variance Components
Designs for evaluating local and regional scale trends. DP Larsen, TM Kincaid, SE Jacobs, NS Urquhart. Bioscience; Dec 2001, 51(12):1069-1078
"... knowing the relative magnitude of an attribute's temporal, spatial, and residual variation is crucial for making efficient design decisions. Thus, estimating the magnitude of the components of variation and assessing their implications for trend detection is an important part of developing and evaluating monitoring designs."

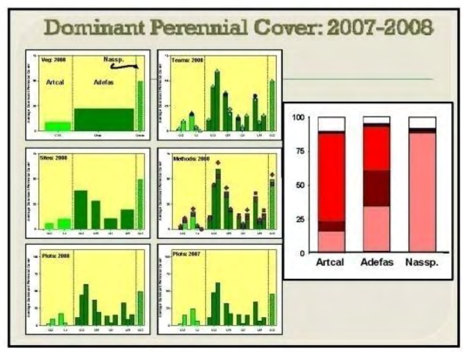

Variance Components
Evaluating the power of monitoring plot designs for detecting long-term trends in the numbers of common guillemots. M Sims, S Wanless, MP Harris, PI Mitchell, DA Elston. Journal of Applied Ecology; 2006, 43:537–546
"We examined different sampling design options for monitoring common guillemots by evaluating the power to detect trends in abundance. ...It is clear that some useful improvements could be made without a substantial increase in observer effort."

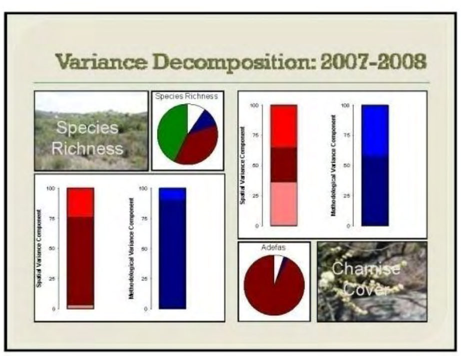

Sources of Variability in Our Data
• Temporal
• 2007 v 2008 unburned sentinel sites
• Burned sites were excluded for this analysis
• Spatial
• Vegetation Community
• Site
• Plot
• Methodological
• Inter-Observer
• Method

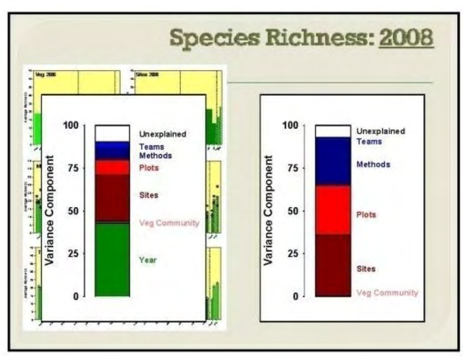

Species Richness: 2007-2008
Year to year variability accounts for approximately 40% variance in species richness
Species Richness

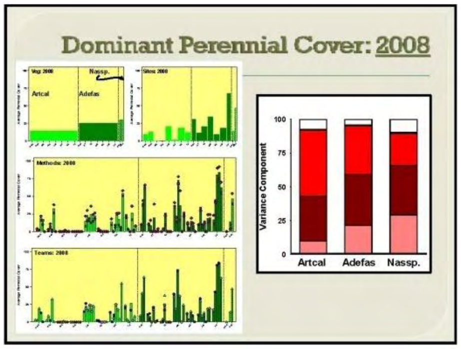

Species Richness: 2007-2008
Spatial variability accounts for another 35% variance in species richness
Variance Component
Unexplained
Teams
Methods
Plots
Sites
Veg Community
Year

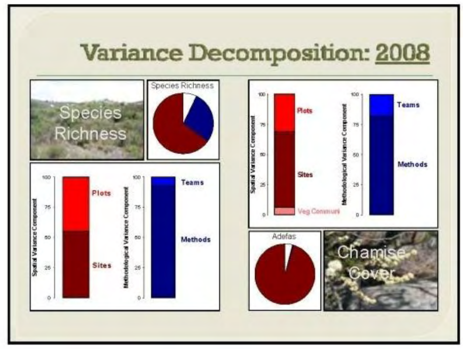

Species Richness: 2007-2008
Variance Component
Unexplained
Teams
Methods
Plots
Sites
Veg Community
Year
Methods account for only 10% of the variance in species richness


Dominant Perennial Cover: 2007-2008
Artcal
Adefas
Nassp.

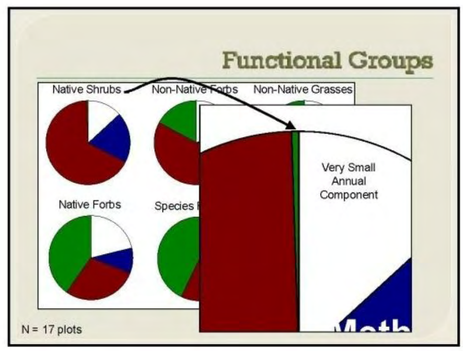

Variance Decomposition: 2007-2008
Species Richness
Species Richness
Adefas
Chamise Cover

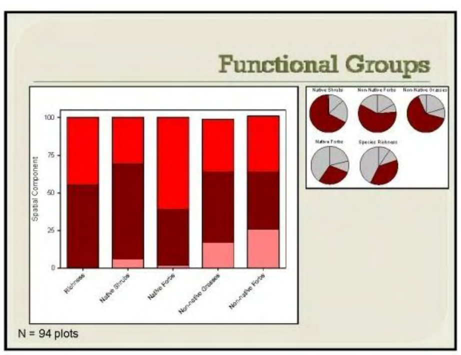

Species Richness: 2008
Variance Component
Unexplained
Teams
Methods
Plots
Sites
Veg Community
Year
Variance Component
Unexplained
Teams
Methods
Plots
Sites
Veg Community

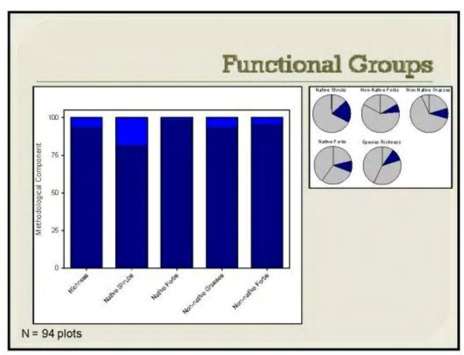

Dominant Perennial Cover: 2008
Artcal
Adefas
Nassp.
Variance Component
100
75
50
25
0

