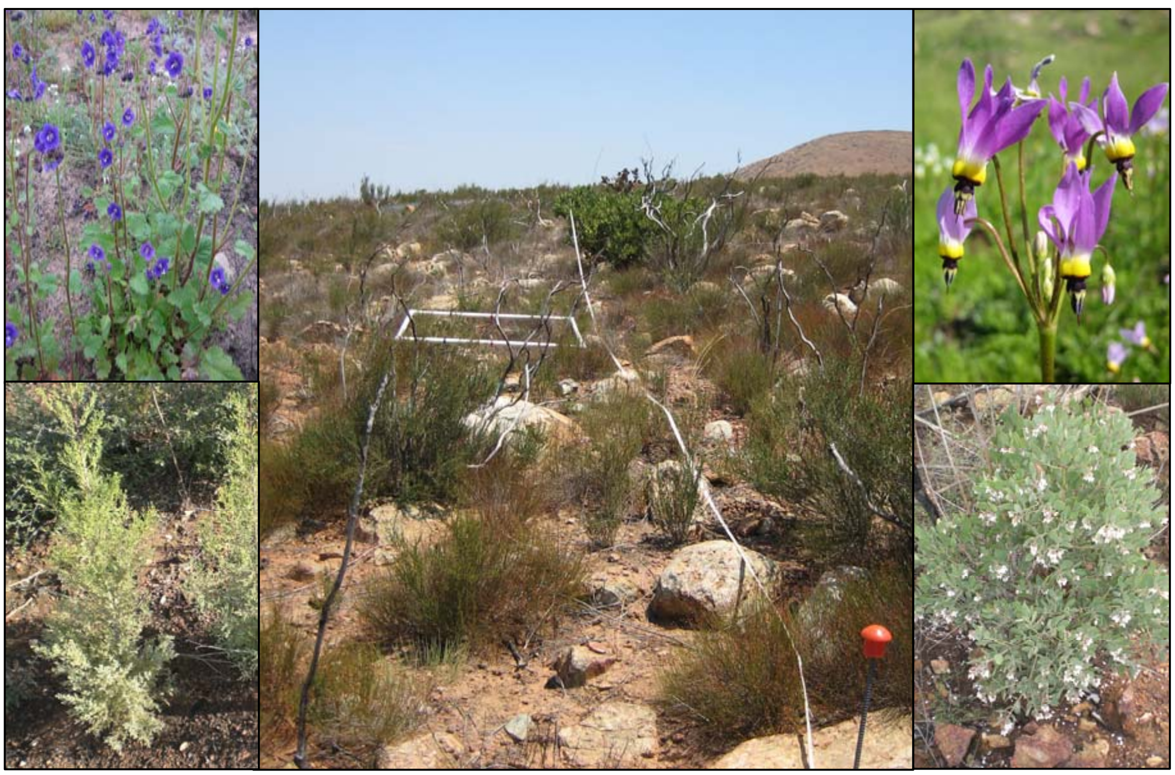
Plant Community Responses to Large-scale Wildfires at Four Wildlife Areas in Southern California

Data Summary



Prepared for:

San Diego Association of Governments

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
WESTERN ECOLOGICAL RESEARCH CENTER

Plant Community Responses to Large-scale Wildfires in Southern California

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Abstract

In 2003 and 2007, southern California experienced several large fires which burned thousands of hectares of wildlife habitats and conserved lands. In order to investigate the effects of the fires on plant communities, we compared the results from vegetation sampling conducted prior to the fires to results from four consecutive years of post-fire sampling among 38 burned and 17 unburned plots. The sampling plots were spread over four vegetation types (chaparral, coastal sage scrub, woodland/riparian, and grassland) and four open space areas within San Diego County. Our survey results indicated that burned plots of chaparral and coastal sage scrub lost shrub and tree canopy cover after the fires and displayed shifts in overall community structure. Post-fire community structure within burned chaparral and coastal sage scrub plots was more similar to that found in grasslands. We did not find differences in species richness or community composition in grasslands or woodland/riparian vegetation where shrub and tree cover did not significantly change after the fires. Across all plots both before and after the fires, non-native grass was the most abundant "species", followed by chamise (*Adenostoma fasciculatum*) which was consistently the second most abundant species. We saw increases in the cover rates for several species, including peak rush-rose (*Helianthemum scoparium*) and *Ceanothus* spp., in burned chaparral and coastal sage scrub plots. California sagebrush (*Artemisia californica*) and California buckwheat (*Eriogonum fasciculatum*) appear to have declined drastically in our coastal sage scrub samples with little to no signs of recovering. Chamise, Tecate cypress (*Cupressus forbesii*), and pines (*Pinus* spp.) also declined, but it apprears that there has been some progress in the post-fire recovery of these species. We discuss these individual species results as they relate to specific life history traits, such as susceptibility to initial mortality and post-fire changes in habitat suitability. We foresee that a continued unnatural fire regime for southern California will result in a simplification of the southern California vegetation communities, especially in the shrublands.

Introduction

Wildfires have long been a part of the natural and human altered environments of southern California, a fact that is unlikely to change anytime in the near future. Native vegetation communities have evolved with some variation of this fire regime and have adapted with various survival strategies (Hanes 1971, Vogl and Schorr 1972, Keeley and Keeley 1981, Zedler et al. 1983, Keeley and Keeley 1984, Keeley and Fotheringham 2001). Despite fire suppression efforts and management plans, large and small wildfires continue to occur from both natural ignition sources and those associated with an increasing human population (Keeley et al. 1999, Keeley et al. 2004). In addition, the intervals between these fires have been substantially reduced from historic levels, resulting in an overall increased frequency of fires. Increased fire frequency has been shown to cause the type conversion of shrublands (e.g., chaparral and coastal sage scrub) to grasslands (Zedler et al. 1983, Keeley 2005).

Direct and indirect effects from fire can have both negative and positive impacts on local species and communities. Negative impacts of the fires may include direct mortality and the loss of habitat suitability. Fire may have positive impacts for those species that can survive fires and for those adapted to the open or disturbed habitat and the opportunities present therein. As has been shown previously, there is the potential for conversion of diverse scrub and chaparral vegetation types to less diverse grasslands which may be unsuitable habitat for some species.

In October and November of 2003, large-scale fires swept across southern California, burning over 300,000 ha of wild lands. This included nearly 130,000 ha burned in the Cedar and Otay fires in San Diego County. In addition to the loss of nearly 5,000 structures and 15 human fatalities (CDF 2003), these large fires undoubtedly impacted local plant communities in a region already recognized as being one of the greatest at risk for biodiversity loss (Mittermeier et al. 1997). The first large habitat reserve created in San Diego County, the Multiple Species Conservation Plan (MSCP) (City of San Diego 1997) was directly in the footprints of these two fires. Half of the protected lands within the MSCP were affected by the fires, and some protected habitats were entirely within the fire perimeter. In the fall of 2007, a second round of large-scale fires impacted San Diego County. In some instances, lands burned in the 2003 events re-burned in 2007. Concern over the recovery of these habitats and the species within them motivated our efforts to conduct this research. With the detailed data on vegetation communities that we had collected previously within the footprints of these fires, we were in a unique position to address this concern.

The primary objective of this study was to increase our understanding of the short term response and interactions of different plant species and communities to fire. Through intensive community monitoring in these burned areas and comparisons to pre-fire community structure and unburned areas, we expected to learn 1) whether the species richness or composition of plant communities were affected by the fire, and 2) if any of the impacted plant communities were recovering to the original, pre-fire community or were in the process of converting to an alternate community.

Materials and Methods

Study Sites

We conducted vegetation surveys at four separate locations following the southern California wildfires of 2003, Elliott Chaparral Reserve (Elliott Reserve), Little Cedar Ridge (Little Cedar), Rancho Jamul Ecological Reserve-Hollenbeck Canyon Wildlife Area (Rancho Jamul), and Santa Ysabel Open Space Preserve (Santa Ysabel). All sites were located in San Diego County, California, USA, (Figure 1) and were sampled before and after the fires using identical survey methods. The number of study plots included in this study varied by site, vegetation community, and fire history. This design was based on the availability of pre-fire sample data and the extent of the two series of wildfires (Table 1). With few exceptions, the vegetation at all sites had not burned within the past eight years and was considered to be senescent. Detailed descriptions of each site are given below.

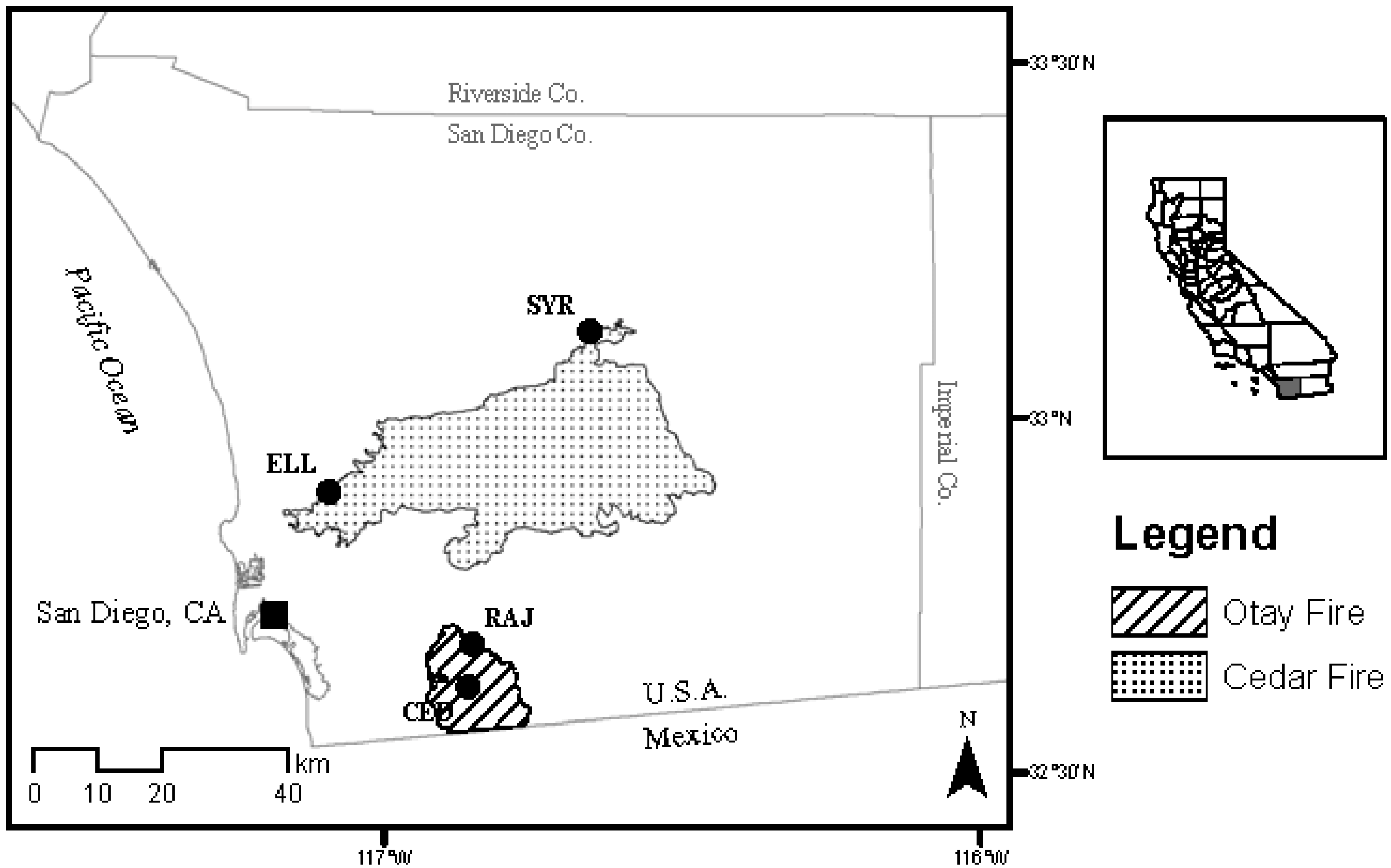

Figure 1. Post-fire vegetation survey sites. The four vegetation study sites in San Diego County, CA, were Little Cedar (CED), Elliott Reserve (ELL), Rancho Jamul (RAJ), and Santa Ysabel (SYR).

Table 1. Study plots within each study site, showing coordinates, pre-fire vegetation type, fire severity rating and distance to perimeter for each fire that occurred at the study site. Fire severity ratings are based on the Burn Area Reflectance Classification (BARC), 1 – no burn, 2 – low severity, 3 – moderate severity, and 4 – high severity. "-" indicates that the plot did not burn in the given fire. Distances for plots within the fire perimeter are presented as positive values; negative values indicate the plots were outside of the fire perimeter. "CSS" indicates coastal sage scrub, and "WR" indicates woodland/riparian.

Little Cedar Ridge

			Pre-fire	2003 (Otay Fire)		2007 (Harris Fire)	
Plot	Latitude	Longitude	Vegetation Type	Fire Severity	Distance to Perimeter, m	Fire Severity	Distance to Perimeter, m
1	32.61590 N	116.86029 W	Chaparral	4	3,938	-	-107
2	32.61648 N	116.86039 W	Chaparral	4	3,902	-	-44
3	32.61703 N	116.86012 W	CSS	4	3,906	1	21
4	32.61813 N	116.86054 W	CSS	4	3,829	1[a]	119
5	32.61829 N	116.86176 W	CSS	4	3,722	1[a]	73
6	32.62052 N	116.86099 W	CSS	4	3,709	1[a]	292
7	32.62524 N	116.86346 W	Chaparral	3	3,385	1	819
8	32.62632 N	116.86501 W	Chaparral	3	3,206	1	984
9	32.62914 N	116.86559 W	Chaparral	3	3,139	1	1,055

Elliott Chaparral Preserve

			Pre-fire	2003 (Cedar Fire)	
Plot	Latitude	Longitude	Vegetation Type	Fire Severity	Distance to Perimeter, m
3	32.89266 N	117.10002 W	Chaparral	3	660
4	32.88952 N	117.10067 W	Chaparral	3	940
7	32.88998 N	117.10341 W	Chaparral	3	802
9	32.89090 N	117.09747 W	Chaparral	1	936
10	32.89209 N	117.08911 W	CSS	2	1,187
11	32.89194 N	117.08856 W	CSS	3	1,214
12	32.89234 N	117.08786 W	Chaparral	2	1,200
14	32.89268 N	117.08907 W	CSS	3	1,120
15	32.89383 N	117.08849 W	CSS	3	1,020
17	32.89453 N	117.08676 W	CSS	1	1,030

a - field validation indicated some level of fire impacts although the BARC was reported as level 1 (no burn).

Table 1 (continued).

Rancho Jamul Ecological Reserve / Hollenbeck Canyon

Plot	Latitude	Longitude	Pre-fire Vegetation Type	2003 (Otay Fire) Fire Severity	2003 (Otay Fire) Distance to Perimeter, m	2007 (Harris Fire) Fire Severity	2007 (Harris Fire) Distance to Perimeter, m
1	32.69390 N	116.86154 W	WR	-	-1,004	-	-241
2	32.69332 N	116.86370 W	Grassland	-	-795	-	-80
3	32.69203 N	116.86277 W	Grassland	-	-858	-	-238
4	32.69677 N	116.86924 W	Grassland	-	-341	3	11
6	32.68710 N	116.86918 W	Grassland	-	-177	2	49
7	32.67965 N	116.86771 W	CSS	3	73	2	95
9	32.68545 N	116.85428 W	CSS	-	-562	-	-433
10	32.68763 N	116.85533 W	CSS	-	-723	-	-693
11	32.66649 N	116.86859 W	CSS	2	903	2	1,463
12	32.66184 N	116.87047 W	WR	2	1,456	3	2,014
13	32.67351 N	116.86090 W	Grassland	2	522	2	625
14	32.67394 N	116.85802 W	Grassland	2	570	2	608
15	32.66375 N	116.85367 W	Grassland	2	1,541	2	1,808
16	32.66606 N	116.85534 W	Grassland	2	1,278	2	1,532
19	32.66651 N	116.84005 W	CSS	2	830	2	867
21	32.67306 N	116.85371 W	CSS	2	493	2	829
35	32.68946 N	116.81755 W	CSS	-	-2,279	2[b]	807
36	32.68300 N	116.81836 W	CSS	-	-1,584	2	1,023
37	32.67999 N	116.82117 W	WR	-	-1,176	2	869

Santa Ysabel Open Space Preserve

Plot	Latitude	Longitude	Pre-fire Vegetation Type	2003 (Cedar Fire) Fire Severity	2003 (Cedar Fire) Distance to Perimeter, m	2007 (Witch Creek Fire) Fire Severity	2007 (Witch Creek Fire) Distance to Perimeter, m
2	33.10291 N	116.70272 W	Chaparral	-	-1,559	2	1,109
7	33.12312 N	116.71293 W	Grassland	-	-3,837	-	-69
8	33.13186 N	116.71965 W	Chaparral	-	-4,798	-	-202
9	33.12490 N	116.67471 W	Grassland	-	-886	-	-2,108
10	33.12461 N	116.67061 W	WR	-	-638	-	-2,411
11	33.11903 N	116.66672 W	CSS	2	50	-	-2,516
12	33.11452 N	116.65921 W	Chaparral	2	1,193	-	-2,684
13	33.11260 N	116.64715 W	Chaparral	3	733	-	-3,140
14	33.11352 N	116.64657 W	Chaparral	3	829	-	-3,254
15	33.13470 N	116.65308 W	CSS	-	-943	-	-4,391
17	33.12031 N	116.64302 W	WR	1	735	-	-4,053
18	33.12120 N	116.64305 W	Chaparral	2	673	-	-4,132
19	33.10988 N	116.62514 W	WR	2	394	-	-4,540
20	33.10836 N	116.61601 W	WR	4	318	-	-5,220
21	33.11547 N	116.61425 W	Grassland	2	763	-	-5,731
22	33.11571 N	116.61808 W	WR	2	555	-	-5,438
24	33.12076 N	116.61792 W	WR	-	-70	-	-5,767

b - ground level inspection indicated no fire impacts although the BARC was reported as level 2 (low burn).

Elliott Chaparral Reserve: The Elliott Reserve was adjacent to the Marine Corps Air Station Miramar and was approximately 25 km from the coast. Although Elliott Reserve itself was only 43 ha, much of the adjacent military lands were also undeveloped wildlands. Study plots were centered at 32.89217° N and 117.09460° W, with an average elevation of 195 m (Figure 2). The vegetation at Elliott Reserve consisted mainly of chaparral and coastal sage scrub, dominated by chamise (*Adenostoma fasciculatum*), California buckwheat (*Eriogonum fasciculatum*), and annual, non-native grasses (*Avena* and *Bromus*) (Hickman 1996). Elliott Reserve was located at the west end of the Cedar Fire footprint, which completely burned the site in October of 2003. Prior to the Cedar Fire, the majority of Elliott Reserve burned in 1944 or 1945 (CDF 2006). This site was managed by the Nature Reserve System of the University of California at San Diego (UCSD).