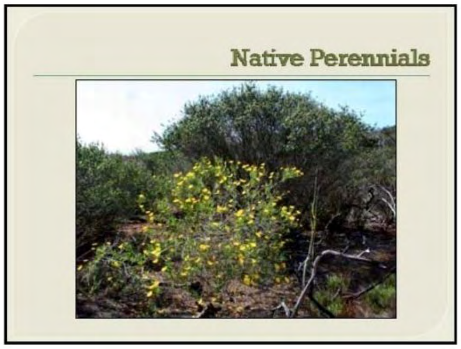

Variance Decomposition: 2008
Species Richness
Species Richness
Plots
Sites
Teams
Methods
Veg Component
Adefas
Chamise Cover

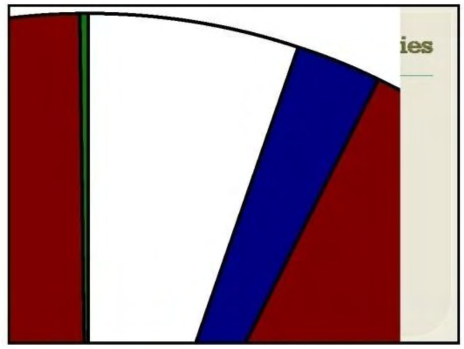

Functional Groups

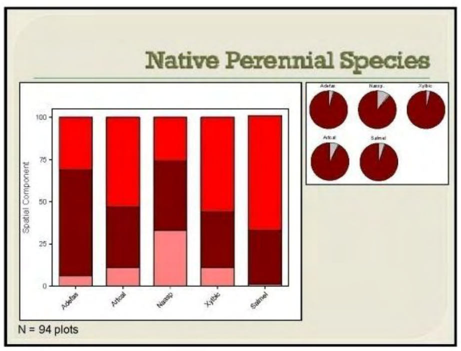

Functional Groups
Native Shrubs
Non-Native Forbs
Non-Native Grasses
Native Forbs
Very Small Annual Component
N = 17 plots

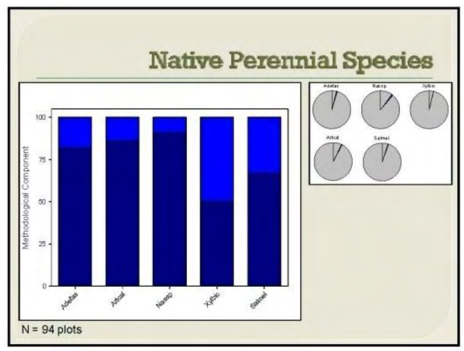

Functional Groups
Spatial Component
N = 94 plots


Functional Groups
Methodological Component
N = 94 plots

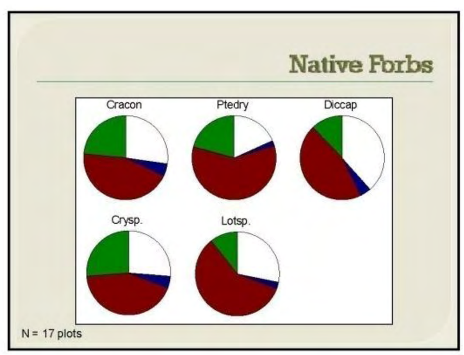

Native Perennials

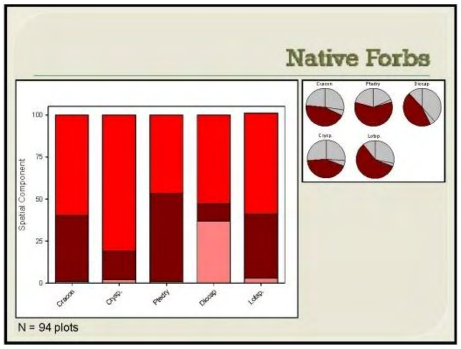


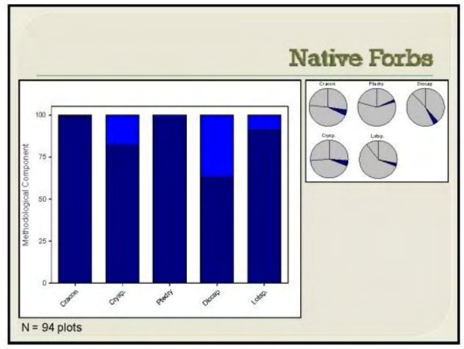

Native Perennial Species
N = 94 plots


Native Perennial Species
N = 94 plots

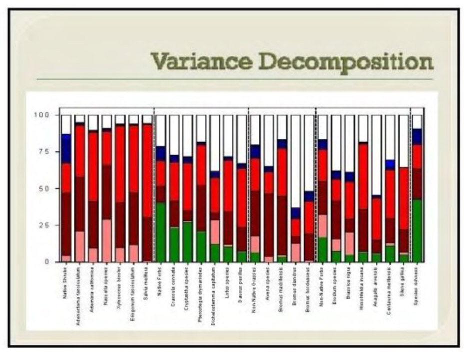

Native Forbs

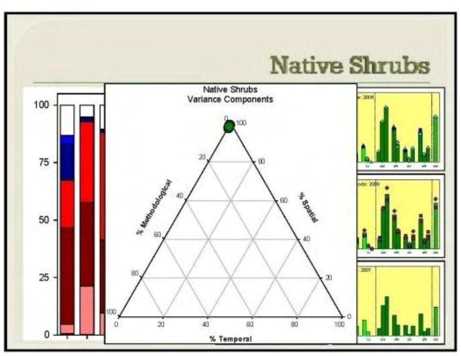

Native Forbs
Cracon
Ptedry
Diccap
Crysp.
Lotsp.
N = 17 plots

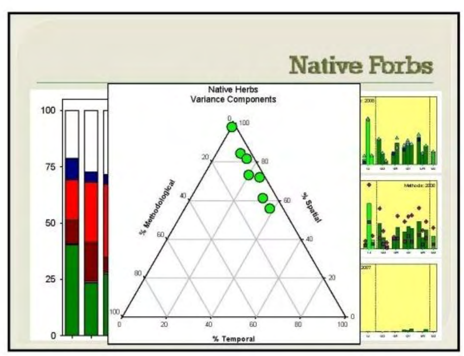

Native Forbs
Spatial Component
N = 94 plots

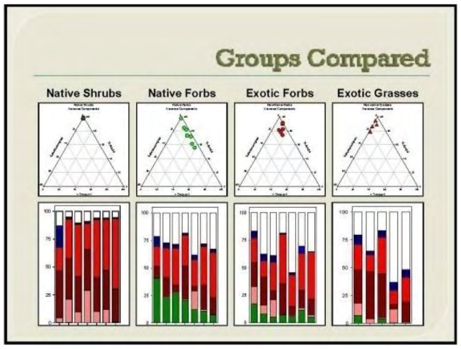

Native Forbs
Methodological Component
N = 94 plots

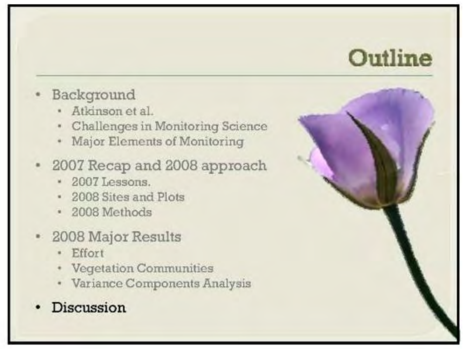

Selected Groups

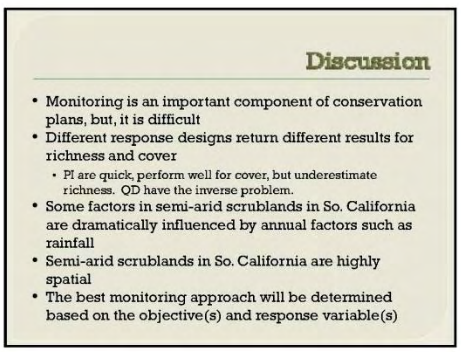

Variance Decomposition

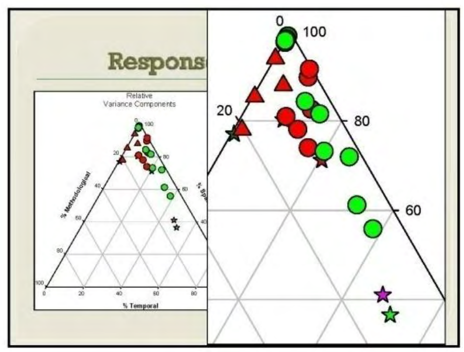

Native Shrubs
Native Shrubs
Variance Components
% Methodological
% Spatial
% Temporal

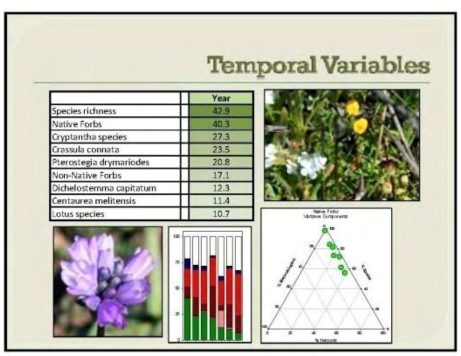

Native Forbs
Native Herbs
Variance Components
% Methodological
% Spatial
% Temporal



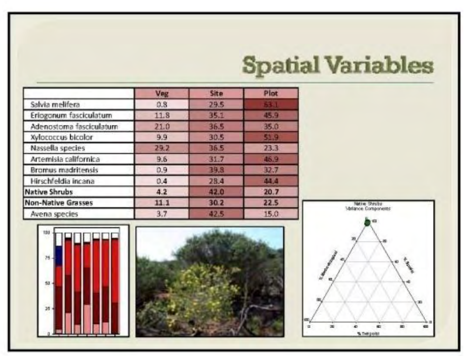




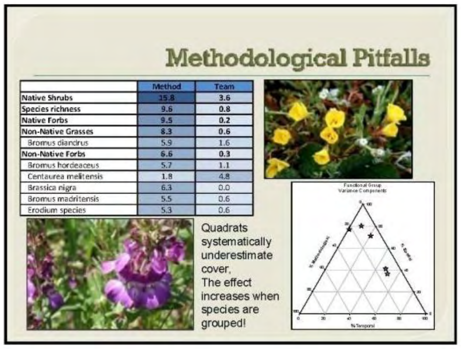




	Year
Species richness	42.9
Native Forbs	40.3
Cryptantha species	27.3
Crassula connata	23.5
Pterostegia drymariodes	20.8
Non-Native Forbs	17.1
Dichelostemma capitatum	12.3
Centaurea melitensis	11.4
Lotus species	10.7

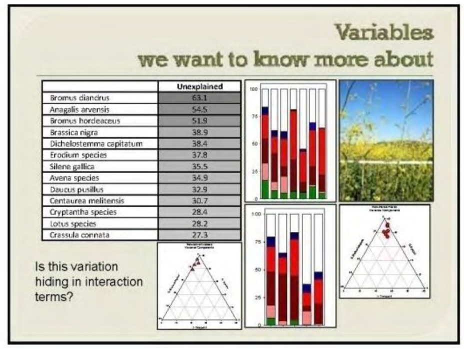


	Veg	Site	Plot
Salvia melifera	0.8	29.5	63.1
Eriogonum fasciculatum	11.8	35.1	45.9
Adenostoma fasciculatum	21.0	36.5	35.0
Xylococcus bicolor	9.9	30.5	51.9
Nassella species	29.2	36.5	23.3
Artemisia californica	9.6	31.7	46.9
Bromus madritensis	0.9	39.8	32.7
Hirschfeldia incana	0.4	28.4	44.4
Native Shrubs	**4.2**	**42.0**	**20.7**
Non-Native Grasses	**11.1**	**30.2**	**22.5**
Avena species	3.7	42.5	15.0


Methodological Pitfalls

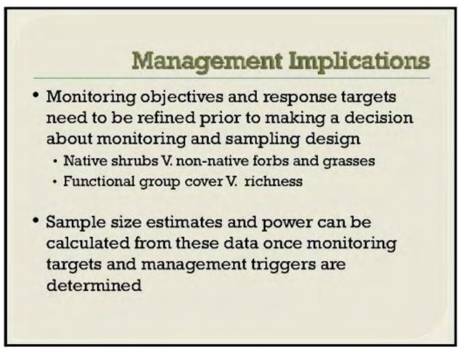
	Method	Team
Native Shrubs	15.8	3.6
Species richness	9.6	0.8
Native Forbs	9.5	0.2
Non-Native Grasses	8.3	0.6
Bromus diandrus	5.9	1.6
Non-Native Forbs	6.6	0.3
Bromus hordeaceus	5.7	1.1
Centaurea melitensis	1.8	4.8
Brassica nigra	6.3	0.0
Bromus madritensis	5.5	0.6
Erodium species	5.3	0.6

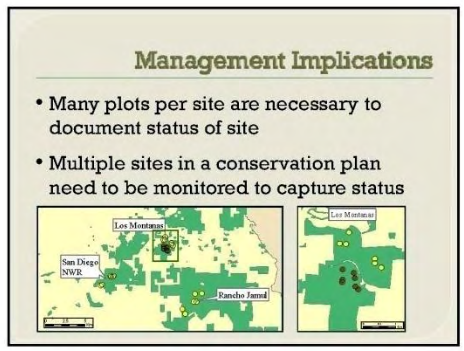
Quadrats systematically underestimate cover.
The effect increases when species are grouped!