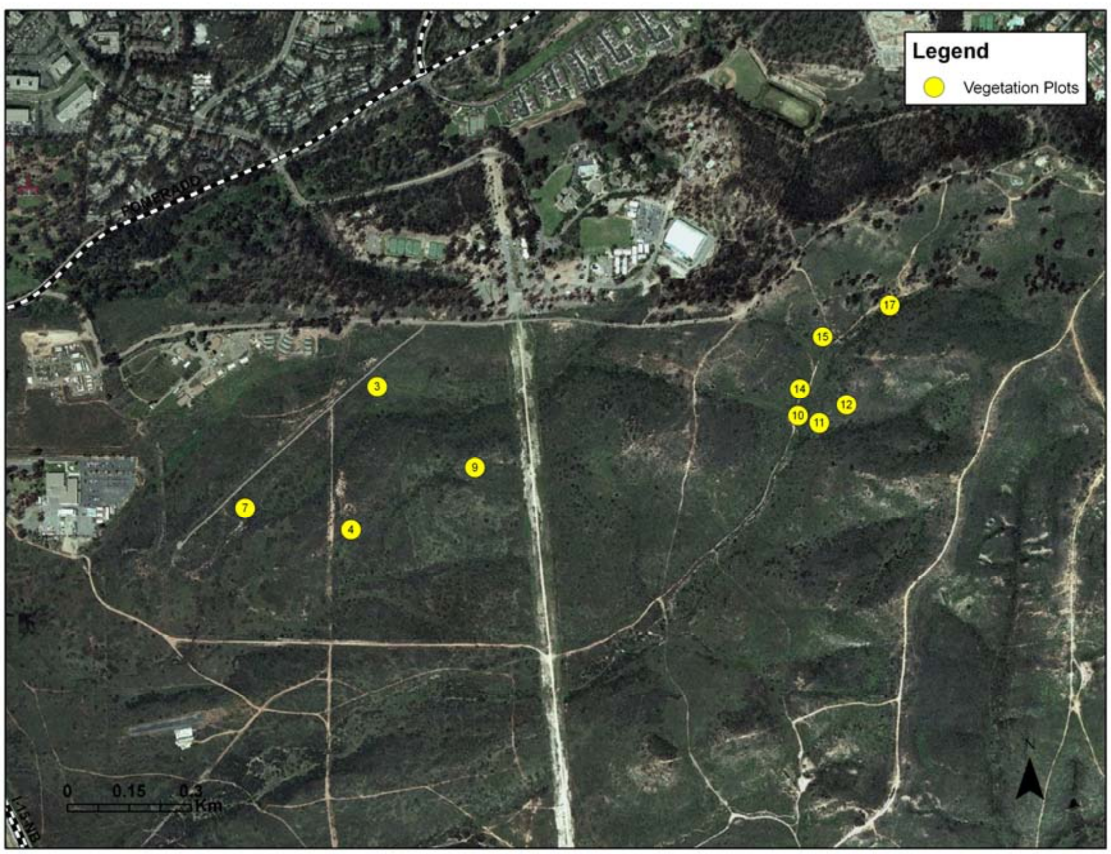

Figure 2. Elliott Reserve. Vegetation was sampled at ten study plots at Elliott Reserve.

Little Cedar Ridge: Near the international border in southern San Diego County, the Little Cedar study site was located on the northern slopes of Otay Mountain and was managed by the Bureau of Land Management (BLM) as part of the Otay Mountain Wilderness. The Otay Mountain Wilderness was approximately 6,800 ha and ranged in elevation from 250 to 1000 m. Our study plots covered a small portion of Otay Mountain and were centered around 32.62078° N and 116.86202° W, with an average elevation of 400 m (Figure 3). The majority of vegetation in the study area was characterized as chaparral and coastal sage scrub based on the dominant plants chamise, Tecate cypress (*Cupressus forbesii*), wild oats (*Avena*), and California buckwheat (Hickman 1996). The entire area surrounding the study plots burned completely during the Otay Fire in October 2003. Although fire perimeter maps indicate that the northern portion of this site burned once again in the 2007 Harris Fire, ground level inspection revealed that only three of the nine study plots were impacted by this second fire. No record of previous fire could be found for this portion of Otay Mountain (CDF 2006).

Rancho Jamul Ecological Reserve and Hollenbeck Canyon Wildlife Area: Rancho Jamul Ecological Reserve and Hollenbeck Canyon Wildlife Area, jointly referred to here as Rancho Jamul, were located just 6 km north of Little Cedar. Both properties were managed by the California Department of Fish and Game. Only the southern portion of the Rancho Jamul property burned during the 2003 Otay Fire. In the 2007 Harris Fire, many of the same plots burned in 2003 were re-burned. Additionally, several plots on the Hollenbeck Canyon portion of the site, which were untouched by fire in 2003, burned in the 2007 Harris Fire (Figure 4). On the Hollenbeck Canyon property, three plots were burned in 1996, seven years prior to the initial, pre-fire surveys conducted in 2003 and were classified as unburned for these analyses. One other plot burned in 1968. No other fire records could be found for the remaining study plots at this site (CDF 2006). Rancho Jamul is located at 32.67873° N and 116.85431° W, with an average elevation of 250 m (Figure 5). Rancho Jamul Ecological Reserve covered approximately 1,500 ha, and the Hollenbeck Canyon Wildlife Area was approximately 1,450 ha. Rancho Jamul encompassed a variety of vegetation communities including native and non-native grasslands, coastal sage scrub, oak and sycamore woodlands, and riparian environments. In addition to the natural vegetation, there were extensive fallow

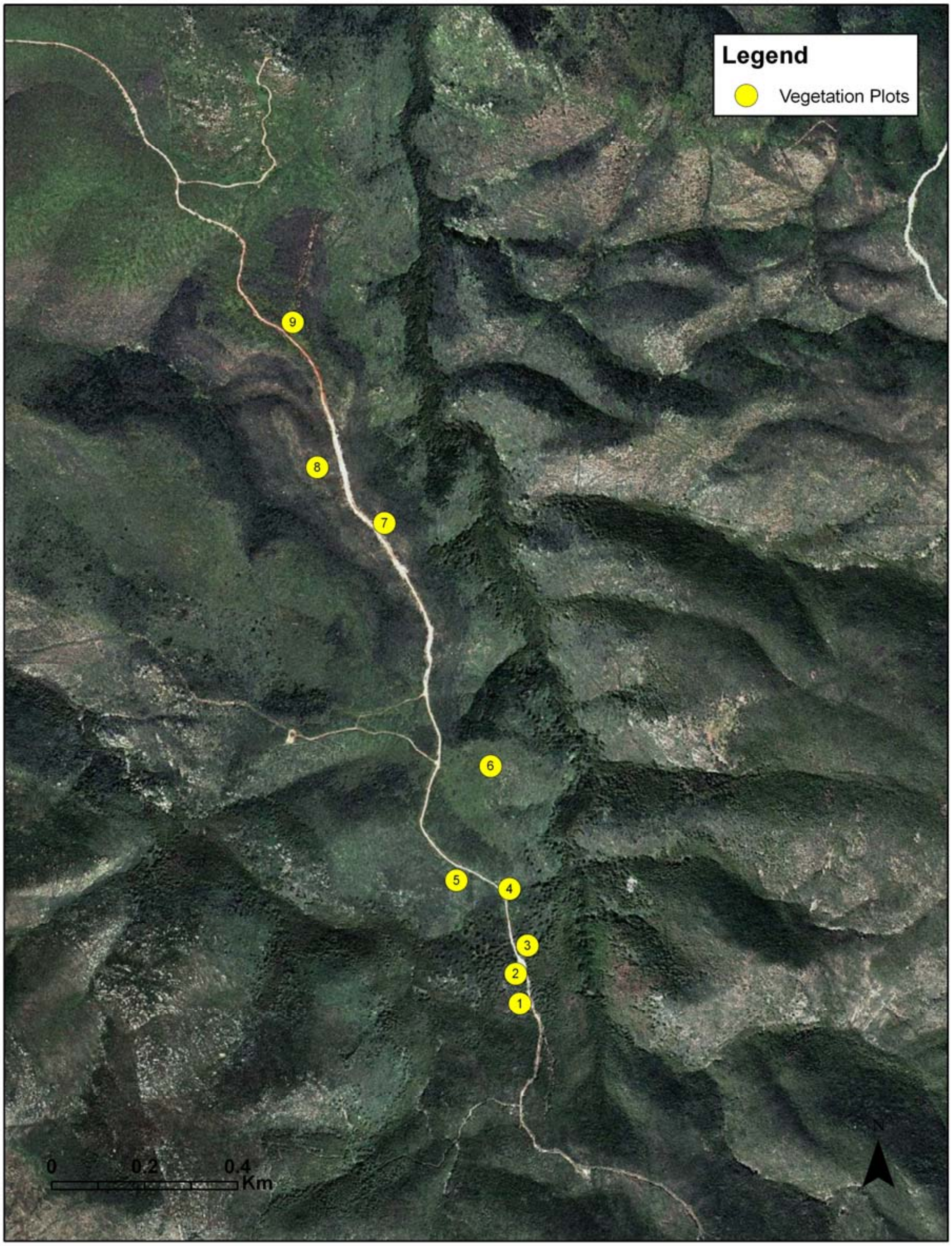

Figure 3. Little Cedar. Near Otay Mountain Wilderness, nine study plots were sampled.

A)

B)

Figure 4. Plot 36 at Hollenbeck Canyon. A) The 2003 Otay Fire did not touch plot 36. B) The 2007 Harris Fire consumed nearly all of the vegetative material on the plot.

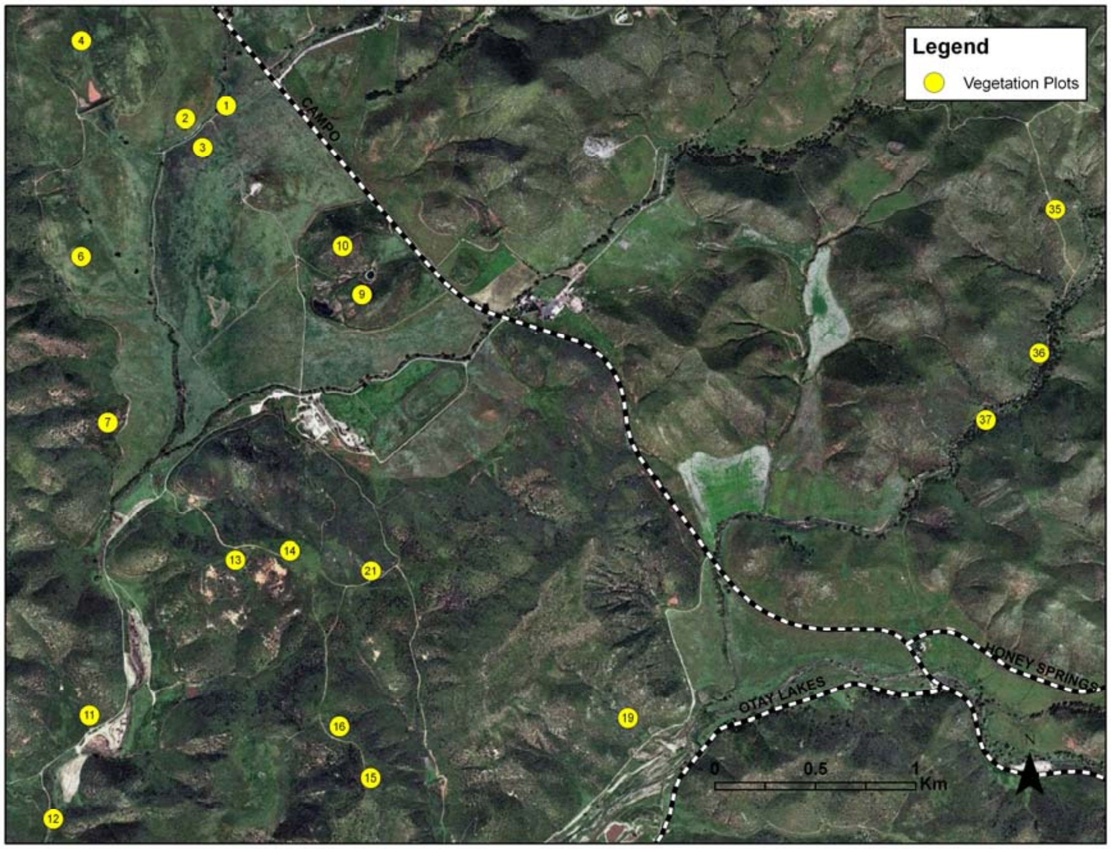

Figure 5. Rancho Jamul. Twenty vegetation plots were sampled at Rancho Jamul.

agricultural fields. Dominant plants at the site included annual non-native grasses, California buckwheat, California sagebrush (*Artemisia californica*), coast live oak (*Quercus agrifolia*), western sycamore (*Platanus racemosa*), laurel sumac (*Malosma laurina*), and San Diego sunflower (*Viguiera laciniata*).

Santa Ysabel Open Space Preserve: At an average elevation of 1,078 m, Santa Ysabel was the highest of our four study sites and was located near the small town of Santa Ysabel in the northern portion of San Diego County. The study plots were centered on 33.11984° N and 116.65840° W (Figure 6 and Figure 7). Santa Ysabel supported oak woodlands and pine forests (Figure 8), native and non-native grasslands, chaparral, coastal sage scrub, and riparian environments. Dominating the various habitats were coast live oak, annual non-native grasses, chamise, Engelmann oak (*Quercus engelmannii*), and white sage (*Salvia apiana*). This 1,500 ha site was managed by the

Parks and Recreation Department of the County of San Diego. Santa Ysabel represented the northeastern extent of the Cedar Fire, which burned a portion of the east property in 2003. The Witch Creek Fire of 2007 burned a small portion of the west property. Of the 17 plots at Santa Ysabel, one burned in 1938; two others burned in 1929, and no recorded fires were found for the remaining plots at this site (CDF 2006).

Environmental conditions were relatively uniform across all four study sites. The three lower elevation sites, Elliott Reserve, Little Cedar, and Rancho Jamul, all experienced similar weather patterns and temperatures. Average July maximum temperatures ranged from 28°C to 29°C. Average January low temperatures fell between 5°C and 6°C. Annual precipitation averaged between 28 and 31 cm. At Santa Ysabel, a higher elevation site, the average July high was 33°C; the average January daily low temperature was 1°C, and the annual rainfall was 53 cm. Temperature and precipitation data are 30 year averages for 1966 through 1995 developed by Franklin et al. (2001) from data collected from 104 to 136 climate stations across southern California.

The fire severity levels, as measured by the Burned Area Reflectance Classification (BARC), were extremely variable across the four study sites and multiple fires (Table 1). BARC measures the affect of a fire on the vegetation using a categorical scale with the following rankings: 1 – no burn, 2 – low severity, 3 – moderate severity, and 4 – high severity. Within the 2003 Otay Fire, six of the plots at Little Cedar were rated as severity level 4, and the remaining three plots were scored as level 3 (USDA 2003a). Based on the fire severity maps for the 2007 Harris Fire, seven out of the nine study plots at Little Cedar received a rating of level 1 (USGS 2007). Ground level inspection after the 2007 Harris Fire revealed that three of these seven plots, while scored as fire severity level 1 (no burn), did show some evidence of fire impacts (Appendix 1, Photo Series 2). At Rancho Jamul, only one plot was scored as level 3 fire severity after the 2003 fire, and the eight other impacted plots at Rancho Jamul were reported as a level 2 fire severity (USDA 2003a). Within the 2007 Harris Fire, 14 of the Rancho Jamul study plots burned, two plots at a severity level of 3 and the rest at level 2. Although the fire severity maps include plot 35 at a level 2, ground level inspection revealed no fire impacts to the plot. The vegetation survey plots at Elliott Reserve were only impacted by the 2003 Cedar Fire; no fire occurred at this site in 2007. Two plots within Elliott

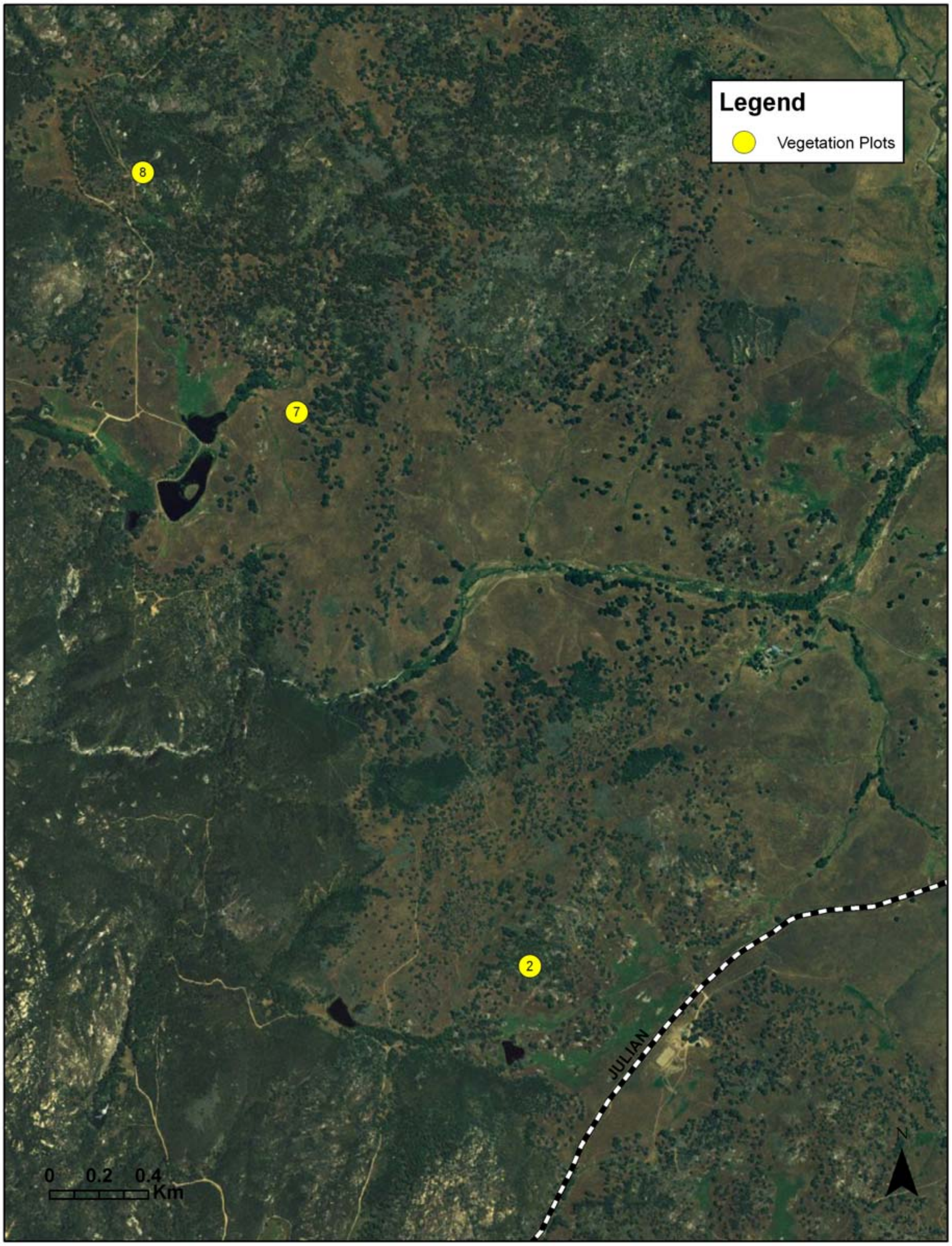

Figure 6. Santa Ysabel – West. Vegetation was sampled at three study plots on the western portion of the Santa Ysabel property.

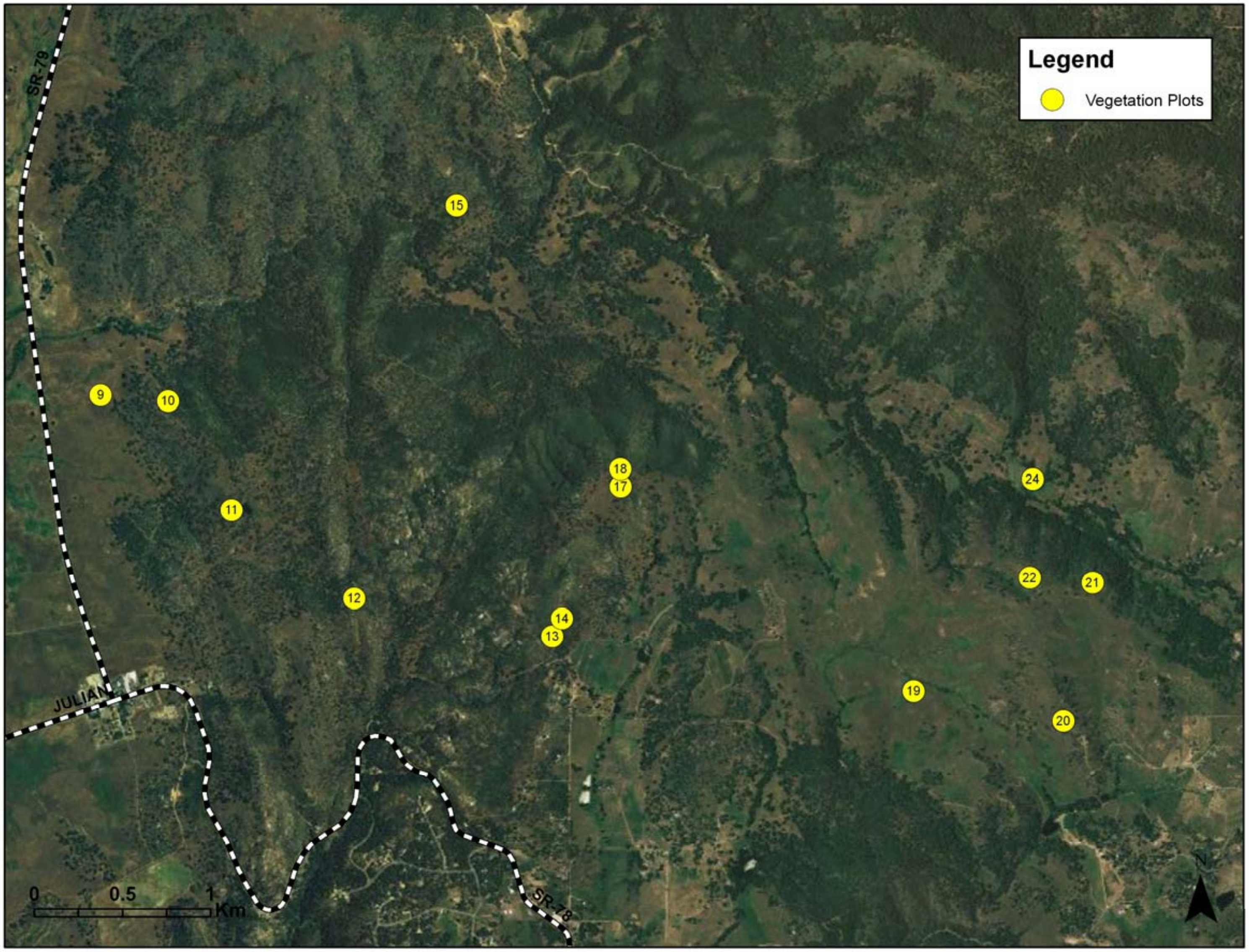

Figure 7. Santa Ysabel – East. Sixteen vegetation plots were sampled on the eastern portion of the Santa Ysabel Property.