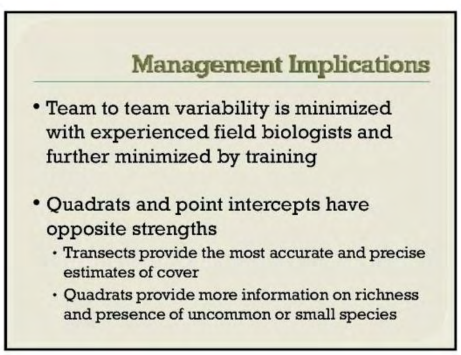

Variables
we want to know more about

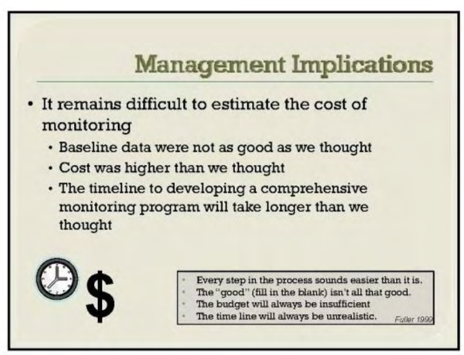
	Unexplained
Bromus diandrus	63.1
Anagalis arvensis	54.5
Bromus hordeaceus	51.9
Brassica nigra	38.9
Dichelostemma capitatum	38.4
Erodium species	37.8
Silene gallica	35.5
Avena species	34.9
Daucus pusillus	32.9
Centaurea melitensis	30.7
Cryptantha species	28.4
Lotus species	28.2
Crassula connata	27.3

Is this variation hiding in interaction terms?

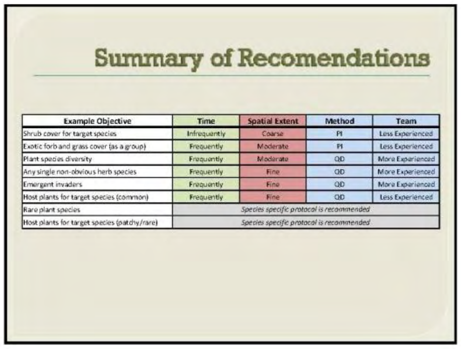

Management Implications
• Monitoring objectives and response targets need to be refined prior to making a decision about monitoring and sampling design
• Native shrubs V. non-native forbs and grasses
• Functional group cover V. richness
• Sample size estimates and power can be calculated from these data once monitoring targets and management triggers are determined


Management Implications
• Many plots per site are necessary to document status of site
• Multiple sites in a conservation plan need to be monitored to capture status
Los Montanas
San Diego NWR
Rancho Jamul
Los Montanas

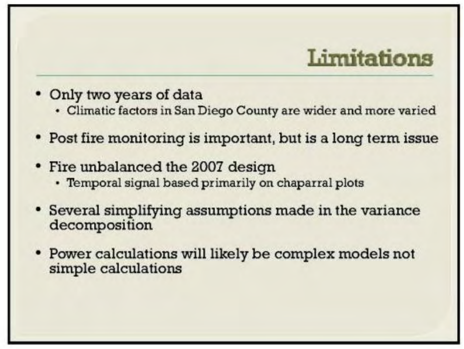

Management Implications
• Team to team variability is minimized with experienced field biologists and further minimized by training
• Quadrats and point intercepts have opposite strengths
• Transects provide the most accurate and precise estimates of cover
• Quadrats provide more information on richness and presence of uncommon or small species

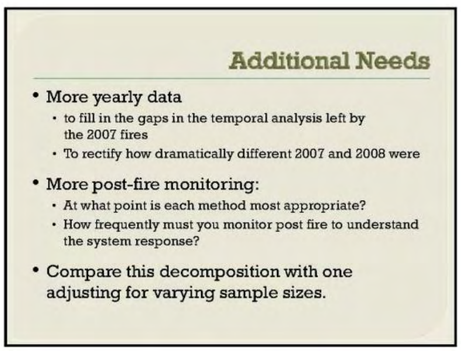

Management Implications
• It remains difficult to estimate the cost of monitoring
• Baseline data were not as good as we thought
• Cost was higher than we thought
• The timeline to developing a comprehensive monitoring program will take longer than we thought
$
Every step in the process sounds easier than it is.
The "good" (fill in the blank) isn't all that good.
The budget will always be insufficient
The time line will always be unrealistic.
Fuller 1990

Deutschman et al. Monitoring Presentation – *November 6, 2008*



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





APPENDIX 2:
PRESENTATION PARTICIPANTS AND RESPONSE TO COMMENTS

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

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

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

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

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

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

#	First	Last	Organization	Comment	Response
9	Jerrie	Stallcup	CBI	Are there situations when letting the design influence the question would be appropriate?	Probably not, with qualifications. The danger is collecting data because we can V. because we have to address specific questions. This question highlights the importance of the Atkinson et al approach, which allows you to set up goals, objectives and questions in a synthetic framework, then modify your design or questions based on the information you collect. EG a monitoring technique should not be static given new results, but does need to have driving goals and objectives to guide the effort.
10	Michael	Beck		Is the data available on-line?	We hope to have it in bios soon, however we did not until recently have the GIS power and time to deliver it to them in a GIS format.
11	Michael	Beck		Can or is this data being correlated with animal species.	Not yet. We have some Hermes copper data and will have some small mammal data. We have discussed putting out wildlife cameras, tracking stations, and other passive monitoring stations to begin this process, however we have not yet made any decisions.
12	Dana	Morin		Have you looked at other indices of diversity	We have not made the calculations. Our richness values are on one extreme of diversity calculations.
13	Betsy	Miller		I have a question about the scale of the sampling: How does the project design allow us to take data from, for example, a 50 meter transect and scale it up to provide meaningful information about the MHPA preserve as a whole? I'm concerned about the	To use this data at a larger spatial scale you would analyze it by averaging the plot level results to that scale—for example—network wide managers would use averages taken at the vegetation community level and draw conclusions about the quality or

#	First	Last	Organization	Comment	Response
				size of the area over which we need information, and the scope that would be required in order to have data to feed back into our adaptive management loop.	suitability of the CSS and chaparral across the MSCP. A reserve manager would analyze this data at the “site” level, and be able to draw conclusions about the CSS and/or chaparral at her or his reserve. The random element of the sampling design should mean that you get a good representative sample throughout each site, which can be averaged to give you a general idea about how things are going throughout whichever spatial scale you choose.