A)

B)

Figure 8. Oak woodland and pine forest plots at Santa Ysabel. A) A large coast live oak stood near plot 9. B) Plot 22 was located under several tall pine trees.

Reserve were rated as a level 1 severity; two plots were level 2, and the remainder were level 3. The full range of fire severity scores were reported within the 2003 Cedar Fire at Santa Ysabel. In 2003, only one of the plots at Santa Ysabel was rated as level 1, a fire severity level 2 occurred at six of the Santa Ysabel vegetation plots; severity level 3 characterized two plots, and only one plot at Santa Ysabel experienced the highest fire severity rating of 4 during the 2003 Cedar Fire (USDA 2003b). Only one plot burned at Santa Ysabel in 2007 and was rated as a level 2 severity burn.

The proximity of our unburned study plots to the nearest fire perimeter ranged from 44 m to 5,767 m outside the perimeters while our burned plots ranged from 11 m to 3,938 m inside the perimeter (Table 1). At Little Cedar, all of our plots were 3 km or greater inside the perimeter of the 2003 Otay Fire. In the 2007 Harris Fire, the Little Cedar plots outside of the fire perimeter were a median distance of 75 m (range: 44 m to 107 m) away from the edge while the plots that burned were a median distance of 292 m (range: 21 m to 1,055 m) within. The median distance of the burned plots to the perimeter of the 2003 Otay fire at Rancho Jamul was 866 m (range: 73 m to 1,541 m), and 826 m (range: 177 m to 2,279 m) for the unburned plots. In 2007, the Rancho Jamul plots outside of the fire perimeter were a median distance of 241 m (range: 80 m to 693 m) away, and those within the perimeter were a median 848 m (range: 11 m to 2,014 m) from the edge. The burned plots at the Elliott Reserve were located a median distance of 1,025 m (range: 660 m to 1,214 m) from the perimeter of the 2003 Cedar Fire. Unique to the Elliott Reserve, the nearest fire perimeters were located in urban areas, suggesting that the plots were even more isolated from unburned native habitat than plots at other sites with similar distance values. At Santa Ysabel, where the 2003 Cedar Fire only burned a portion of the site, our burned samples were a median distance of 614 m (range: 50 m to 1,193 m) inside the perimeter while the unburned samples were a median distance of 886 m (range: 50 m to 4,798) outside of the fire. The single plot at Santa Ysabel that burned in the 2007 Witch Creek Fire was 1,109 m from the edge. The unburned plots were a median distance of 3,653 m (range: 69 m to 5,767 m) outside of the fire.

Vegetation Data Collection

In order to understand and describe the many microhabitats present within the study sites, we sampled several vegetation community variables in the immediate vicinity of each study plot within each study site. We used a linear, point-intercept transect technique modeled after the established field sampling protocol of the California Native Plant Society (CNPS: pp. 416-426 in Sawyer and Keeler-Wolf 1995). Each vegetation transect consisted of a 50-m point-intercept technique (Sawyer and Keeler-Wolf 1995) with species composition, vegetation height, substrate type, and leaf litter depth recorded every 0.5-m (Figure 9). The resulting data were intended to describe the vegetation around the study plot, covering an area almost 2,000-m^2 (25-m radius circle) in size. Community structure and composition variables may be calculated with these vegetation data, based on the number of times a plant species, growth form, or vegetation type was encountered ("hits") along the transect. Bauer's work with linear vegetation transects in southern California (Bauer 1943) has shown this technique to be comparable to the results of the more time consuming quadrate technique, especially in chaparral.

To conduct each point intercept transect, we established a straight line through the center of the study plot. With a 50-m long measuring tape, we centered the transect on the center pitfall trap of the herpetofaunal array (Figure 9). The transect line extended 25-m north and 25-m south of the center bucket. Starting from the north end of the transect, we placed a measuring rod vertically every 0.5-m along the measuring tape. At each point, we recorded the maximum height of the vegetation at the point, in centimeters (cm), to document canopy height. With the measuring rod still in place, we recorded all plant species touching the rod. Each species was only recorded once regardless of how many times or individuals of the sample species came into contact with the rod. To facilitate data collection in the field, plant species were recorded using an abbreviated code name. To avoid confusion, plant species were identified using the U.S. Department of Agriculture (USDA) codes developed for each species (USDA 2007).

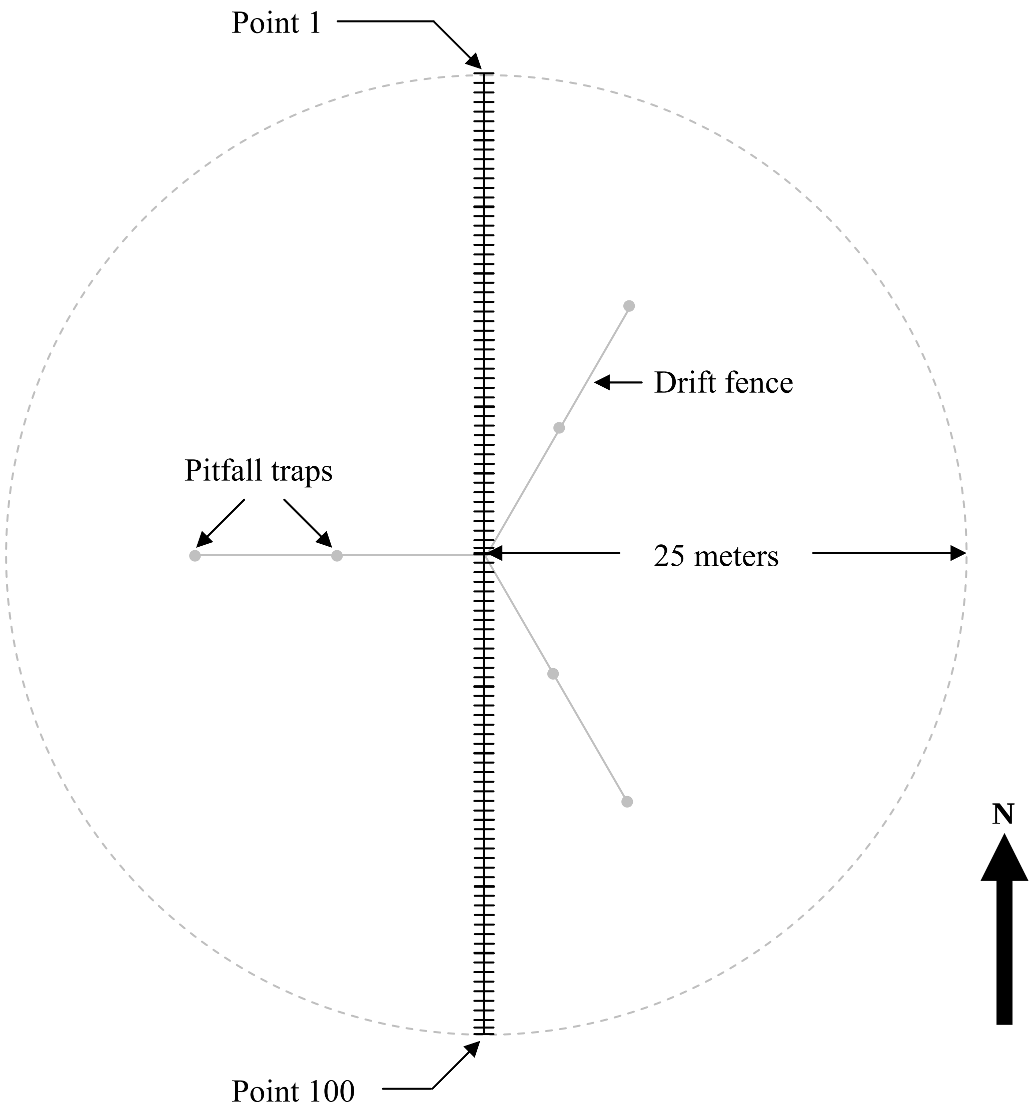

Figure 9. Vegetation transect diagram.

After documenting the canopy height and the plant species at each point, we also recorded the substrate at the point. Substrate was the material at the surface of the ground. For the surveys that we conducted, we recorded substrate as one of the following seven categories:

bare rock – large boulders or bedrock.

cobble stone – pebble to cobble-sized rocks.

cryptogrammic – refers to soil that is covered by a thin layer of cryptograms – lichens and what are commonly known as mosses, liverworts, and hornworts.

leaf litter – includes dead organic material such as fallen leaves, matted grasses, branches, seeds, roots, fruits, and any other loose substance. The substrate was reported as leaf litter in such cases and was independent of what may have been beneath the leaf litter. For example, 2-cm of dead, fallen leaves accumulated over bare rock was recorded as leaf litter and not bare rock.

moss/lichen –used when the measuring rod touches down on thick mats of moss (e.g., *Selaginella* spp.) or rock continuously covered by lichens.

organic dirt –typically dark, soft soil rich in organic matter, as is common in woodlands and dense shrublands.

sandy soil – loose soil that is not any of the other substrate categories.

Where the substrate was reported as "leaf litter", we also recorded the leaf litter depth. Leaf litter depth was measured as the thickness of the dead organic materials sitting on top of the ground. A leaf litter depth was only recorded when the substrate type was leaf litter. For all substrate categories other than leaf litter, leaf litter depth was recorded as 0. In instances where the dead organic materials were scattered and thin, a minimum value of 0.5-cm was recorded for leaf litter depth. Otherwise, leaf litter depth was recorded to the nearest whole centimeter.

Vegetation surveys were conducted five times at each of the study plots (Table 2). The original, pre-fire vegetation surveys were conducted near the time when each plot was originally established and were used to classify each plot into one of four general vegetation types. Post-fire vegetation surveys were conducted annually between 2005 and 2008.

The timing of our vegetation surveys varied greatly by site and by time of year. Under ideal conditions, all surveys would have been conducted at approximately the same time of year or seasonal trigger when plants species were most easily identified by flower, fruit, or leaf characteristics. Depending on the availability of field crews and other resources, our pre-fire vegetation surveys occurred between February and December (Table 3). Our post-fire survey efforts were more limited within the time of year and typically occurred between April and August.

Table 2. Sampling effort at the 55 vegetation transect plots, including the year during which the pre-fire surveys were conducted. The values present are the number of years since the most recent fire on the study plot. "U" indicates that the plot was unburned at the time of the survey. All plots were considered to be unburned at the beginning of the pre-fire time period.

Site	Plot Number	Pre-fire Sample Year	Post-fire Sample Year			
			2005	2006	2007	2008
Little Cedar Ridge						
	1	1995	2	3	4	5
	2	1995	2	3	4	5
	3	1995	2	3	4	5
	4	1995	2	3	4	1
	5	1995	2	3	4	1
	6	1995	2	3	4	1
	7	1995	2	3	4	5
	8	1995	2	3	4	5
	9	1995	2	3	4	5
Elliott Chaparral Preserve						
	3	1996	2	3	4	5
	4	1996	2	3	4	5
	7	1996	2	3	4	5
	9	1996	2	3	4	5
	10	1996	2	3	4	5
	11	1996	2	3	4	5
	12	1996	2	3	4	5
	14	1996	2	3	4	5
	15	1996	2	3	4	5
	17	1996	2	3	4	5

Table 2 (continued).

Site	Plot Number	Pre-fire Sample Year	Post-fire Sample Year			
			2005	2006	2007	2008
Rancho Jamul Ecological Reserve - Hollenbeck Canyon Wildlife Area						
	1	2001	U	U	U	U
	2	2001	U	U	U	U
	3	2001	U	U	U	U
	4	2001	U	U	U	1
	6	2001	U	U	U	1
	7	2001	2	3	4	1
	9	2001	U	U	U	U
	10	2001	U	U	U	U
	11	2001	2	3	4	1
	12	2001	2	3	4	1
	13	2001	2	3	4	1
	14	2001	2	3	4	1
	15	2001	2	3	4	1
	16	2001	2	3	4	1
	19	2001	2	3	4	1
	21	2001	2	3	4	1
	35	2003	U	U	U	U
	36	2003	U	U	U	1
	37	2003	U	U	U	1

Table 2 (continued).

Site	Plot Number	Pre-fire Sample Year	Post-fire Sample Year			
			2005	2006	2007	2008
Santa Ysabel Open Space Preserve						
	2	2002	U	U	U	1
	7	2002	U	U	U	U
	8	2002	U	U	U	U
	9	2002	U	U	U	U
	10	2002	U	U	U	U
	11	2002	2	3	4	5
	12	2002	2	3	4	5
	13	2002	2	3	4	5
	14	2002	2	3	4	5
	15	2002	U	U	U	U
	17	2002	2	3	4	5
	18	2002	2	3	4	5
	19	2002	2	3	4	5
	20	2002	2	3	4	5
	21	2002	2	3	4	5
	22	2002	2	3	4	5
	24	2002	U	U	U	U

Table 3. Time of year when vegetation surveys were conducted.

Site	Pre-fire	2005	2006	2007	2008
Little Cedar Ridge	Dec 8-14, 1995	Mar 28 - Apr 7	May 30 - 31	Mar 21 - 22	Jul 14 - Sep 17
Elliott Chaparral Reserve	Feb 15-22, 1996	Apr 14 - 15	May 17 - 19	Mar 19 - 20	Sep 3 - 16
Rancho Jamul Ecological Reserve	Jun 21 - Aug 14, 2001[1]	Apr 8 - May 2	May 16 - Jun 6	Mar 13 - 21	Jul 16 - Sep17
Santa Ysable Open Space Preserve	Aug 21 - Oct 9, 2001	May 4 - Aug 9	May 23 - Jun 5	Apr 2 - 6	Jul 30 - Sep 9

[1] Arrays 35, 36, and 37 in the Hollenbeck Canyon portion of the property were sampled pre-fire on Jun 17, 2003.

Vegetation Classification

Vegetation at the 55 study plots was grouped into four general categories (1) chaparral, (2) coastal sage scrub, (3) grassland, and (4) woodland/riparian (Table 1). We used a 25% coverage level to determine the vegetation classification of each plot. Based on the pre-fire vegetation survey, if 25% or more of the points along the transect had plant species typically associated with chaparral, coastal sage scrub, or one of the categories making up woodland/riparian (Sawyer and Keeler-Wolf 1995, Hickman 1996), the plot was classified as such. Where more than one vegetation type represented 25% or more of the transect, the more abundant classification was used. This classification was made regardless of the percentage of the plot covered by grassland species. Since much of southern California has experienced some level of disturbance or invasion by exotic grasses, plots were only considered to be grassland if no other vegetation type represented 25% or more of the plot. Most study plots could not be described as 100% one vegetation type or another, but were classified based on the results of the vegetation transect surveys.

Chaparral arrays were dominated by evergreen plant species such as chamise (Sawyer and Keeler-Wolf 1995). We classified study plots as coastal sage scrub based on the presence of such plant species as California sagebrush, white sage, and California buckwheat. A large percentage of grasslands in southern California are populated with several non-native genera of grass, including wild oats (*Avena* spp.) and brome grass (*Bromus* spp.), although some native grasses are interspersed. The woodland/riparian category includes oak (*Quercus* spp.) woodlands, pine (*Pinus* spp.) forests, western sycamore and willow (*Salix* spp.) riparian areas (Appendix 1), as well as seeps. For all vegetation types, data for shrubs and trees were used for analyses of cover as well as plant community composition. Because surveys were done in different seasons, we did not use data for forbs and annuals, as they commonly disarticulated in the summer and fall periods, leaving open ground through winter.

Data Classification and Reduction

We classified and reduced the vegetation community data using two different techniques. For the descriptive statistics, we created the variable "fire history" and classified each sample at a plot based on the number of years since the most recent fire. Study plots which remained unburned throughout the study were classified as "U". Surveys conducted on plots that burned in either of the 2003 fires were first identified by the number one (1), followed by the number of years since the fire. Surveys conducted on plots that most recently burned in either of the 2007 fires were identified by the number two (2), followed by the number of years since the fire. In this fashion, all surveys conducted at Little Cedar in 2005 were given the "fire history" value of 1.2 (burned in 2003 – second year post-fire). In 2008 at Little Cedar, the "fire history" differed between the plots based on the plots that were re-burned in 2007. Plots 1 through 3 and Plots 7 through 9, which did not burn in the 2007 Harris Fire were classified as 1.5 (burned in 2003 – fifth year post-fire). Plots 4 through 6 burned in 2007, so the 2008 surveys at these plots were identified as 2.1 (burned in 2007 – first year post-fire). We used this classification for assessing and describing the effects of the fires on the percent of shrub and tree cover, changes in species richness, and community similarity between samples.

In some cases, plants species were combined into simpler groups to facilitate describing vegetation communities and any changes that may have occurred. The most frequent example of this was "non-native grass". The many non-native grass species that occurred across the study sites were reduced to a single category of "non-native grass". This category included many species within the genera of *Avena*, *Bromus*, *Cynodon*, *Gastridium*, *Hordeum*, *Lolium*, *Poa*, and *Vulpia*.

For the multivariate analysis described below, many of the rare plant species detected during the vegetation transects were removed from the dataset. Three criteria were used to determine which species to include in the dataset for each study site. Plant species that were detected in 10% or more of the total samples at a study site were included. In some cases, this excluded plant species that were primary indicators of a vegetation type and that were only present before the fires. To accommodate for this, we also included any species that occurred on 10% or more of the plots within a site pre-fire. The third category of plant species included were those that met neither of the previous criteria but that represented 10% or more of any given sample collected at a study site. *Ceanothus* spp. is an example of the first criteria, it was detected at 24 out of 45 (53%) of the samples at Little Cedar. At Elliott Reserve, California sagebrush (*Artemisia californica*) was included under the second criteria. We only detected California sagebrush during two out of all 50 surveys (4%) at the site, but it occurred in two out of ten (20%) of the pre-fire samples, and it is an indicator species for coastal sage scrub. Deerweed (*Lotus scoparius*) was included in the review of the Rancho Jamul samples based on the third criteria. In 95 total samples at Rancho Jamul, deerweed only occurred within five (5.3%) samples and did not occur in any of the pre-fire samples (0%). Within the five samples where this species was detected, it accounted for as much as 19% of one of the transects. All species included in the multivariate review are reported in Appendix 2.

Analyses

The detection rates of the many plant species that we documented were highly variable, especially for forbs and small annuals. To account for this, we have limited our review of the vegetation communities to the grasses, shrubs, and trees detected during the linear vegetation transects conducted at each study plot.

We first looked at whether fire had an effect on some of the descriptive statistics of each study plot within each of the four vegetation communities across the four study sites. We looked for changes in shrub and tree species richness, canopy height, substrate frequencies, and the percent of shrub and tree cover. We calculated the number of shrub and tree species at each sampling plot before the fires and then again for each successive post-fire year. We generated an average canopy height for each transect survey. For substrate frequencies, we used the number of points along the 50-m transect where each substrate type was detected as an index of the percent of the plot covered by the given substrate type. The percent of shrub and tree cover was calculated by the number of points along the transect, out of 100, where a shrub or tree species was reported. For each study site, we calculated the pre-fire average for each of these descriptive variables to serve as a baseline for comparing the post-fire results.