APPENDIX 3: PLOT LOCATIONS

Plot_Name	County	Site	Habitat	Plot	2007_Fire	TX_Length	Sentinel	Northing	Westing
SD_BC_CHAP_1	SD	BC	CHAP	1	B	100	Y	33.0917	-116.8957
SD_BC_CHAP_2	SD	BC	CHAP	2	B	100	Y	33.0902	-116.8961
SD_BC_CHAP_3	SD	BC	CHAP	3	B	100	Y	33.0874	-116.9015
SD_BS_CSS_1	SD	BS	CSS	1	B	100	Y	33.0172	-117.0050
SD_BS_CSS_2	SD	BS	CSS	2	B	100	Y	33.0175	-117.0058
SD_BS_CSS_3	SD	BS	CSS	3	B	100	Y	33.0148	-117.0093
SD_CM_CHAP_1	SD	CM	CHAP	1	UB	100	Y	33.0148	-117.0093
SD_CM_CHAP_2	SD	CM	CHAP	2	UB	100	Y	32.9315	-117.2166
SD_CM_CHAP_3	SD	CM	CHAP	3	UB	50	N	32.9299	-117.2182
SD_CM_CHAP_4	SD	CM	CHAP	4	UB	50	N	32.9284	-117.2190
SD_CM_CHAP_5	SD	CM	CHAP	5	UB	50	N	32.9309	-117.2180
SD_CM_CHAP_6	SD	CM	CHAP	6	UB	50	N	32.9314	-117.2159
SD_CR_CHAP_1	SD	CR	CHAP	1	UB	100	Y	32.8238	-116.8867
SD_CR_CHAP_2	SD	CR	CHAP	2	UB	100	Y	32.8206	-116.8771
SD_CR_CHAP_3	SD	CR	CHAP	3	UB	100	Y	32.8274	-116.8715
SD_CR_CHAP_4	SD	CR	CHAP	4	UB	50	N	32.8278	-116.8650
SD_CR_CHAP_5	SD	CR	CHAP	5	UB	50	N	32.8241	-116.8770
SD_CR_CHAP_6	SD	CR	CHAP	6	UB	50	N	32.8248	-116.8860
SD_LH_CSS_1	SD	LH	CSS	1	B	100	Y	33.0518	-117.0807
SD_LH_CSS_2	SD	LH	CSS	2	B	100	Y	33.0504	-117.0792
SD_LH_CSS_3	SD	LH	CSS	3	B	100	Y	33.0531	-117.0789
SD_LM_CHAP_1	SD	LM	CHAP	1	UB	100	Y	32.7247	-116.8952
SD_LM_CHAP_2	SD	LM	CHAP	2	UB	100	Y	32.7225	-116.8950
SD_LM_CHAP_3	SD	LM	CHAP	3	UB	100	Y	32.7261	-116.8955
SD_LM_CHAP_4	SD	LM	CHAP	4	UB	50	N	33.7270	-116.8990
SD_LM_CHAP_5	SD	LM	CHAP	5	UB	50	N	32.7243	-116.9890
SD_LM_CHAP_6	SD	LM	CHAP	6	UB	50	N	32.7236	-116.8990
SD_LM_CHAP_7	SD	LM	CHAP	7	UB	50	N	32.7217	-116.8940

Plot_Name	County	Site	Habitat	Plot	2007_Fire	TX_Length	Sentinel	Northing	Westing
SD_LM_CSS_1	SD	LM	CSS	1	UB	50	N	32.7370	-116.8970
SD_LM_CSS_2	SD	LM	CSS	2	UB	50	N	32.7288	-116.8890
SD_LM_CSS_3	SD	LM	CSS	3	UB	50	N	32.7341	-116.9000
SD_LM_CSS_4	SD	LM	CSS	4	UB	50	N	32.7300	-116.8890
SD_LM_CSS_5	SD	LM	CSS	5	UB	50	N	32.7276	-116.8870
SD_LM_CSS_6	SD	LM	CSS	6	UB	50	N	32.7339	-116.8980
SD_LP_CHAP_1	SD	LP	CHAP	1	UB	50	N	32.9510	-117.1710
SD_LP_CHAP_2	SD	LP	CHAP	2	UB	50	N	32.9500	-117.1630
SD_LP_CHAP_3	SD	LP	CHAP	3	UB	50	N	32.9442	-117.1650
SD_LP_CHAP_4	SD	LP	CHAP	4	UB	50	N	32.9423	-117.1740
SD_MV_CSS_1	SD	MV	CSS	1	B	100	Y	32.5742	-116.7540
SD_MV_CSS_2	SD	MV	CSS	2	B	100	Y	32.5742	-116.7540
SD_MV_CSS_3	SD	MV	CSS	3	B	100	Y	32.5730	-116.7592
SD_MV_CSS_4	SD	MV	CSS	4	B	50	N	32.5730	-116.7592
SD_MV_CSS_5	SD	MV	CSS	5	B	50	N	32.5729	-116.7680
SD_MV_CSS_6	SD	MV	CSS	6	B	50	N	32.5706	-116.7570
SD_MV_CSS_7	SD	MV	CSS	7	B	50	N	32.5693	-116.7720
SD_RJ_CSS_1	SD	RJ	CSS	1	B	50	N	32.6586	-116.8740
SD_RJ_CSS_2	SD	RJ	CSS	2	B	50	N	32.6668	-116.8550
SD_RJ_CSS_3	SD	RJ	CSS	3	B	50	N	32.6758	-116.8480
SD_RJ_CSS_4	SD	RJ	CSS	4	B	50	N	32.6531	-116.8700
SD_RJ_CSS_5	SD	RJ	CSS	5	B	50	N	32.6668	-116.8590
SD_RJ_CSS_6	SD	RJ	CSS	6	B	50	N	32.6751	-116.8571
SD_SDNWR_CSS_1	SD	SDNWR	CSS	1	B	100	N	32.6943	-116.9662
SD_SDNWR_CSS_2	SD	SDNWR	CSS	2	B	100	N	32.6933	-116.9671
SD_SDNWR_CSS_3	SD	SDNWR	CSS	3	B	100	N	32.6939	-116.9702
SD_SDNWR_CSS_4	SD	SDNWR	CSS	4	B	100	N	32.6929	-116.9700
SD_SDNWR_CSS_5	SD	SDNWR	CSS	5	B	100	N	32.6845	-116.9819
SD_SDNWR_CSS_6	SD	SDNWR	CSS	6	B	100	N	32.6833	-116.9838

Plot_Name	County	Site	Habitat	Plot	2007_Fire	TX_Length	Sentinel	Northing	Westing
SD_SE_CSS_1	SD	SE	CSS	1	UB	50	N	33.0085	-117.2477
SD_SE_CSS_2	SD	SE	CSS	2	UB	50	N	33.0095	-117.2460
SD_SE_CSS_3	SD	SE	CSS	3	UB	50	N	33.0093	-117.2480
SD_SE_CSS_4	SD	SE	CSS	4	UB	50	N	33.0080	-117.2510
SD_SE_CSS_5	SD	SE	CSS	5	UB	50	N	33.0087	-117.2520
SD_SE_CSS_6	SD	SE	CSS	6	UB	50	N	33.0087	-117.2520
SD_SE_CSS_7	SD	SE	CSS	7	UB	50	N	33.0080	-117.2519
SD_TJ_CSS_1	SD	TJ	CSS	1	UB	100	Y	32.5446	-117.0756
SD_TJ_CSS_2	SD	TJ	CSS	2	UB	100	Y	32.5426	-117.1016
SD_TJ_CSS_3	SD	TJ	CSS	3	UB	100	Y	32.5434	-117.0986
SD_TJ_CSS_4	SD	TJ	CSS	4	UB	50	N	32.5436	-117.0760
SD_TJ_CSS_5	SD	TJ	CSS	5	UB	50	N	32.5392	-117.0819
SD_TJ_CSS_6	SD	TJ	CSS	6	UB	50	N	32.5414	-117.1020