Changes in the vegetation community may not be reflected in a single descriptive statistic; therefore, we also looked for changes in overall community structure using multivariate techniques. Multivariate analyses were performed with PRIMER-E software

(Version 6, Plymouth, UK; Clarke 1993). Within PRIMER-E, we used similarity dendrograms to look for shifts in the community structure (Clarke 1993). Using fourth-root transformed species detection rate data, we first created a Bray-Curtis similarity matrix among all samples. Fourth-root transformation was used to remove some weight from the most abundant species and shift more weight to the rarer species for a more balanced community analyses (Clarke and Green 1988). To generate the Bray-Curtis similarity matrix, PRIMER-E calculated the percentage of similarity between each sample in the dataset by comparing the species that occurred in each with the frequency we detected each species in every other sample (Clarke and Warwick 2001). PRIMER-E measured the similarity as a percentage, 0 % to 100 %, with a similarity of 0 % indicating that two samples had no species in common. If all of the same species occur in two samples in exactly the same numbers, the similarity between the two samples would be 100 % (Bray and Curtis 1957). The similarity among sample plots, as determined in the Bray-Curtis similarity matrix, was then plotted using similarity dendrograms. We used the hierarchical clustering functions within PRIMER-E to generate the similarity dendrograms based on a group-averaging linkage process. To generate a similarity dendrogram, PRIMER-E searches the Bray-Curtis similarity matrix to find the two samples with the highest level of similarity and combines them into a new category. The similarity of this new category to the remainder of the original samples was re-calculated based on the average of the similarities of the two combined samples to each of the remaining original samples. With the newly combined category in place, PRIMER-E generates a new Bray-Curtis similarity matrix and repeats the process until all samples have been merged into one group.

To investigate potential shifts in community composition, which may serve as early indications for the type conversion of shrublands into grasslands, we included the results from several pre-fire, grassland vegetation transects in the review of study sites where no grassland plots existed. At Little Cedar and Elliott Reserve, where all of our study plots were either chaparral or coastal sage scrub, we included four grassland samples from Rancho Jamul. Based on a preliminary review of the Rancho Jamul samples, we included plots 4, 13, 15, and 16 (all classified as grassland plots) in the review of Little Cedar and Elliott Reserve. Plots 4 and 13 were considered to be non-native grasslands with few plant species other than exotic grasses. Plots 15 and 16 were more diverse and contained high proportions of native grass species and some minor shrub cover, as well as some non-native grass cover. The levels of shrub cover at plots 15 and 16 were insufficient to classify either of these plots as shrublands. We used grassland samples from Rancho Jamul instead of Santa Ysabel due to the fact that Little Cedar, Elliott Reserve, and Rancho Jamul are all low elevation sites, and Santa Ysabel is a high elevation site.

To investigate the effects of the fire on the relative abundance of individual species, we calculated the percent of the plot covered by a species within each sample at the plot. Because there were a large number of species detected across all vegetation surveys, many of which had low detection rates, we chose to focus our analyses and interpretation on the species which were indicator species for selected vegetation communities.

Results

Sample Results

Our vegetation transect survey efforts resulted in 275 samples across the four study sites (Table 2). The pre-fire samples ranged in time between 1995 (Little Cedar) and 2003 (Hollenbeck Canyon). Post-fire samples were collected annually between 2005 and 2008. During the pre-fire samples, all plots within all study sites were considered to be unburned. All of the sample plots within Little Cedar and Elliott Reserve burned in the 2003 fires (Table 1). Three of the plots at Little Cedar re-burned in 2007, plots 4 through 6. At Rancho Jamul, we were able to collect three years of post 2003 fire data before the site re-burned in 2007. All of the plots that burned in 2003 at Rancho Jamul (nine out of 19 across the site) re-burned in 2007, along with four additional, previously unburned plots. We collected four years of post-fire samples at the 17 plots at Santa Ysabel where ten plots burned in 2003. At the one plot that burned at Santa Ysabel in 2007, we were only able to collect 1 year post 2007 fire data. This plot had not burned in the 2003 fires.

Changes in Vegetation Structure

The percentage of the study plots covered by shrub and tree species, as measured by the vegetation transect surveys, declined more in the burned chaparral and coastal sage scrub study plots than in the grassland and woodland/riparian plots. At Little Cedar, where the pre-fire shrub and tree cover averaged 77.2% (SE = 10.3, n = 5) in chaparral plots and 61.3% (SE = 4.8, n = 4) in coastal sage scrub, the post-fire level of cover ranged between 20 and 45% (Figure 10). At the three coastal sage scrub plots that also burned in 2007, the 2008 average shrub and tree coverage was only 12% (SE = 6.7, n = 3).

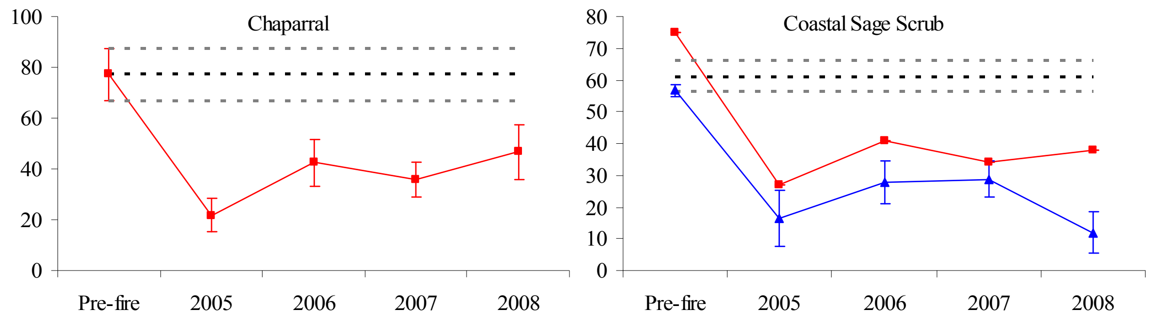

Figure 10. Shrub and tree cover at Little Cedar. Values presented are the average percent of shrub and tree cover ±SE among samples within the given vegetation type and sample year. Symbol and line color indicate the fire history of the plots; red represents plots that burned in 2003, and blue represents plots that burned in both 2003 and 2007. The black dashed line is the pre-fire average percent of shrub and tree cover across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. The x-axes are sample years, and the y-axes are percent cover.

At Santa Ysabel, where all four vegetation types were present, we saw a decline in shrub and tree cover within chaparral, coastal sage scrub, and woodland/riparian. The two shrubland vegetation types (chaparral and coastal sage scrub), had the lowest values in 2005, with the exception of the one plot that burned in 2007 (Figure 11). The decline in cover within the burned woodland/riparian plots was more gradual and reached the lowest level in 2008. In grasslands, where there was little shrub and tree cover to start with, there was subsequently little change over the four years of post-fire sampling.

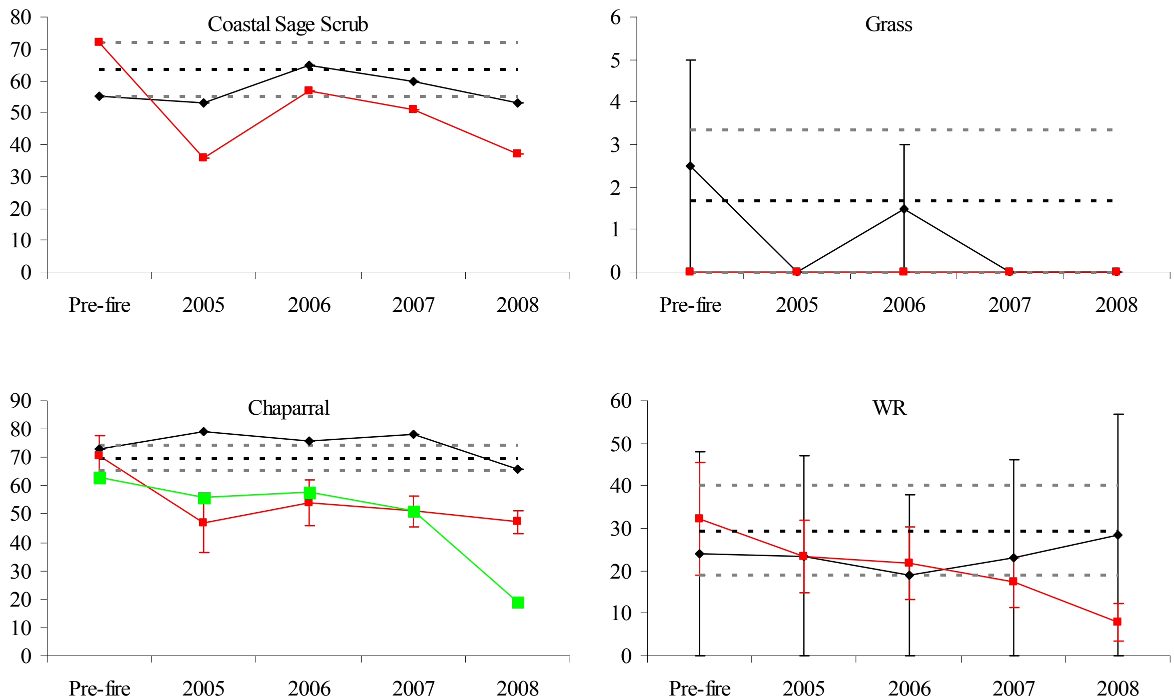

Figure 11. Shrub and tree cover at Santa Ysabel. Values presented are the average percent of shrub and tree cover ±SE among samples within the given vegetation type and sample year. Symbol and line color indicate the fire history of the plots; black represents plots that did not burn; red represents plots that burned in 2003, and green represents plots that burned in 2007. The black dashed line is the pre-fire average percent of shrub and tree cover across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. The x-axes are sample years, and the y-axes are percent cover. "WR" indicates woodland/riparian.

The chaparral and coastal sage scrub study plots at Elliott Reserve dropped from the pre-fire average, which was the highest level of cover measured within each vegetation type across any of the sample years. The level of shrub and tree cover was lowest in 2005 (the first post-fire sample) but increased steadily with each consecutive year of sampling. Although there was a tendency to increase, the post-fire level of shrub and tree cover at Elliott Reserve was less than 75% of the level measured pre-fire (Figure 12).

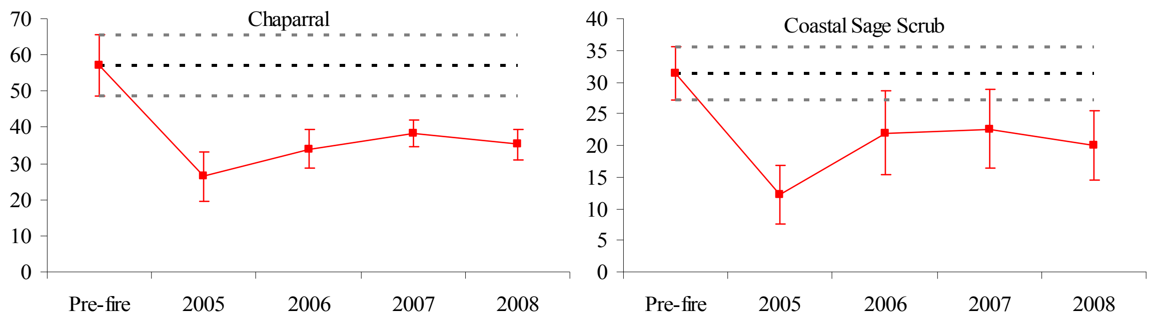

Figure 12. Shrub and tree cover at Elliott Reserve. Values presented are the average percent of shrub and tree cover ±SE among samples within the given vegetation type and sample year. Symbol and line color indicate the fire history of the plots; red represents plots that burned in 2003. The black dashed line is the pre-fire average percent of shrub and tree cover across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. The x-axes are sample years, and the y-axes are percent cover.

The coastal sage scrub plots at Rancho Jamul saw perhaps the greatest decline in shrub and tree cover of all of the samples we measured. Pre-fire, the average shrub and tree cover within all coastal sage scrub plots was 65.6% (SE = 5.3, n = 8). After the 2003 fire, the burned plots only contained 8% (SE = 7.7, n = 4) cover in 2005 (Figure 13), with only moderate increases in 2006 and 2007. When many of these sample plots burned again in 2007, the average shrub and tree cover dropped even lower to only 3% (SE = 1.3, n = 4). Two of the coastal sage scrub plots at Rancho Jamul contained between 69% and 75% shrub and tree cover before the fires, but we have recorded no cover at either plot during any of the post-fire survey years (Appendix 1). Shrub and tree cover within the grassland plots remained within the range of variability detected in the pre-fire samples. For the three woodland/riparian plots at Rancho Jamul, shrub and tree cover remained relatively constant (Appendix 1); each woodland/riparian plot represented a different fire history that occurred on the study site.

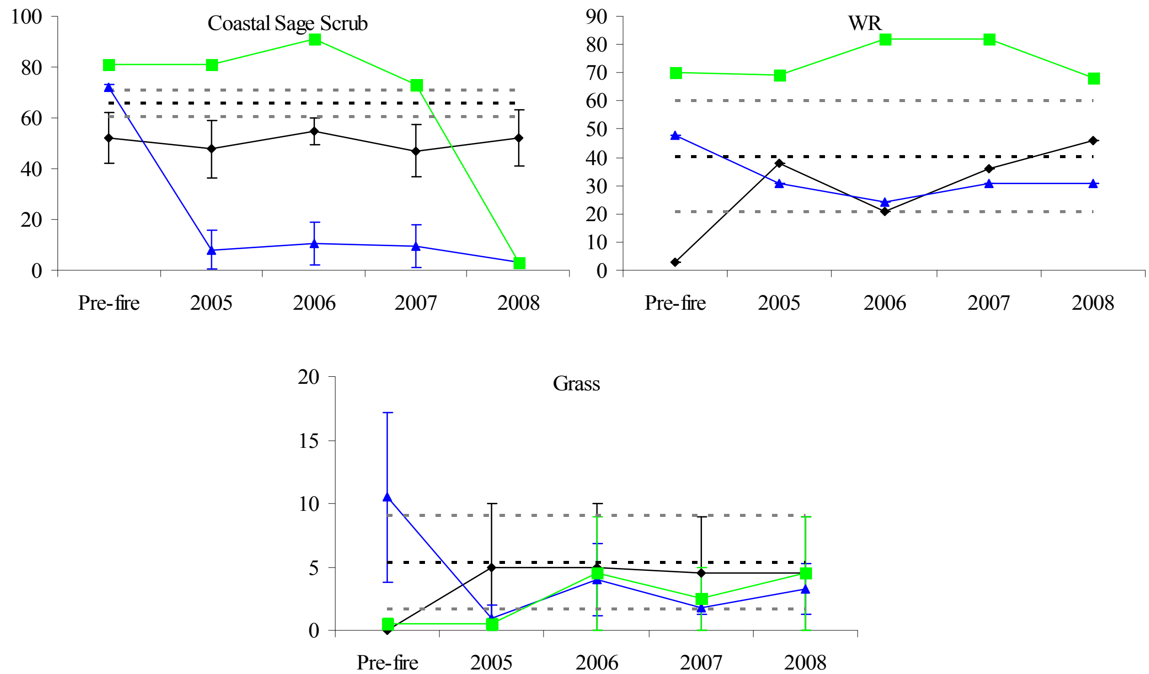

Figure 13. Shrub and tree cover at Rancho Jamul. Values presented are the average percent of shrub and tree cover ±SE among samples within the given vegetation type and sample year. Symbol and line color indicate the fire history of the plots; black represents plots that did not burn; blue represents plots that burned in both 2003 and 2007, and green represents plots that burned in 2007. The black dashed line is the pre-fire average percent of shrub and tree cover across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. The x-axes are sample years, and the y-axes are percent cover. "WR" indicates woodland/riparian.

Shrub and Tree Species Richness

Shrub and tree species richness varied between the different vegetation types and study sites. The highest average pre-fire species richness that we detected was in the coastal sage scrub plots at Little Cedar where we found an average of 6.75 (SE = 1.38, n = 4) species per coastal sage scrub plot. The pre-fire chaparral plots at Santa Ysabel were second highest with an average of 6.33 (SE = 0.95, n = 6) species per plot. The lowest average shrub and tree species richness was in the grassland plots at Santa Ysabel, 0.33 (SE = 0.33, n = 3).

Within each study site, we looked at the annual average shrub and tree species richness within each vegetation type and fire history pattern that occurred at the site. At Little Cedar, where the average pre-fire species richness in chaparral plots was 3.2 (SE = 0.86, n = 5), the post-fire trend was for an increase in species richness, ending with an average of 5.6 (SE = 0.93, n = 5) (Figure 14). Within the coastal sage scrub plots at Little Cedar, there were two fire histories, those plots that burned only in 2003 (n = 1) and those plots that burned in both 2003 and 2007 (n = 3). The results for the single coastal sage scrub plot that burned only in 2003 indicated that there was potentially a higher pre-fire species richness (10 species) at this plot then the average 6.75 (SE = 1.38, n = 4) species per plot we detected across the pre-fire samples (Figure 14). Post-fire, the species richness at this plot dropped to within the average pre-fire range for coastal sage scrub at this site. The three plots that burned in both years tended to decline in species richness in 2005, but were recovering slightly in 2006 and 2007. The 2008 surveys indicate that the species richness declined again to nearly the same level as detected for 2005.

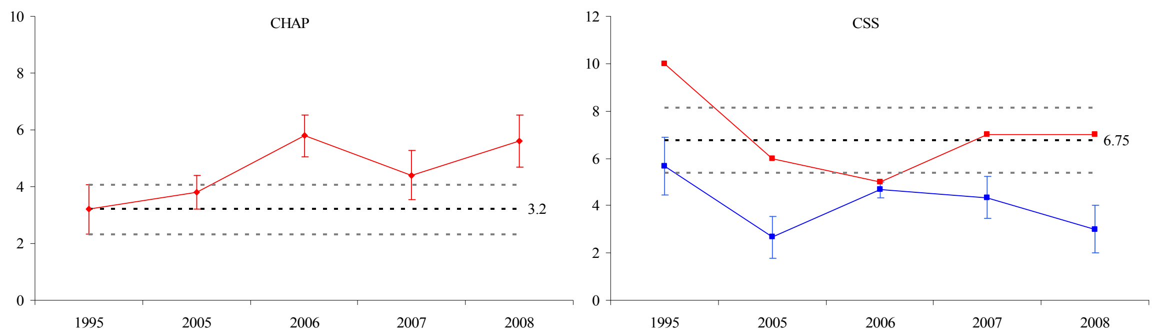

Figure 14. Shrub and tree species richness at Little Cedar. Values presented are the average species richness ±SE among samples within the given vegetation type and sample year. In all graphs, the vertical axes are species richness, and the horizontal axes are sample year. Symbol and line color indicate the fire history of the plots; red represents plots that burned in 2003, and blue represents plots that burned in both 2003 and 2007. The black dashed line is the average pre-fire shrub and tree species richness across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. “CHAP” indicates chaparral, and “CSS” indicates coastal sage scrub.

At the Elliott Reserve study site, we studied two vegetation types, coastal sage scrub and chaparral, all with the same fire history. All plots here burned one time in 2003. In the chaparral plots at Elliott Reserve, we saw a only a slight increase in species richness over the pre-fire average of 4.2 (SE = 1.02, n = 5) species per plot. From the 2008 surveys, the final species richness across the chaparral plots was 5 (SE = 0.55, n = 5) (Figure 15). The shrub and tree species richness dipped slightly in the coastal sage scrub plots at Elliott Reserve in 2005 from the pre-fire average of 4.6 (SE = 1.03, n = 5) but appear to have recovered to nearly the same levels by the 2008 samples.

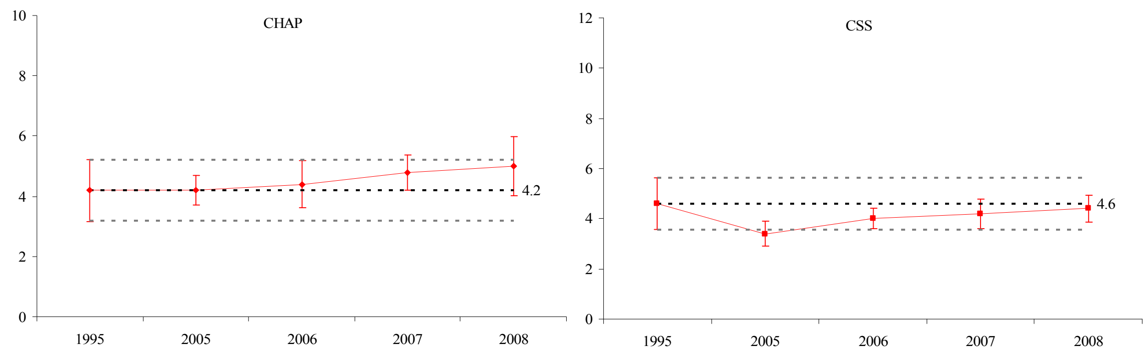

Figure 15. Shrub and tree species richness at Elliott Reserve. Values presented are the average species richness ±SE among samples within the given vegetation type and sample year. In all graphs, the vertical axes are species richness, and the horizontal axes are sample year. Symbol and line color indicate the fire history of the plots; red represents plots that burned in 2003. The black dashed line is the average pre-fire shrub and tree species richness across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. "CHAP" indicates chaparral, and "CSS" indicates coastal sage scrub.

We sampled three different vegetation types at Rancho Jamul, all with plots that experienced three different fire histories. At the coastal sage scrub plots that remained unburned throughout the length of our study (n = 3), the average shrub and tree species richness remained fairly consistent with the pre-fire rate of 3.1 (SE = 0.40, n = 8) averaged across all coastal sage scrub plots at Rancho Jamul (Figure 16). The four plots that burned twice appear to have declined in species richness and tended to remain at the reduced level through the 2008 samples (Appendix 1). One plot remained unburned until the 2007 fires after which the species richness declined to nearly the same levels as measured at the twice burned plots. The woodland/riparian plots at Rancho Jamul tended to be dominated by just a few tree species and typically had low species richness compared to the chaparral and coastal sage scrub plots discussed to this point. The shrub and tree species richness across all three fire history patterns within the woodland/riparian plots remained at approximately the same levels as detected across all woodland/riparian plots pre-fire (Figure 16). Grassland plots, by definition, had low contributions of shrubs and trees pre-fire; this seemingly did not change across any of the three patterns of fire history (Figure 16).

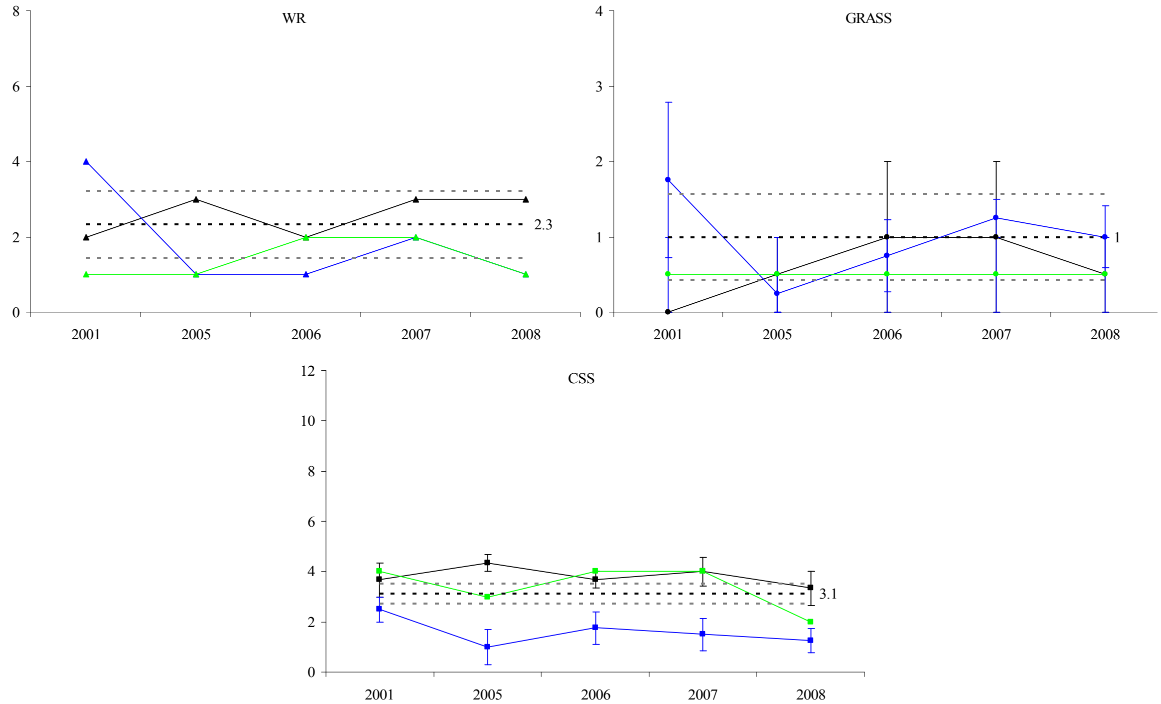

Figure 16. Shrub and tree species richness at Rancho Jamul. Values presented are the average species richness ±SE among samples within the given vegetation type and sample year. In all graphs, the vertical axes are species richness, and the horizontal axes are sample year. Symbol and line color indicate the fire history of the plots; black represents plots that did not burn; blue represents plots that burned in both 2003 and 2007, and green represents plots that burned in 2007. The black dashed line is the average pre-fire shrub and tree species richness across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. "WR" indicates woodland/riparian; "GRASS" indicates grassland, and "CSS" indicates coastal sage scrub.

We sampled all four vegetation types at Santa Ysabel where three patterns of fire history occurred, unburned, burned in 2003, and burned in 2007. Across all six chaparral plots pre-fire, the average shrub and tree species richness was 6.3 (SE = 0.95, n = 6). Only one plot remained unburned for the entire study, and species richness appears to remain relatively high over the four post-fire samples at this plot (Figure 17). The plots that burned in 2003 tended to hover around the pre-fire average with little change. The single plot that burned in 2007 started out with slightly lower species richness (4) and dropped to the lowest level of species richness detected within any of the chaparral plots at Santa Ysabel (2). We only had two coastal sage scrub plots at Santa Ysabel; one burned in 2003, and the other did not. At the unburned plot, species richness tended to increase over the four post-fire samples from the pre-fire average of 4.5 (SE = 0.5, n = 2). The burned coastal sage scrub plot declined from its pre-fire level of species richness (Figure 17). As reported above for the grassland at Rancho Jamul, shrub and tree species richness varied little across all of the vegetation samples at Santa Ysabel from the pre-fire average of 0.33 (SE = 0.33, n = 3) species per plot (Figure 17). Within the woodland/riparian plots at Santa Ysabel, where the pre-fire average species richness was 2.2 (SE = 0.87, n = 6), we saw only a slight decline in the plots that burned in the 2003 fires (Figure 17). The single unburned woodland/riparian plot increased from four species pre-fire to a maximum of six species of shrubs or trees post-fire.

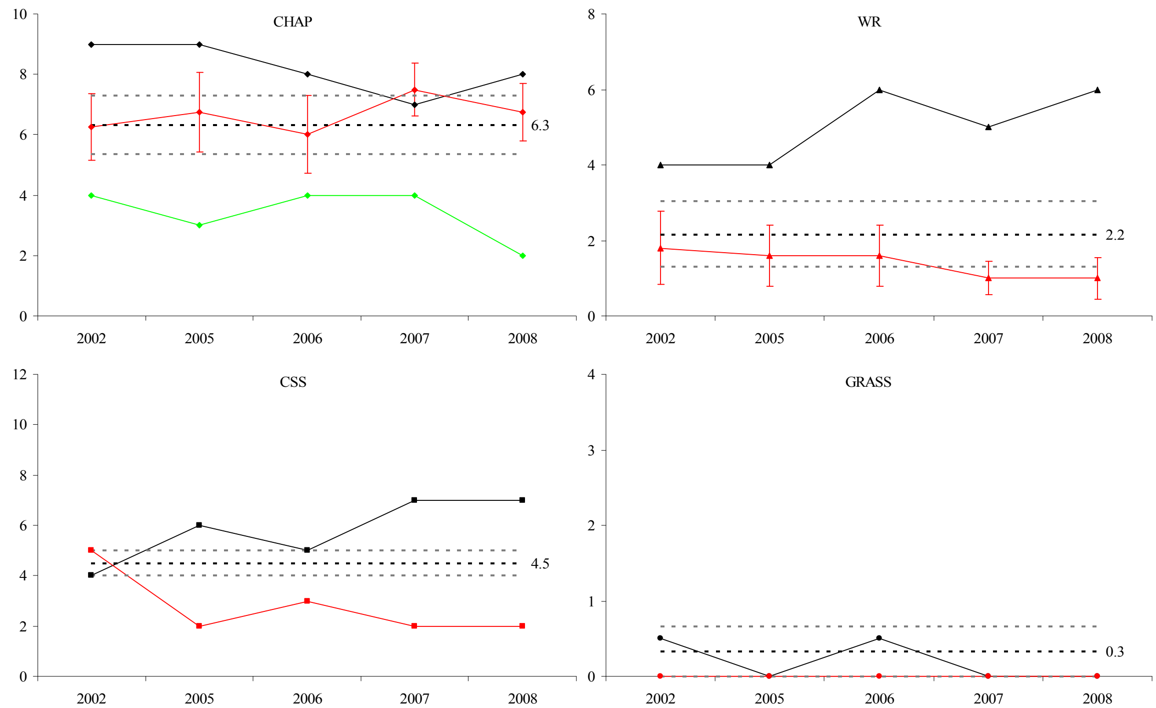

Figure 17. Shrub and tree species richness at Santa Ysabel. Values presented are the average species richness ±SE among samples within the given vegetation type and sample year. In all graphs, the vertical axes are species richness, and the horizontal axes are sample year. Symbol and line color indicate the fire history of the plots; black represents plots that did not burn; red represents plots that burned in 2003, and green represents plots that burned in 2007. The black dashed line is the average pre-fire shrub and tree species richness across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. "CHAP" indicates chaparral; "WR" indicates woodland/riparian; "CSS" indicates coastal sage scrub and "GRASS" indicates grassland.

Canopy Height

As might be expected, the average canopy height declined in the study plots that burned, but in some cases, this decline did not occur until several years after the fires. At Little Cedar, the average canopy height in the chaparral plots dropped from the pre-fire high of 130.5 cm (SE = 44.1, n = 5) to as low as 15 cm (Figure 18). Within the coastal sage scrub plots at Little Cedar, the pre-fire average canopy height differed by almost 45 cm between the plot that burned in 2003 only, and those plots that burned both years. Post-fire, the average canopy height at these plots dropped to approximately 33 cm.

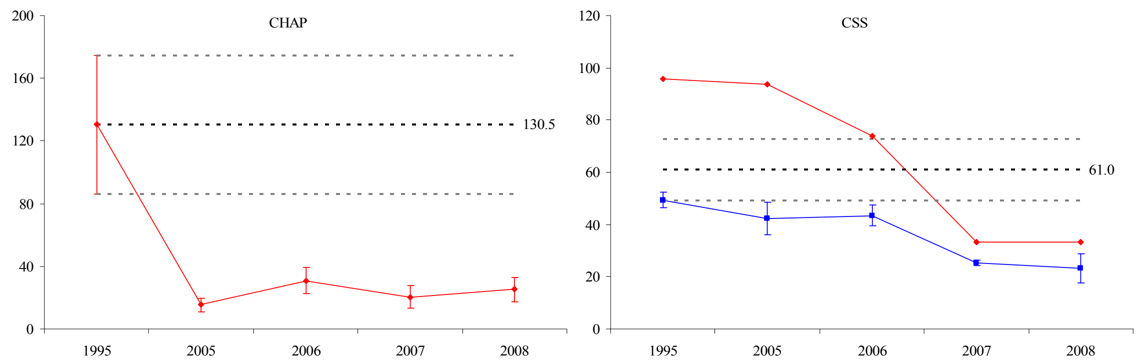

Figure 18. Canopy height at Little Cedar. Values presented are the average canopy height ±SE among samples within the given vegetation type and sample year. In all graphs, the vertical axes are canopy height in cm, and the horizontal axes are sample year. Symbol and line color indicate the fire history of the plots; red represents plots that burned in 2003, and blue represents plots that burned in both 2003 and 2007. The black dashed line is the average pre-fire canopy height across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. "CHAP" indicates chaparral, and "CSS" indicates coastal sage scrub.

In the chaparral plots at Elliott Reserve, we saw a dramatic decrease in average canopy height over the pre-fire average of 67.2 cm (SE = 12.8, n = 5). From the 2008 surveys, the final canopy height across the chaparral plots was 23.7 cm (SE = 1.90, n = 5) (Figure 19). The canopy height dipped more gradually in the coastal sage scrub plots at Elliott Reserve from the pre-fire average of 35.3 cm (SE = 3.49, n = 5) to a low of 17.2 cm (SE = 2.8, n = 5) by the 2008 samples.

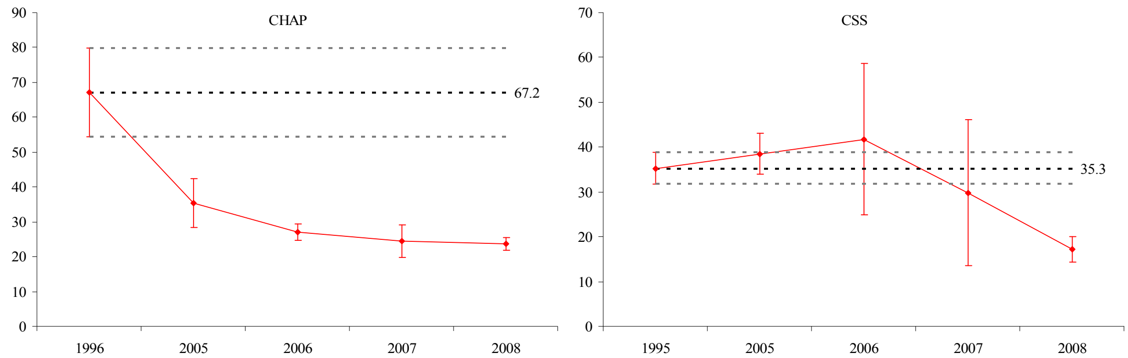

Figure 19. Canopy height at the Elliott Reserve. Values presented are the average canopy height ±SE among samples within the given vegetation type and sample year. In all graphs, the vertical axes are canopy height in cm, and the horizontal axes are sample year. Symbol and line color indicate the fire history of the plots; red represents plots that burned in 2003. The black dashed line is the average pre-fire canopy height across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. "CHAP" indicates chaparral, and "CSS" indicates coastal sage scrub.

At the coastal sage scrub plots at Rancho Jamul that remained unburned throughout the length of our study (n = 3), the average canopy height remained fairly consistent with the pre-fire rate of 66.1 cm (SE = 8.9, n = 8) averaged across all coastal sage scrub plots at Rancho Jamul (Figure 20). The canopy height at the four plots that burned twice appeared to have declined steadily and tended to remain at the reduced level through the 2008 samples. One coastal sage scrub plot remained unburned until the 2007 fires after which the canopy height declined to a level slightly below that measured at the twice burned plots. The woodland/riparian plots at Rancho Jamul had a much wider range of variability within the canopy height when compared to the chaparral and coastal sage scrub plots discussed to this point (Figure 20), due to the western sycamore which was just outside of the pre-fire transect line but was included in all post-fire surveys. The average canopy height across all three fire history patterns within the woodland/riparian plots remained at or above the levels as detected across all woodland/riparian plots pre-fire (Figure 20). Grassland survey plots from all three fire history patterns at Rancho Jamul have declined slightly from the pre-fire average of 53.2 cm (SE = 5.5, n = 8) (Figure 20), a decrease potentially related to non-fire related factors.

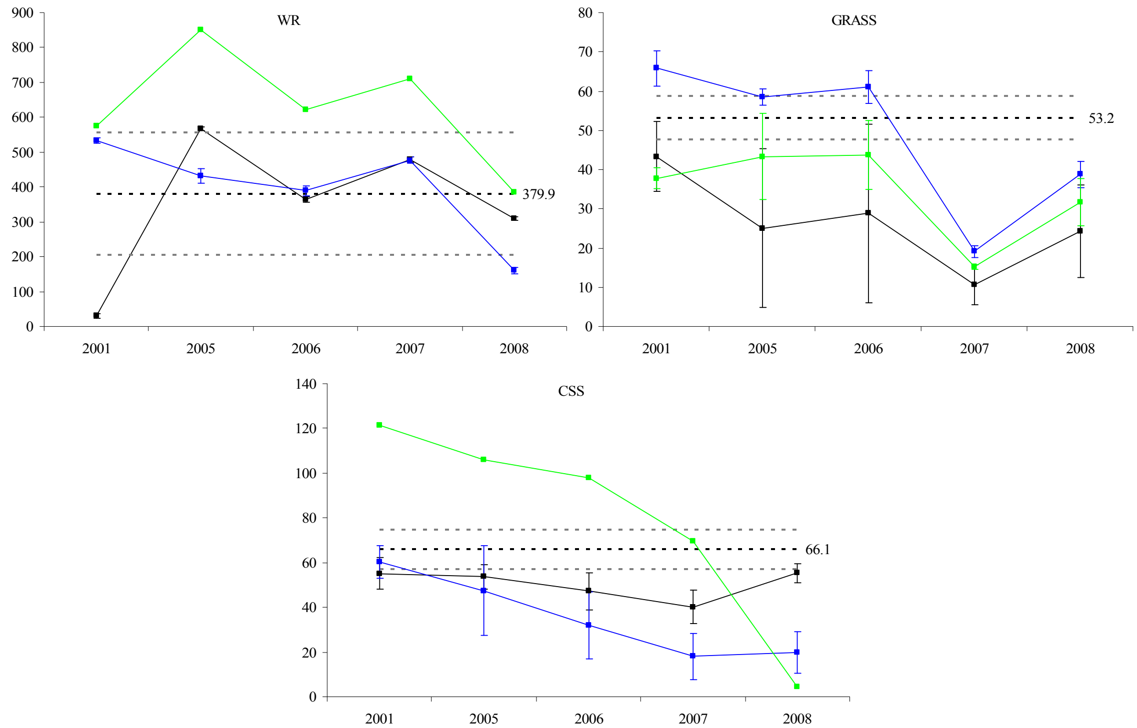

Figure 20. Canopy height at Rancho Jamul. Values presented are the average canopy height ±SE among samples within the given vegetation type and sample year. In all graphs, the vertical axes are canopy height in cm, and the horizontal axes are sample year. Symbol and line color indicate the fire history of the plots; black represents plots that did not burn; blue represents plots that burned in both 2003 and 2007, and green represents plots that burned in 2007. The black dashed line is the average pre-fire canopy height across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. "WR" indicates woodland/riparian; "GRASS" indicates grassland, and "CSS" indicates coastal sage scrub.

Across all six chaparral plots at Santa Ysabel pre-fire, the average canopy height was 115.7 cm (SE = 27.5, n = 6). The one unburned chaparral plot remained within the range of variability measured pre-fire (Figure 21). The plots that burned in 2003 tended to gradually decline reaching the lowest levels in 2008, 48.2 cm (SE = 18.8, n = 4). The single plot that burned in 2007 started out with a slightly lower average canopy height and dropped to the lowest level detected within any of the chaparral plots at Santa Ysabel. Of the two coastal sage scrub plots at Santa Ysabel, both remained within the range of variability measured pre-fire for the entirety of the study. The burned coastal sage scrub plot tended to decline from its pre-fire canopy height (Figure 21). Within the grassland plots at Santa Ysabel, canopy height fluctuated from the pre-fire average of

13.9 cm (SE = 4.9, n = 3), higher than the pre-fire average in 2005 and 2006 and then slightly lower in the following two years (Figure 21). Within the woodland/riparian plots at Santa Ysabel, where the pre-fire average canopy height was 258.0 cm (SE = 106.4, n = 6), we saw a gradual decline in the plots that burned in the 2003 fires (Figure 21) to a 2008 low of 20.1 cm (SE = 7.2, n = 5). The single unburned woodland/riparian plot stayed within the pre-fire range of variability.