Appendix 4: Three County Species List

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

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

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

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

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

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

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

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

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

APPENDIX 6: DATA SHEETS AND DESCRIPTION

Point Intercept Transect Data Sheets:

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

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

Transect 1

Site	
Plot	
Field Crew	

Date	
Start Time	
End Time	

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

Transect 1

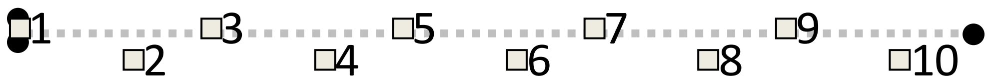
Site	Date
Plot	**Start Time**
Field Crew	**End Time**

Ground Cover

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

Quadrat Data Sheets:

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



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

Quadrats

1-10 (all plots)

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

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

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

Back of Sheet

NOTES

Appendix 7: Burned Vegetation Characterization

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

Species Richness

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

Overall there was only a small increase in species richness from 2007 to 2008. In 2007 we identified 101 species in the plots that would later burn. In 2008 we found 113 species, however some of the species identified previously were not present, and a number of new species appeared in these plots. At some sites the turnover of species was somewhat remarkable. In the case of some species we can assume they benefited from the effect of fire and others increased rainfall. A handful of species not identified in each year could be due to observer error or an interaction of fire, rain and other annual factors we are unable to appraise at this time.

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

	All Species		Native Shrubs		Native Forbs		Native Grasses		Non-native Forbs		Non-native Grasses	
	07	08	07	08	07	08	07	08	07	08	07	08
All Sites	**101**	**113**	**23**	**22**	**49**	**68**	**3**	**3**	**17**	**14**	**9**	**6**
CSS Sites	**75**	**89**	**16**	**14**	**31**	**51**	**4**	**3**	**16**	**14**	**8**	**7**
Blue Sky	46	53	7	7	20	31	1	0	10	10	8	5
Lake Hodges	35	44	5	4	14	26	2	2	11	7	3	5
Marron Valley	31	50	12	8	11	24	2	1	2	12	4	5
Chaparral Sites	**56**	**69**	**14**	**15**	**21**	**39**	**3**	**0**	**10**	**9**	**8**	**6**
Boden Canyon	56	69	14	15	21	39	3	0	10	9	8	6

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

Most functional groups experienced some species turnover, including native shrubs. The turnover of native shrubs can almost be entirely attributed to the effect of fire as they live on a longer life cycle and change therefore happens slowly, except during point events. At Blue Sky we saw no change in shrub species richness, however we did see species turn over. Of the seven species we observed in 2007 we lost *Hesperoyucca whipplei*, and *Rhamnus crocea*. Those species were replaced by Lotus scoparius and Malacothamnus fasciculatum. These species both tend to follow disturbance and are common in post-fire CSS. At Lake Hodges we lost Rhamnus crocea and Mimulus aurantiacus, but gained Malosma laurina, whose seeds germinate in response to fire. At Boden Canyon (the only burned chaparral site) we lost Salvia apiana, a highly oily and resinous species which tends to burn completely, and gained Lotus scoparius and Quercus berberidifolia. Again, Lotus scoparius is a well documented fire following plant species with a more rapid life cycle than other shrubs. Quercus berberidifolia germinates from acorns, which may have been hidden under thatch and not burned, or, given the limited size of the seedlings it could have been a different species with similar leaves that was misidentified.

At Marron Valley we lost a large number of shrub species including: Eriogonum fasciculatum, Ephedra californica, Lotus scoparius, Bahiopsis laciniata, Cylindropuntia californica, and Baccharis sarathroides. The only species we encountered that was new this year was Encelia californica. The reason for so much turn over in shrub species might be related to the initial diversity and initial cover of those species. Of the burned sites, Marron Valley was one of the most diverse (second to Boden Canyon), probably because it is a transition area from coast to desert, with desert species such as *Ephedra californica* and Lycium andersonii mixed with more coastal species like Eriogonum fasciculatum and Artemisia californica. Most of the species that were lost had under 1% average cover before the fire, except for Eriogonum fasciculatum which was just under 4% cover prior to the fire, but which tends to burn completely. The only species that had under 1% cover that was detected after the fire in 2008 was Isocoma menziesii. We know that rare or patchy species are hard to detect and are often easy to miss on a plot level. It may be that the shrub species lost at Marron Valley are not lost, per se, but are no longer on our transects. It is also possible that there has been a real and dramatic decline in shrub diversity and that seeding will have to occur from outside the fire perimeter.

Where we saw the loss of native grass species, the majority of those species were perennial bunch grasses, such as Nassella species, and Muhlenbergia rigens.

Surprisingly we typically lost non-native grass species as well as seeing turnover of some species. In general Vulpia myuros and Gastridium ventricosum appeared at sites where it had not been previously. Bromus diandrus and Bromus hordeaceus were the species that most typically fell out of the list, this could be a real effect, or it could be due to difficulty discriminating between the different Bromus species later in the spring when the burned sites were sampled.

Species Distribution

We define a species' distribution in terms of the number of plots a species was found in, regardless of that specie's cover. We only discuss the distribution of species in burned CSS plots because we only had one burned chaparral site.

The most widespread species was the non-native herb *Erodium* species, which occurred at all 19 burned CSS plots. Herbaceous *Lotus* species were present in 18 CSS plots, as was the non-native grass *Bromus madritensis*. The most widespread native shrub species was *Artemisia californica*, occurring in 14 of the 19 CSS plots.

Dominant Species

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

In the plots that burned last year, *Eriogonum fasciculatum*, *Artemisia californica* and *Adenostoma fasciculatum* were the dominant native shrub species prior to fire. After fire the cover of those species was reduced from around 10% to around 1% or less. The majority of the cover for those shrubs in 2008 comes from seedlings and stump-sprouting individuals. The non-native grass *Bromus madritensis* and the non-native forb *Centaurea melitensis* actually saw a marginal decline in cover, however, the non native forb *Erodium* saw a tremendous increase, from around 10% on average to around 30% across the burned plots. *Hirschfeldia incana* and *Silene gallica* saw more than the three fold increase of *Erodium*, but these species started at a much lower cover. Herbaceous lotus and *Cryptantha* increased in cover in the same way. In the unburned plots we saw similar increases for native and non-native forbs and concluded that this effect was largely due to increased moisture from 2007 to 2008. There is a possibility that fire and water are interacting in burned plots to yield these types of increases for certain species. For example we did not see the same prevalence of *Lotus* species in unburned plots, where as we did see increased Cryptantha cover. As a nitrogen fixer *Lotus* species may be playing a role in the post-fire dynamic, less so than *Cryptantha* could.