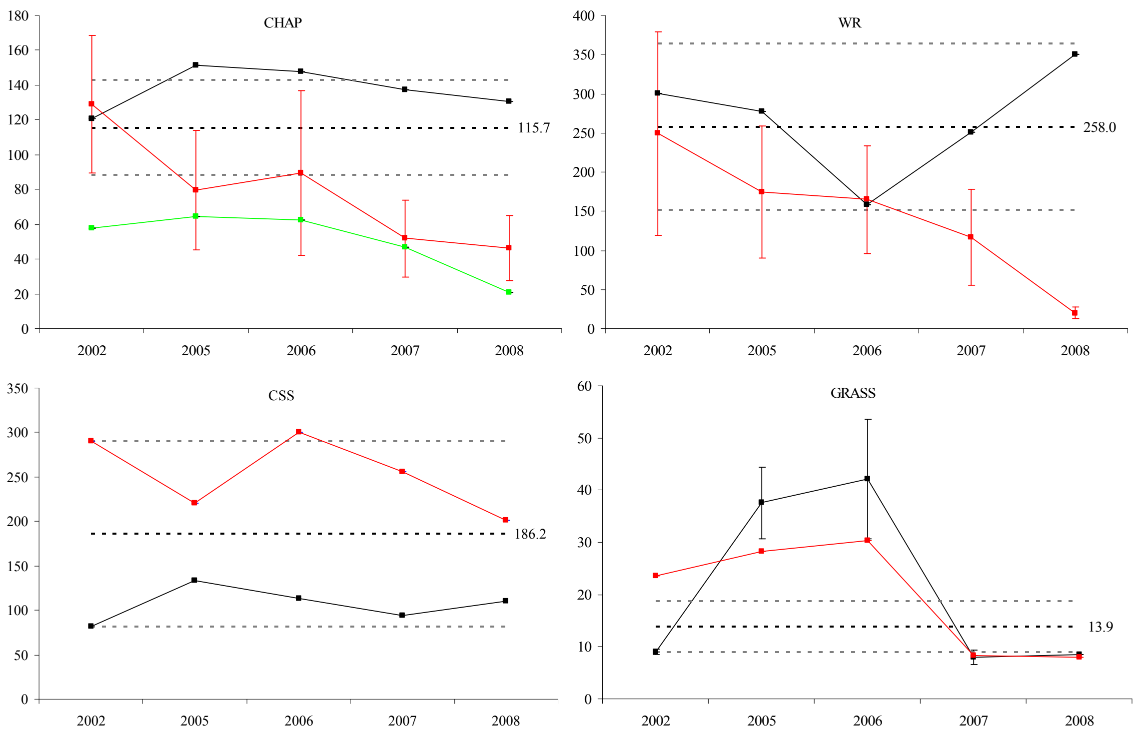

Figure 21. Canopy height at Santa Ysabel. Values presented are the average canopy height ±SE among samples within the given vegetation type and sample year. In all graphs, the vertical axes are canopy height in cm, and the horizontal axes are sample year. Symbol and line color indicate the fire history of the plots; black represents plots that did not burn; red represents plots that burned in 2003, and green represents plots that burned in 2007. The black dashed line is the average pre-fire canopy height across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. "CHAP" indicates chaparral; "WR" indicates woodland/riparian; "GRASS" indicates grassland, and "CSS" indicates coastal sage scrub.

Substrate Frequencies

After an initial review of the substrate data and the data collection process, we found that the category "sandy soil" was the most robust and consistently collected category of substrate. Based on this evaluation, we present the results for the frequency of sandy soil as a substrate but include the results for all substrate categories in Figures 22 through 25. At Little Cedar, where the average pre-fire level of sandy soil was 5.6 % (SE = 0.8, n = 9), the highest average percentage of sandy soil was measured in 2005 in the plots that only burned in 2003, 74.2% (SE = 9.2, n = 6) (Figure 22). At the study plots at Elliott Reserve, the average pre-fire frequency of sandy soil was 10.4% (SE = 3.6, n = 10) but after the fires, this measured as high as 86.0 % (SE = 2.5, n = 10) (Figure 23). Rancho Jamul potentially experienced the smallest shift in the average percent of sandy soil (Figure 24). Pre-fire, all plots at Rancho Jamul averaged only 11.5% (SE = 2.5, n = 19) sandy soil and, post-fire, only increased to the highest level of 35.3 % (SE = 11.6, n = 6) in the unburned plots in 2007. Post-fire, the frequency of sandy soil as a substrate increased in the Santa Ysabel plots that burned over the pre-fire average of 4.9 % (SE = 2.1, n = 17) (Figure 25).

Based on the vegetation transect protocol, "leaf litter" was the most frequently reported pre-fire substrate type when averaged across all four study sites, 66% (SE = 4.2, n = 55). Leaf litter remained the most frequently reported substrate type across all four subsequent years of vegetation surveys. However, there are complications associated with the leaf litter category, and these are discussed below in the *Discussion*.

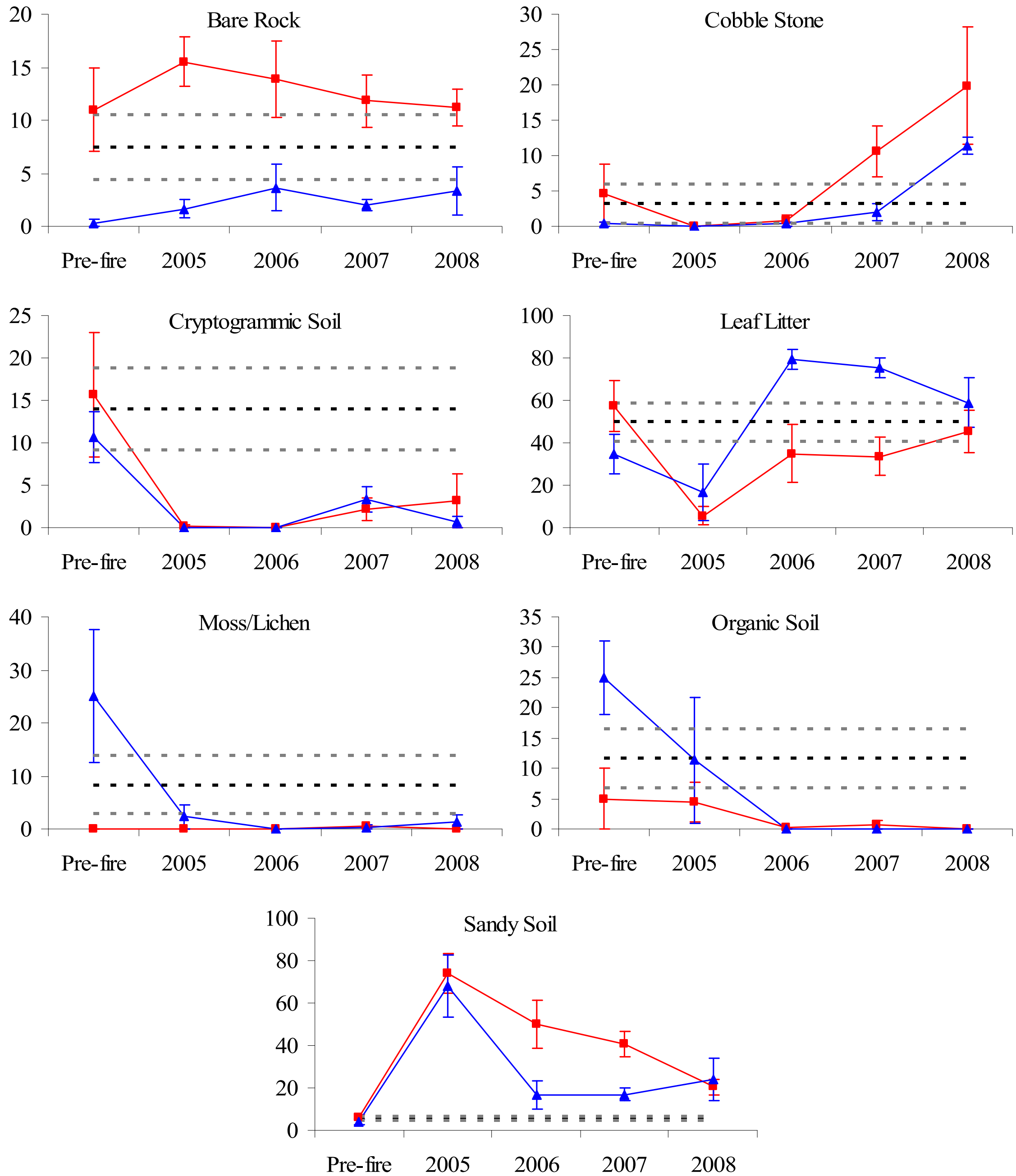

Figure 22. Substrate cover at Little Cedar. Values presented are the average coverage ±SE among samples within the given vegetation type and sample year. In all graphs, the vertical axes are percent cover, and the horizontal axes are sample year. Symbol and line color indicate the fire history of the plots; red represents plots that burned in 2003, and blue represents plots that burned in both 2003 and 2007. The black dashed line is the average pre-fire substrate cover across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean.

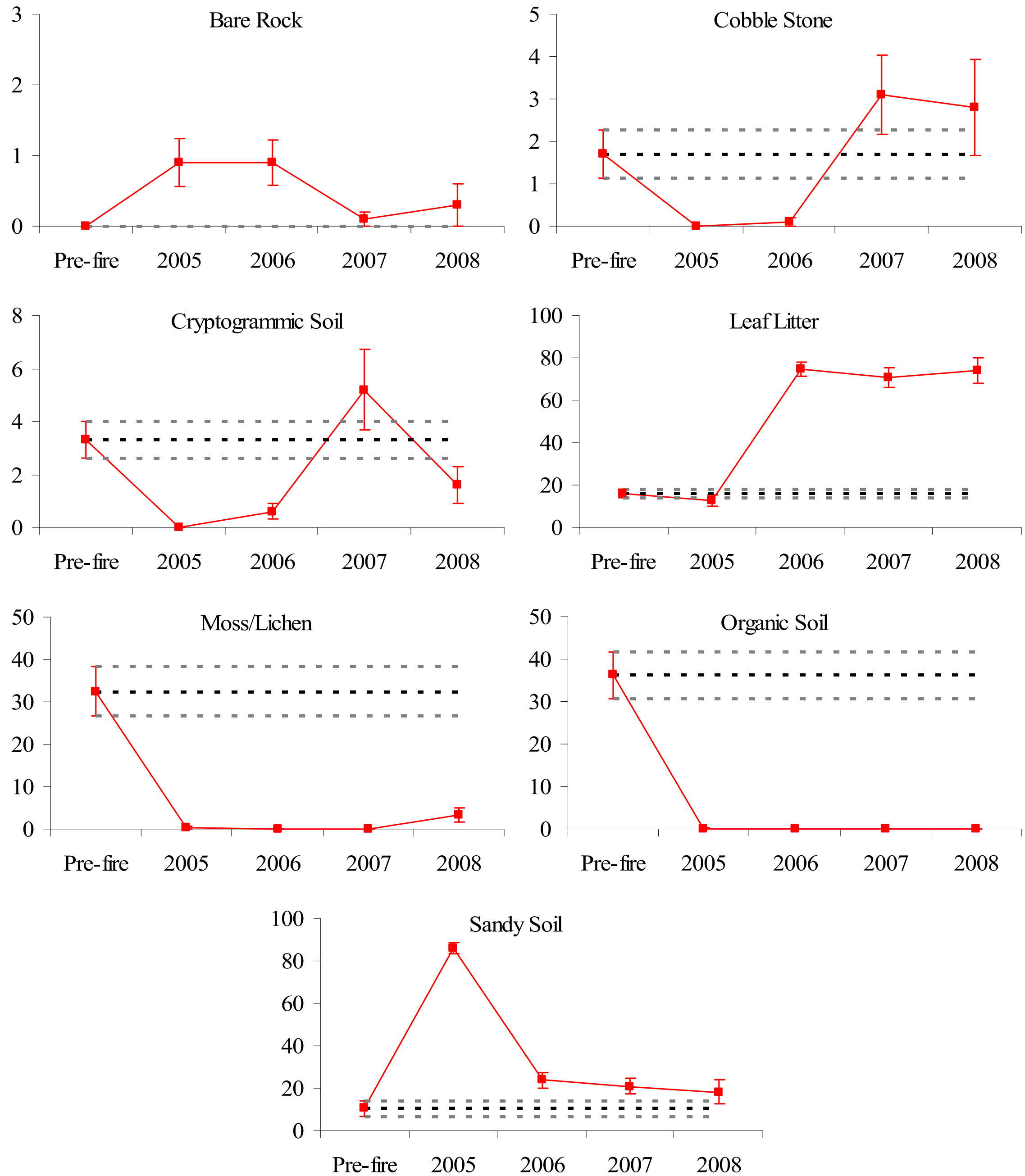

Figure 23. Substrate cover at Elliott Reserve. Values presented are the average coverage ±SE among samples within the given vegetation type and sample year. In all graphs, the vertical axes are percent cover, and the horizontal axes are sample year. Symbol and line color indicate the fire history of the plots; red represents plots that burned in 2003. The black dashed line is the average pre-fire substrate cover across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean.

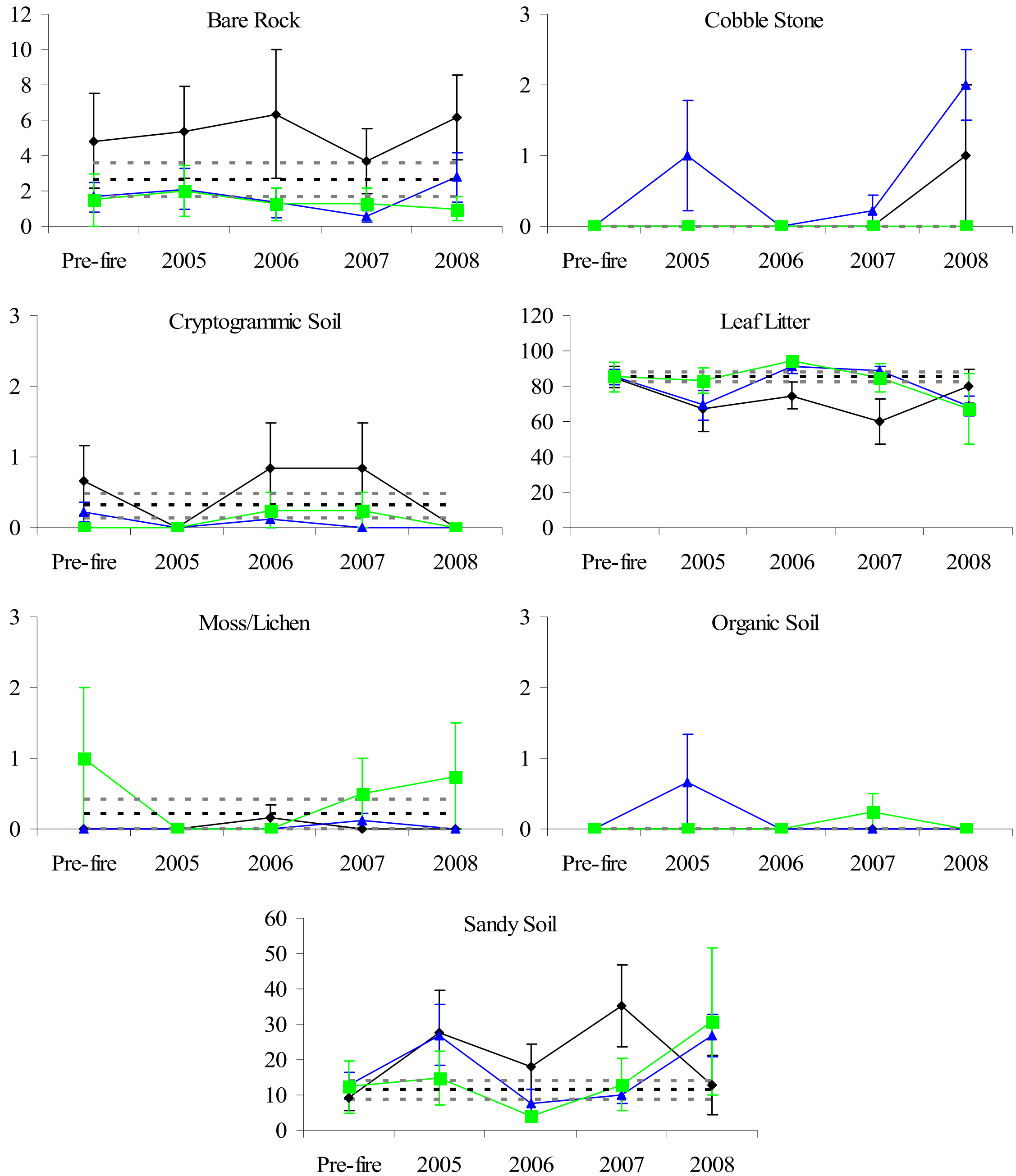

Figure 24. Substrate cover at Rancho Jamul. Values presented are the average coverage ±SE among samples within the given vegetation type and sample year. In all graphs, the vertical axes are percent cover, and the horizontal axes are sample year. Symbol and line color indicate the fire history of the plots; black represents plots that were unburned; blue represents plots that burned in both 2003 and 2007, and green is for plots burned in 2007. The black dashed line is the average pre-fire substrate cover across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean.

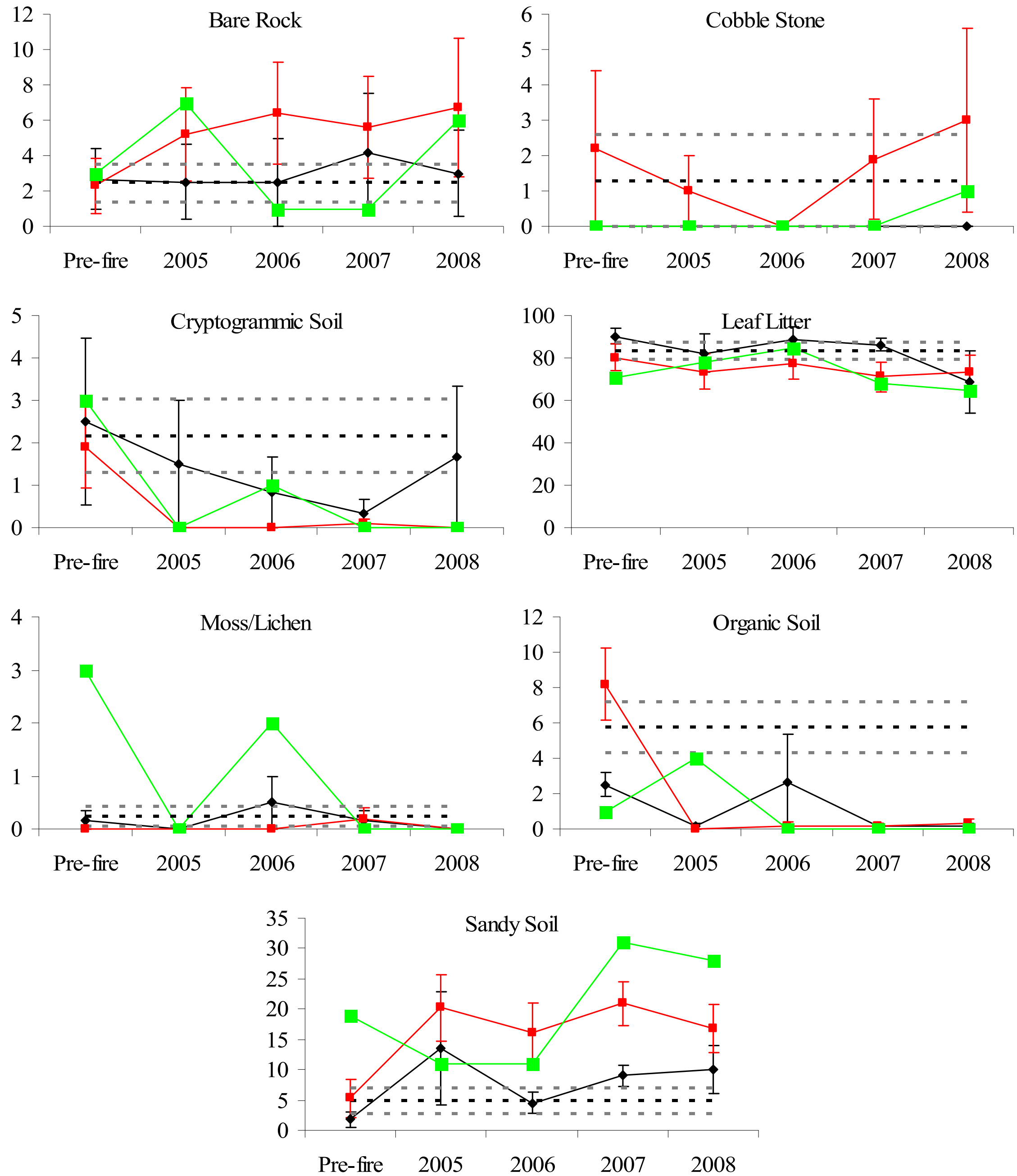

Figure 25. Substrate cover at Santa Ysabel. Values presented are the average coverage ±SE among samples within the given vegetation type and sample year. In all graphs, the vertical axes are percent cover, and the horizontal axes are sample year. Symbol and line color indicate the fire history of the plots; black represents unburned plots; red represents plots that burned in 2003, and green represents plots that burned in both 2007. The black dashed line is the average pre-fire substrate cover across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean.