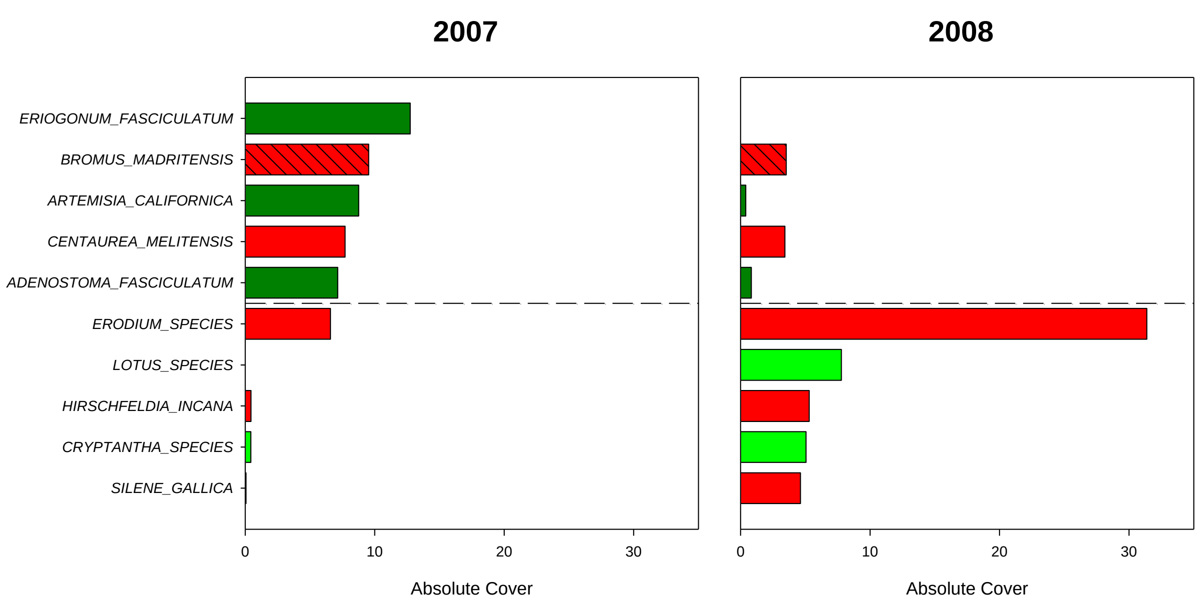


Figure A-1: Absolute cover of dominant species after fire. Shrub cover fell close to 0 as a result of fire. The increase in native and non-native forbs was likely an interaction of increased rainfall and fire disturbance.

DOMINANT COASTAL SAGE SCRUB SPECIES

We lost three CSS scrub sites (Blue Sky, Lake Hodges, and Marron Valley) to fire in 2007, for a total of 9 plots. All three CSS sites burned completely, with very few shrub skeletons left standing inside the plots, indicating an intense fire. From the "overall" results presented above we see that the increase in *Erodium* was largely in CSS, where the average cover of *Erodium* was greater than 40% across the 9 plots that were burned. The same is true for *Lotus* species, which increased dramatically in CSS, but less so in Chaparral.

The difference between the post fire cover of *Artemisia californica* and *Eriogonum fasciculatum* is small, but notable. Given the tendency for these species to burn completely and their inability to resprout from root systems (except when only slightly damaged), the majority of the cover we recorded was due to seedlings. Prior to fire, *Eriogonum fasciculatum* held about 5% more cover than *Artemisia californica*, however after fire *Artemisia* cover was slightly higher. The difference in cover between these two species suggests that *Artemisia californica* may have had greater germination success than *Eriogonum fasciculatum* this year. This observation was also made informally in the field. It is not clear if the same proportion of seedlings will recruit to adult shrubs, or if *Eriogonum fasciculatum* will make up in survivorship what it lost, this year, in germination.

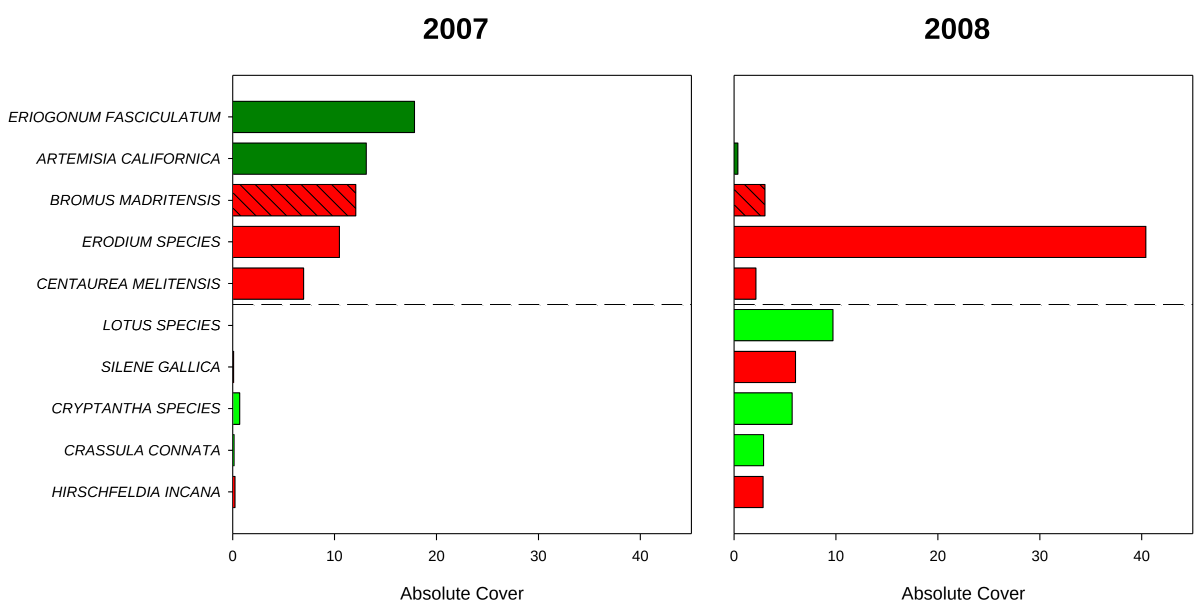


Figure A-2: Absolute cover of dominant CSS species after fire. Shrub cover fell close to 0 as a result of fire. The increase in native and non-native forbs was likely an interaction of increased rainfall and fire disturbance.