Leaf Litter Depth

In many of the vegetation type – study site combinations, the average leaf litter depth (LLD) would appear to have remained consistent with the pre-fire level and that measured at unburned plots. At Little Cedar, where all of our plots burned, the LLD at the chaparral plots dropped to nearly zero during the surveys conducted in 2005, the first post-fire survey. They had continued to be low until 2008 when LLD begins to approach the pre-fire range of variability (Figure 26). Within the coastal sage scrub plots, LLD only appears to be low in 2005. All subsequent samples seem to be similar to pre-fire measurements.

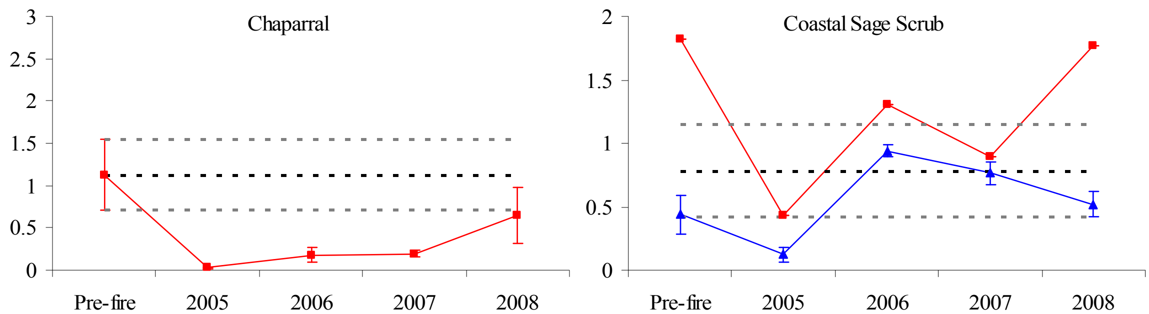

Figure 26. Leaf litter depth at Little Cedar. Values presented are the average leaf litter depth ±SE among samples within the given vegetation type and sample year. Symbol and line color indicate the fire history of the plots; red represents plots that burned in 2003, and blue represents plots that burned in both 2003 and 2007. The black dashed line is the pre-fire average leaf litter depth across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. The x-axes are sample years, and the y-axes are leaf litter depth in cm.

At Santa Ysabel, LLD has steadily declined over the four post-fire samples, but we also see a matching decline in the unburned samples. In the six chaparral plots, there was a decrease in LLD across all three patterns of fire history. As of the 2008 sample, the unburned plot, the plots that burned in 2003, and the one plot that burned in 2007, all had lower average LLD than the pre-fire average 1.6 cm (SE = 0.4, n = 6) (Figure 27). In the burned grassland, coastal sage scrub, and woodland/riparian plots there is a downward trend present in both the burned and unburned samples.

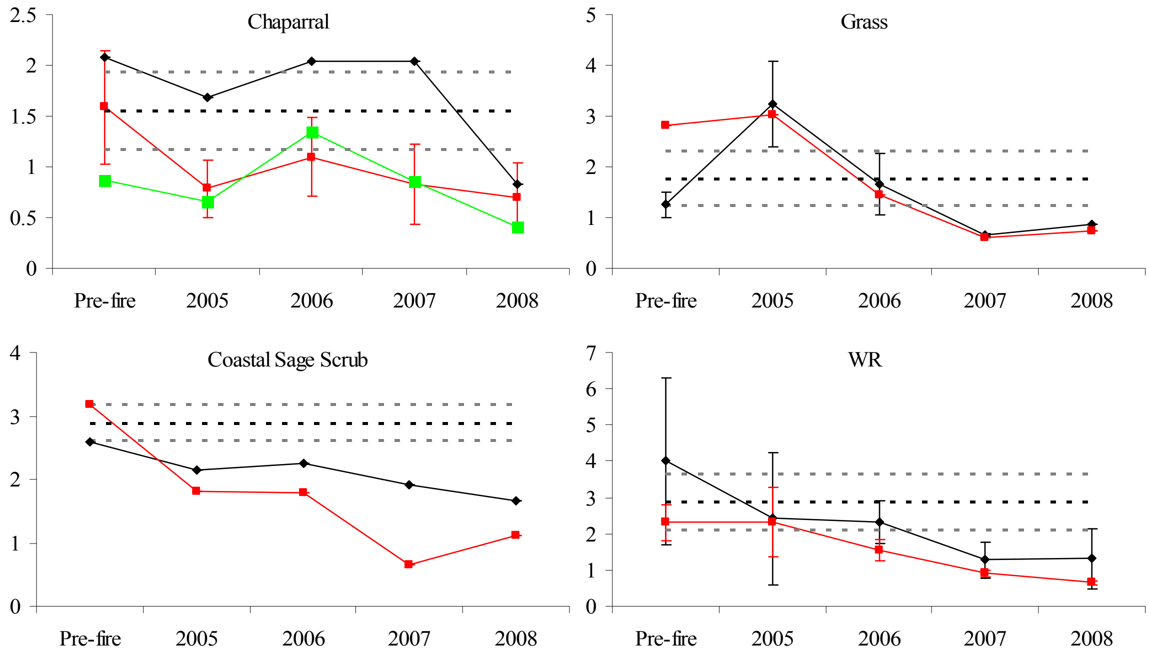

Figure 27. Leaf litter depth at Santa Ysabel. Values presented are the average leaf litter depth ±SE among samples within the given vegetation type and sample year. Symbol and line color indicate the fire history of the plots; black represents plots that did not burn; red represents plots that burned in 2003, and green represents plots that burned in 2007. The black dashed line is the pre-fire average leaf litter depth across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. The x-axes are sample years, and the y-axes are leaf litter depth in cm. "WR" indicates woodland/riparian.

With just one pattern of fire history, the Elliott Reserve plots, all of which burned in 2003, showed an increase in the average LLD measured during the vegetation transect surveys. Chaparral and coastal sage scrub both showed a large spike in 2006 when the average LLD was well above the pre-fire levels (Figure 28). We saw the same pattern in both vegetation types, where the highest measured values were in 2006, followed by two consecutive years of more moderate values.

The most notable change in LLD at Rancho Jamul was in the one coastal sage scrub study plot that burned in 2007. In 2008, the first year after the 2007 Harris Fire, the LLD was nearly zero (Figure 4B). Otherwise, LLD patterns at Rancho Jamul were similar between the three vegetation types and patterns of fire history (Figure 29).

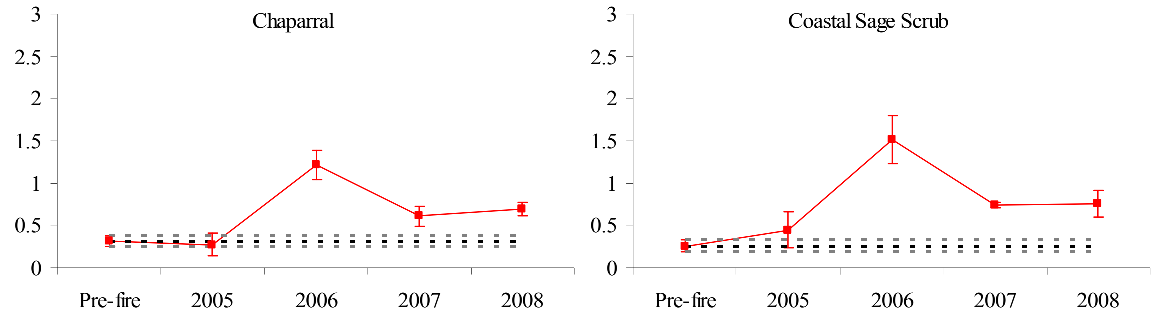

Figure 28. Leaf litter depth at Elliott Reserve. Values presented are the average leaf litter depth ±SE among samples within the given vegetation type and sample year. Symbol and line color indicate the fire history of the plots; red represents plots that burned in 2003. The black dashed line is the pre-fire average leaf litter depth across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. The x-axes are sample years and the y-axes are leaf litter depth in cm.

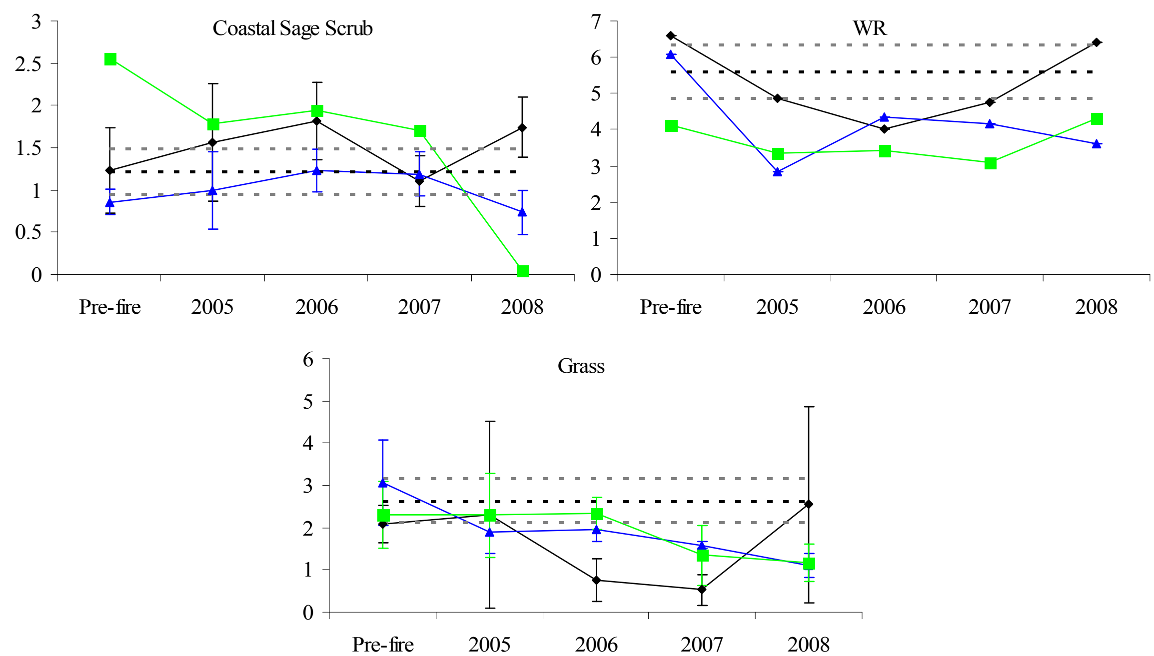

Figure 29. Leaf litter depth at Rancho Jamul. Values presented are the average leaf litter depth ±SE among samples within the given vegetation type and sample year. Symbol and line color indicate the fire history of the plots; black represents plots that did not burn; blue represents plots that burned in both 2003 and 2007, and green represents plots that burned in 2007. The black dashed line is the pre-fire average leaf litter depth across all plots within the given vegetation type. Gray dashed lines represent ±SE of the pre-fire mean. The x-axes are sample years, and the y-axes are leaf litter depth in cm. "WR" indicates woodland/riparian.

Vegetation Community Similarities and Shifts in Structure

Using the similarity dendrograms generated through PRIMER-E, we have reviewed the results from the vegetation surveys for each study site over time. Within each dendrogram, we have identified clusters of samples that appear to have high levels of shared characteristics.

At Little Cedar, the 45 samples from the nine plots were organized into approximately six groups based on the shared characteristics of the samples within each cluster. The post-fire chaparral samples seem to more closely align with the corresponding unburned pre-fire samples (Figure 30, nodes A, B, and F) than with any of the grassland samples included to look for possible shifts in community structure. All 10 samples from plots 7 and 8, both before and after the fires, appeared to form a single continuous cluster (Figure 30, node A). The samples from plots 1 and 2 were split into three groups within a larger group (node B), pre-fire, the first post-fire sample, and a third group made up of the 2006, 2007, and 2008 samples. Plot 9 at Little Cedar grouped out as a separate cluster that included the pre-fire and all post-fire samples, indicating that the vegetation at plot 9 was potentially different from that at any other plot and that it did not change from the pre-fire state (node F). However, within each of these three chaparral nodes, the post-fire samples remain more similar to each other than the pre-fire unburned samples.

We saw a potential shift in the level of community similarities shared by the coastal sage scrub plots at Little Cedar. The pre-fire coastal sage scrub plots at Little Cedar, plots 3, 4, 5, and 6, grouped with the two native grassland samples from Rancho Jamul (Figure 30, node C). The majority of the burned post-fire samples from these coastal sage scrub plots grouped out together as a burned coastal sage scrub cluster (node D) separate of the unburned condition and any of the grassland samples from Rancho Jamul. There were two exceptions to this burned coastal sage scrub group, both from plot 4. The first post-2003 fire sample and the first post-2007 fire sample were most similar to the non-native grassland samples from Rancho Jamul (Figure 30, node E).

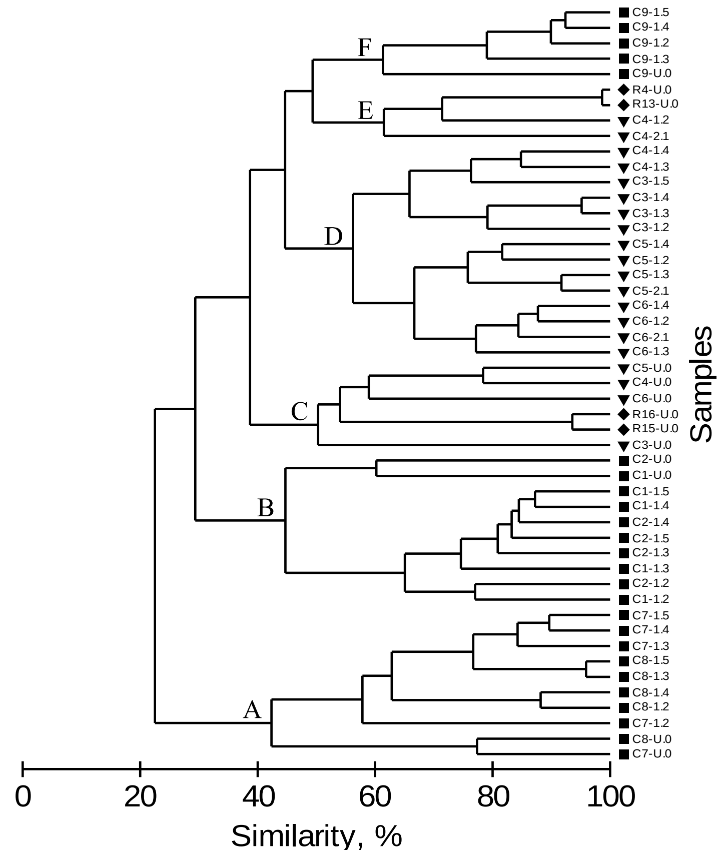

Figure 30. Little Cedar similarity dendrogram. The text label for each sample identifies the study site (Little Cedar [C] or Rancho Jamul [R]), the plot, and the fire history. Within the fire history, "U" indicates that the plot was unburned at the time of the survey; "1" indicates samples from plots burned in 2003, and "2" shows samples from plots burned in 2007. The number following the decimal represents the number of years since the most recent fire at the plots. The shape of each symbol represents the vegetation type at each plot based on the pre-fire survey results. The triangles (▼) show coastal sage scrub plots, and squares (■) indicate chaparral plots. The diamonds (♦) are grassland samples from Rancho Jamul. The full sample identifier might read, for example, "▼C5-2.1", indicating the vegetation transect results from Little Cedar plot 5, a coastal sage scrub plot, one year after the 2007 fire.

The similarity dendrogram for Elliott Reserve produced several groups with high levels of shared similarities and indicated several examples of changes in the vegetation communities. One potential shift involves the majority of the results from the burned chaparral and coastal sage scrub plots which group together into three clusters separate of the unburned samples. The majority of the unburned, pre-fire chaparral and coastal sage scrub plots at Elliott Reserve formed two groups within the dendrogram (Figure 31, D and E, respectively). The samples from burned chaparral and coastal sage scrub plots formed several groups independent from the respective unburned nodes. Samples from burned chaparral plots fell within two nodes. Within node F, post-fire chaparral plots account for 17 out of the 23 samples, and the balance are post-fire coastal sage scrub samples. All but one sample from plot 9, originally characterized as chaparral, appear to have changed little pre-fire to post-fire; the post-fire burned samples are most similar to the pre-fire unburned sample originally collected at the plot (Figure 31, node H). The

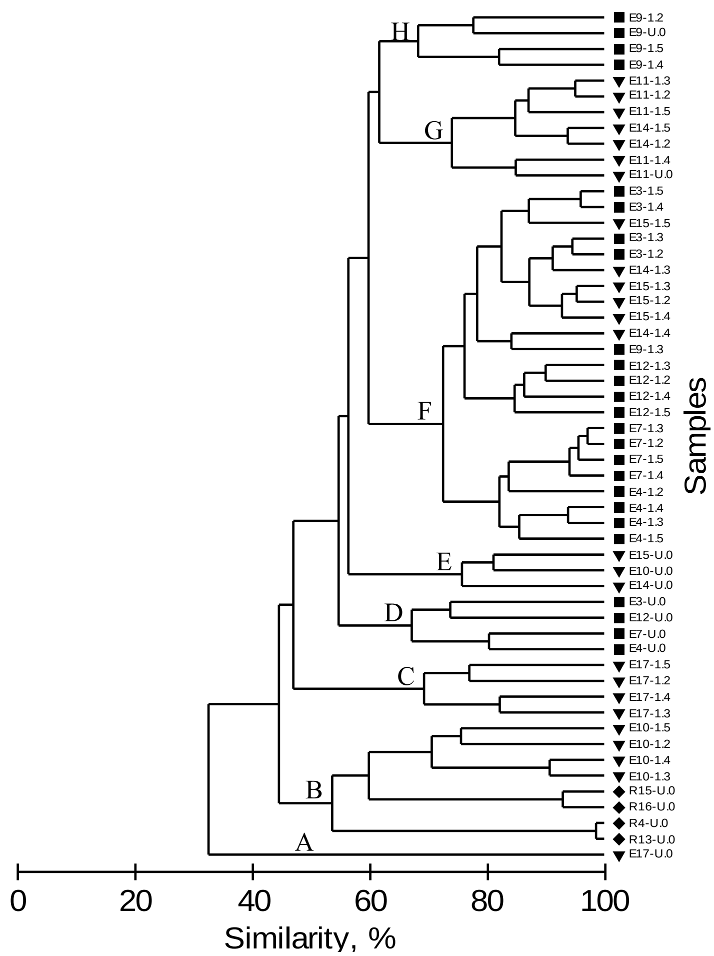

Figure 31. Elliott Reserve similarity dendrogram. The text label for each sample identifies the study site (Elliott Reserve [E] or Rancho Jamul [R]), the plot, and the fire history. Within the fire history, "U" indicates that the plot was unburned at the time of the survey; "1" indicates samples from plots burned in 2003, and "2" shows samples from plots burned in 2007. The number following the decimal represents the number of years since the most recent fire at the plots. The shape of each symbol represents the vegetation type at each plot based on the pre-fire survey results. The triangles (▼) show coastal sage scrub plots, and squares (■) indicate chaparral plots. The diamonds (♦) are grassland samples from Rancho Jamul. The full sample identifier might read, for example, "■E4-1.2", indicating the vegetation transect results from Elliott Reserve plot 4, a chaparral plot, two years after the 2003 fire.

post-fire coastal sage scrub samples are more scattered within the dendrogram. Some fell within the burned chaparral group (node F); others fell within the burned coastal sage scrub group (node G), and the post-fire samples from plot 10 align with the grassland samples included from Rancho Jamul (node B). The post-fire samples from plot 10 were the only ones to share a high level of similarity with the grassland samples. The post-fire samples from plot 14, originally classified as a coastal sage scrub plot, toggle back and forth between grouping with the burned chaparral group (fire-years 1.3 and 1.4, node F) and the burned coastal sage scrub (fire-year 1.2 and 1.5, node G). Describing node G as a burned coastal sage scrub cluster is complicated by the inclusion of the pre-fire sample from plot 11. This matching up of the pre-fire sample from plot 11 with so many post-fire samples may indicate that other factors were already affecting this plot even before the fire occurred. The pre-fire vegetation sample from plot 17 separated out from the rest of the samples with a shared similarity of only 37.6% (node A). The post-fire samples from plot 17 also formed a homogeneous group (node C).