By comparing the cover of dominant CSS species across sites we see that some of the post-fire changes were ubiquitous, while others were site specific. For example, *Erodium* cover was high in CSS across all three sites, especially Lake Hodges and Marron Valley, in 2008. Lake Hodges, however, saw the most alarming increase from 2007 to 2008, increasing from 9% cover, to 55% cover, where as Marron Valley had already had high *Erodium* cover and Blue Sky which had substantially less than the other two sites in both years. Herbaceous *Lotus* species, however, got the largest push at Blue Sky, and only saw moderate increases at Lake Hodges and Marron Valley. The lower cover of *Erodium*, coupled with the post fire pulse of *Lotus* may be a reflection of Blue Sky's pre-fire condition, with more native shrub cover, and less non-native cover over all in 2007 than the other burned CSS sites.

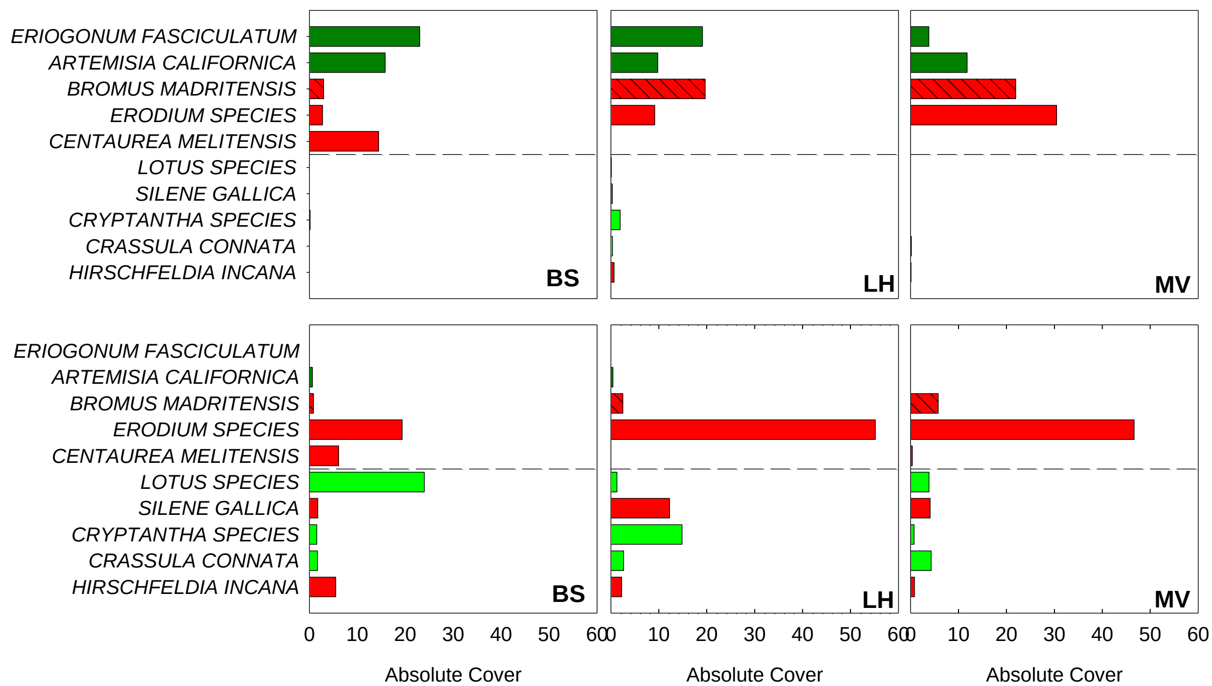


Figure A-3: *Absolute cover of dominant CSS species after fire by site.*

Dominant Chaparral Species

We were only able to look at the effect of fire at Boden Canyon since the other chaparral sites escaped the fire. At Boden Canyon the fire intensity was more heterogeneous than it was at the CSS sites that burned. This may be an effect of topography in the canyon, or simply conditions during the fire. Plot 1 was only partially burned by a spot fire about 20m in diameter near the origin. This plot had the most *Ceanothus crassifolius*, which explains why the cover of this native shrub was reduced less dramatically than other native shrubs that were dominant in other plots. Plot 2 totally burned, however there were some shrub skeletons still standing, some even with secondary branches remaining, indicating that the fire was of moderate intensity at this plot. Plot 3 burned completely and more of the shrub skeletons were consumed overall, indicating a more intense fire than at the other plots. Plots 2 and 3 had a mixture of *Adenostoma fasciculatum* and *Cneoridium dumosum*, both species which saw a decline, but not total elimination. The reason why native chaparral shrubs did not see as dramatic a decline as CSS shrubs is probably related to stump sprouting, and the fact that CSS shrubs often burn more readily than chaparral shrub species.

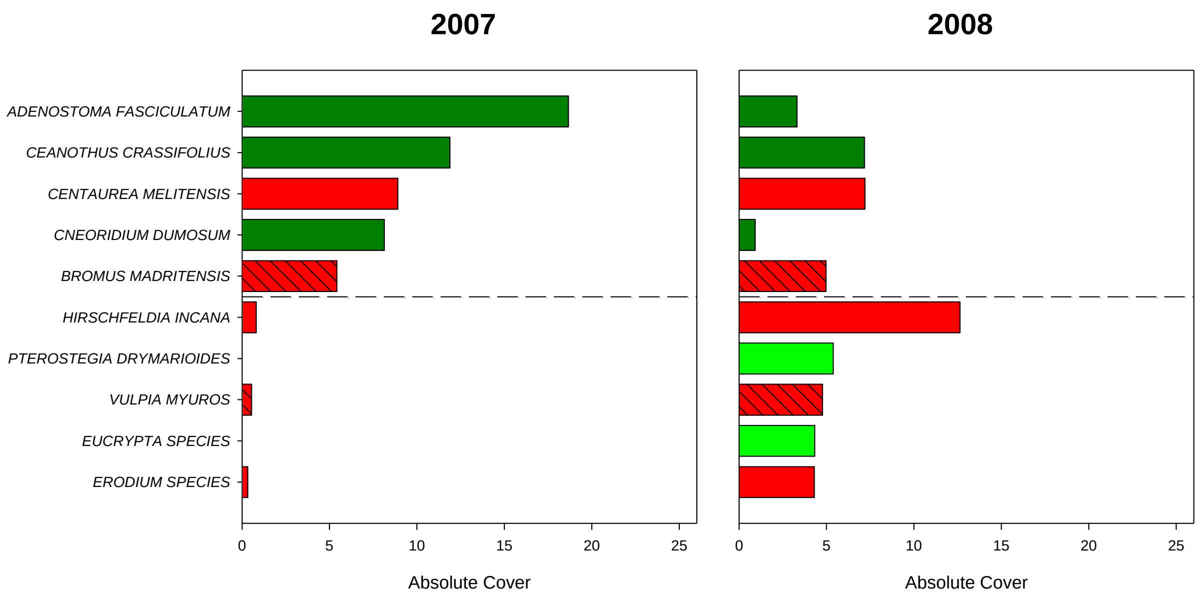


Figure A-4: *Absolute cover of major species at Boden Canyon*