Compared to the similarity dendrograms for Little Cedar and Elliott Reserve, the one for Rancho Jamul includes samples from several plots that did not burn during the course of the study, and it has an interesting anomaly not seen within any of our other study sites. The pre-fire and unburned post-fire coastal sage scrub samples formed a fairly distinct group (Figure 32, node B). This group also contained two post-fire, burned samples from plot 7, which despite burning twice, appear to have made a recovery as indicated by the inclusion of the 2007 and 2008 samples in the unburned coastal sage scrub group and not the grassland cluster. For the burned samples from coastal sage scrub plots 7, 11, 19, 21, and 36, there was a distinct shift away from the unburned condition as measured pre-fire and at the plots that remained unburned over the entirety of the study, all became more similar to the grassland samples (node E). An additive impact of multiple fires was seen at plot 19 specifically. The first three post-fire samples paired up with the samples from the native needlegrass plots (node F). After the 2007 fire, the 2008 sample from plot 19 (R19-2.1) moved into the non-native grass cluster (node E).

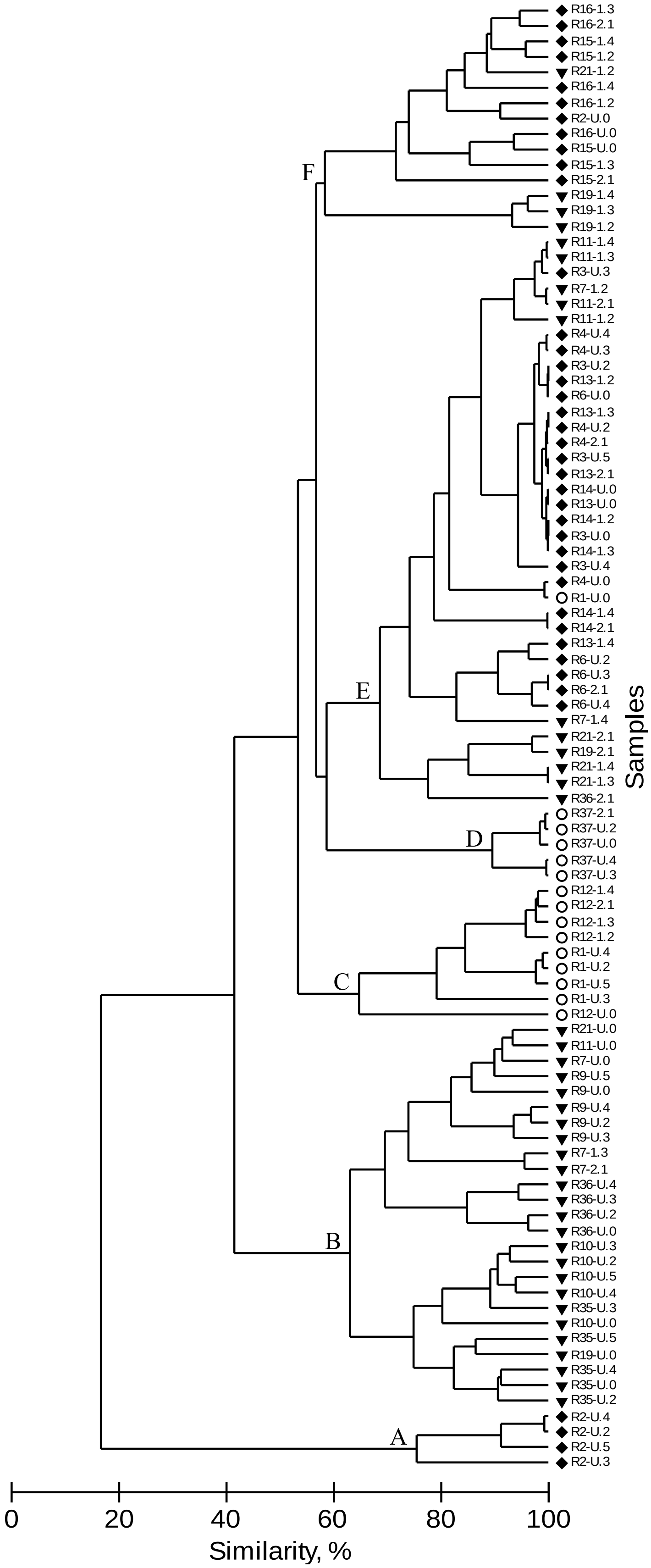

Figure 32. Rancho Jamul similarity dendrogram. The text label for each sample identifies the study site (Rancho Jamul [R]), the plot, and the fire history. Within the fire history, "U" indicates that the plot was unburned at the time of the survey; "1" indicates samples from plots burned in 2003, and "2" shows samples from plots burned in 2007. The number following the decimal represents the number of years since the most recent fire at the plots. The shape of each symbol represents the vegetation type at each plot based on the pre-fire survey results. The triangles (▼) show coastal sage scrub plots; squares (■) indicate chaparral plots; diamonds (♦) are for grassland, and circles (○) represent woodland/riparian. The full sample identifier might read, for example, "♦R4-U.2", indicating the vegetation transect results from Rancho Jamul plot 4, an unburned grassland plot, four years after the 2003 fire.

The largest node generated in the Rancho Jamul similarity dendrogram included the majority of the grassland plots, both burned and unburned samples (Figure 32, node E). This group was made up mostly of plots containing large portions of non-native grasses and also contained a portion of the burned coastal sage scrub samples. Although the pre-fire sample at plot 2 resulted in this area being categorized as a grassland plot, the post-fire samples uncharacteristically were removed from the node containing the majority of the grassland samples and were grouped out separate from the rest of the samples from the entire study site (node A). The work being done at plot 2, outside of the efforts of USGS, has resulted in a completely unique situation among our results; a grassland plot may no longer be grassland and be on a path towards becoming a shrubland (Figure 32, node A). Review of the raw data indicated that this was due to a complete absence of non-native grasses in the post-fire samples. A separate group characterized by the native needlegrass, *Nassella* spp., was formed along with the remainder of the burned coastal sage scrub samples (node F).

Within the similarity diagram for Rancho Jamul, the woodland/riparian plots were divided between two groups. The samples from plot 37 were dominated by oaks and do not appear to have been severely altered by the 2007 fire at this site. The burned sample was more than 90% similar to the nearest unburned sample from the same plot (Figure 32, node D). We sampled two plots with western sycamores at Rancho Jamul, plots 1 and 12. All pre- and post-fire samples from these two plots combined to form a single homogeneous group (node C) with both burned and unburned samples.

The four post-fire samples at each of the Santa Ysabel plots appear to have remained fairly consistent with the corresponding pre-fire samples. The chaparral plots divided out into three groups. All of the samples from plot 8, all of which represent the unburned condition, formed a single group (Figure 33, node A). Plots 2, 12, 13, and 14 formed one continuous group, mixing the burned samples within the unburned (node D). The last chaparral plot at Santa Ysabel, plot 18, sorted out to be most similar to plot 10 which we had classified as a woodland/riparian area (node B). Both plot 18 and 10 contained high levels of oaks, manzanita species, and non-native grasses. The vegetation

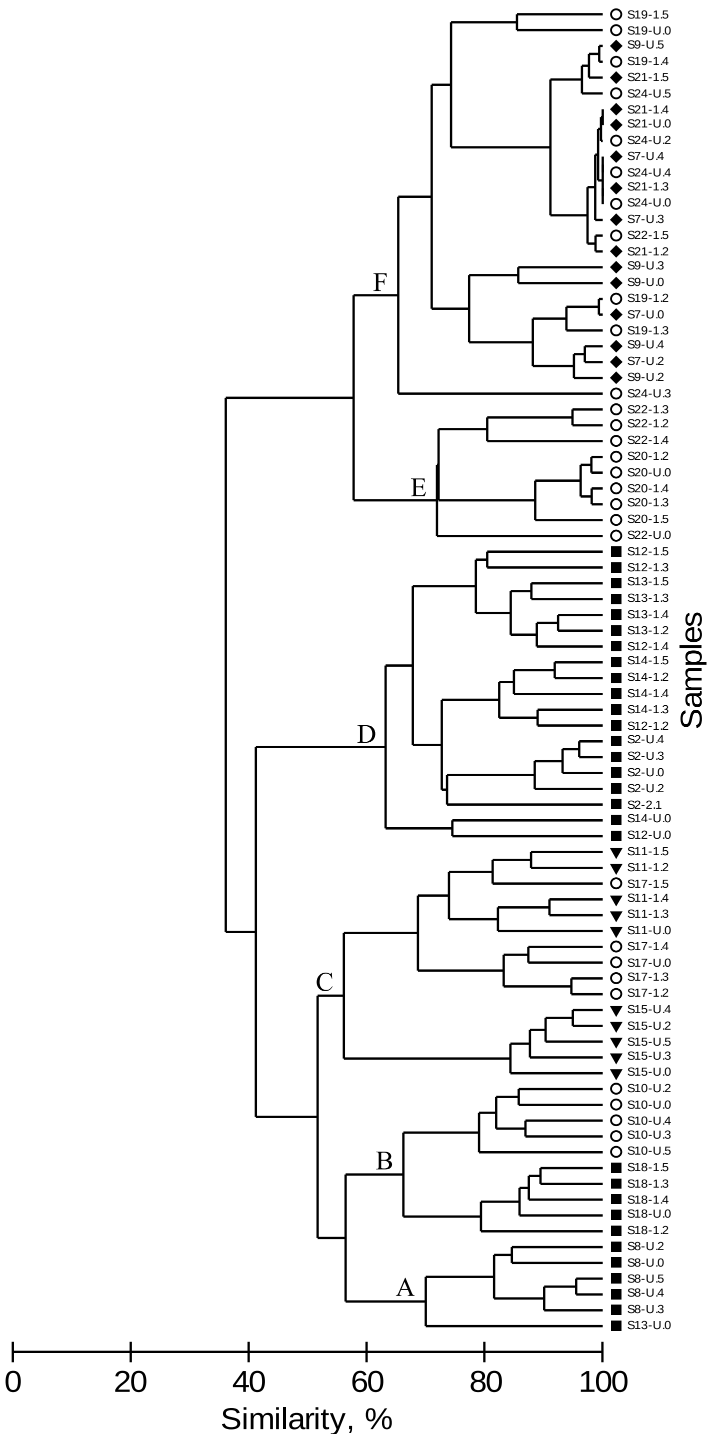

Figure 33. Santa Ysabel similarity dendrogram. The text label for each sample identifies the study site (Santa Ysabel [S]), the plot, and the fire history. Within the fire history, "U" indicates that the plot was unburned at the time of the survey; "1" indicates samples from plots burned in 2003, and "2" shows samples from plots burned in 2007. The number following the decimal represents the number of years since the most recent fire at the plots. The shape of each symbol represents the vegetation type at each plot based on the pre-fire survey results. The triangles (▼) show CSS plots, squares (■) indicate CHAP plots, diamonds (♦) are for GRASS, and circles (○) represent WR. The full sample identifier might read, for example, "○S17-U.0", indicating the vegetation transect results from the pre-fire survey at Santa Ysabel plot 17, a woodland/riparian plot.

samples from plots 20 and 22 formed a cluster based on the presence of pines at these plots (node E). However, the final sample from plot 22, collected in 2008, most closely resembled the grassland plots (node F). The two plots at Santa Ysabel that we had originally categorized as coastal sage scrub best matched an oak woodland plot (node C). Plots 15 and 11, both coastal sage scrub, shared the highest similarity with plot 17. All three had elements of coastal sage scrub in the understory with an upper canopy of oak.

Species-specific Responses

Across all study sites and vegetation types, the conglomerate group "non-native grass" was the most commonly reported "species" during the pre-fire sample and each of the four post-fire sample years. Non-native grass was reported for 43% to 55% of the points along the vegetation transects annually. The most frequently reported single species was chamise which was consistently the second ranked species, right after non-native grass. Chamise was reported to have occurred at 15% of the points along the vegetation transects during the pre-fire samples. Post-fire, chamise varied between 5% and 6% coverage along the transects. In the following section, we look more closely at these two species, as well as several other plant species that are indicators for the four vegetation types, chaparral, coastal sage scrub, grassland, and woodland/riparian.

As indicator species for chaparral habitats, we looked at the changes in the frequencies of chamise, *Ceanothus*, manzanita species, and Tecate cypress, as well as the fire follower peak rush-rose (*Helianthemum scoparium*). Frequency was measured as the number of points out of 100 along the transect where each species was detected. Looking only at the plots where chamise occurred, we saw that the average frequency of detection for this species declined sharply from the pre-fire levels. At both Little Cedar and Elliott Reserve, chamise dropped from the pre-fire high to a much lower level in each of the four post-fire years where it has remained (Figure 34, A and B). At Santa Ysabel, where three different patterns of fire history existed, we potentially saw a lower response to fire. The three plots at Santa Ysabel that burned in 2003 only saw chamise decline to approximately 50% of the pre-fire levels (Figure 34, C). The one plot at Santa Ysabel that burned in 2007 still maintained nearly 20% chamise cover after the fire.

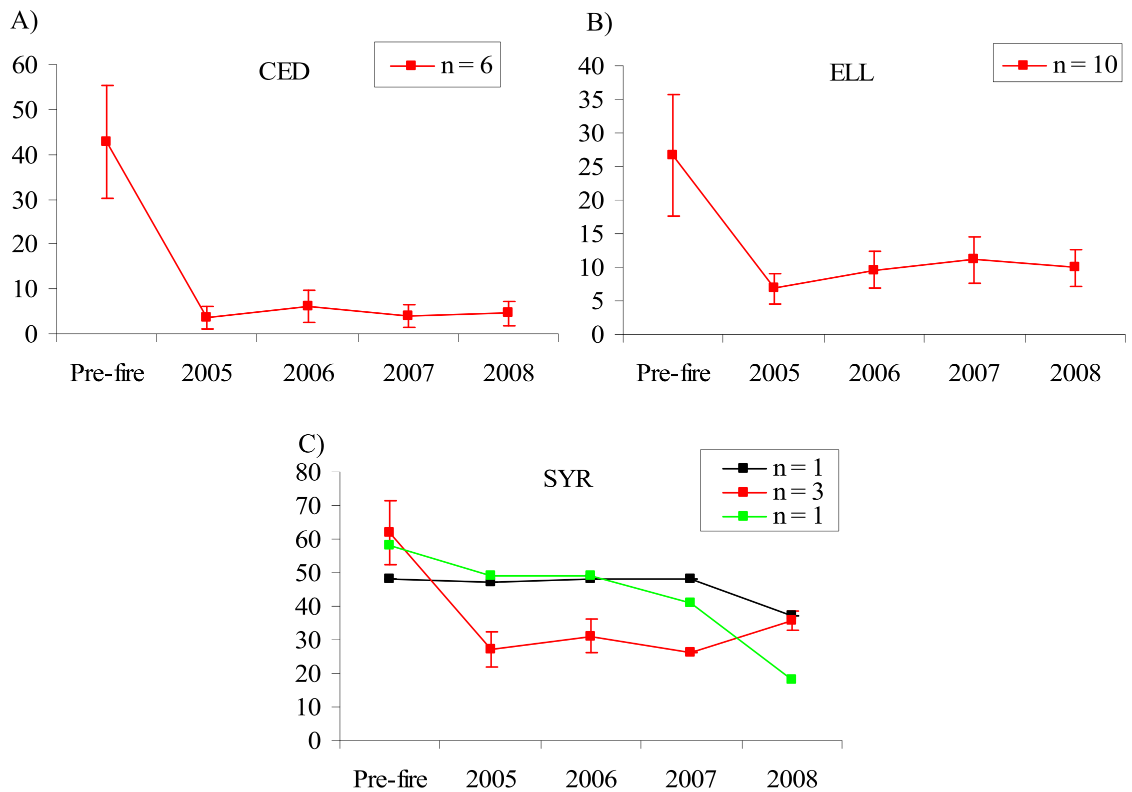

Figure 34. Chamise (*Adenostoma fasciculatum*) detection rates. In all graphs, the x-axes represent the sample year, and the y-axes indicate the average percent of the vegetation transect along which chamise was reported. The number of plots within each site and fire history pattern where chamise was reported is given as n. The values in each graph are the average number of points out of 100 per transect; error bars indicate ±SE. Black shows plots that were unburned; red indicates plots that burned in 2003; blue is for plots burned in both 2003 and 2007, and green is for plots burned in 2007 only. A) Little Cedar (CED), B) Elliot Reserve (ELL), and C) Santa Ysabel (SYR).

The frequencies with which we detected the two manzanita species were lower than those observed for chamise. Mission manzanita (*Xylococcus bicolor*) was consistently identified as a separate species, while many of the species within the genus *Arctostaphylos* were only identified to the genus level and have been combined into a single conglomerate for the purposes here. Mission manzanita was only reported for Little Cedar and Elliott Reserve, where detections in the first post-fire survey indicated a decline (Figure 35, A and B). There has been a slight upward trend in Mission manzanita over the subsequent three years of survey efforts. The *Arctostaphylos* spp. were found at Little Cedar and Santa Ysabel. The two plots at Little Cedar where *Arctostaphylos* spp. was reported showed a great deal of variability over the five samples (Figure 35, C) and may be insufficient to decipher any trends. At Santa Ysabel, where we had five plots with *Arctostaphylos* spp. that burned in 2003 and two plots that remained unburned, we saw little indication that this species was dramatically impacted by the fires (Figure 35, D).

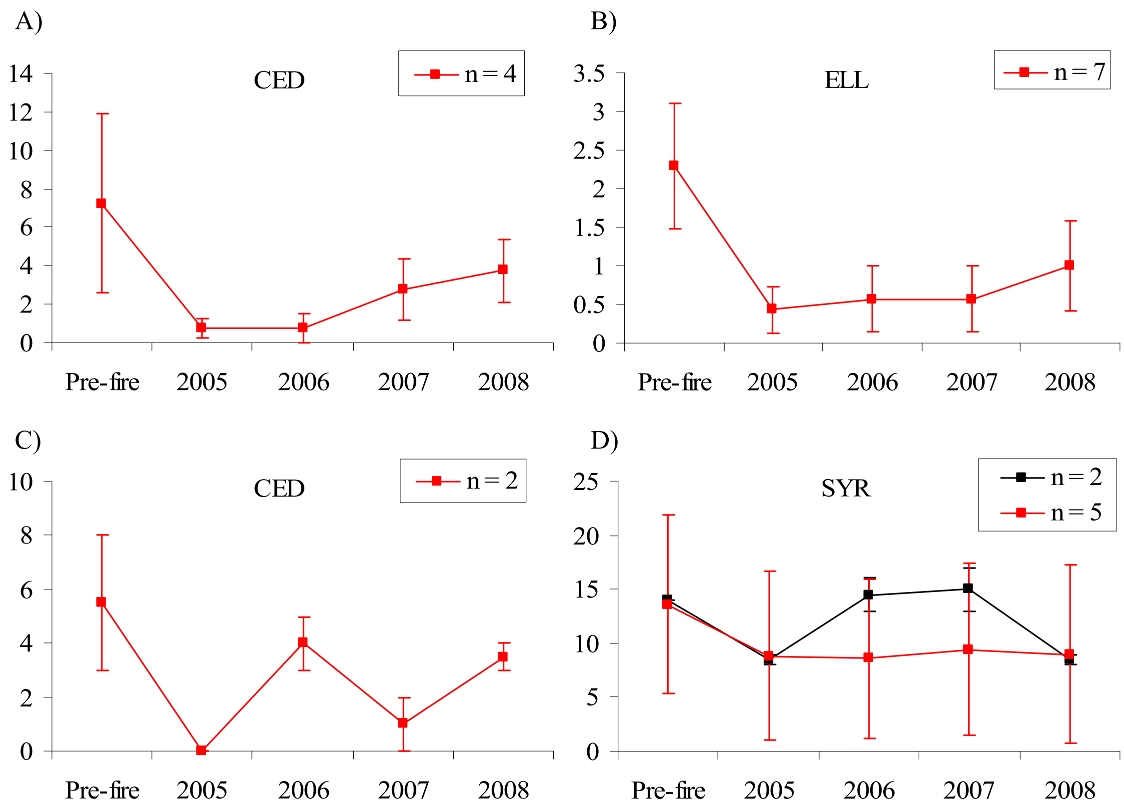

Figure 35. Mission manzanita (*Xylococcus bicolor* (XYBI)) and *Arctostaphylos* spp. (ARCTO3) detection rates. In all graphs, the x-axes represent the sample year, and the y-axes indicate the average percent of the vegetation transect along which manzanita was reported. The number of plots within each site and fire history pattern where manzanita was reported is given as n. The values in each graph are the average number of points out of 100 per transect; error bars indicate ±SE. Black shows plots that were unburned; red indicates plots that burned in 2003; blue is for plots burned in both 2003 and 2007, and green if for plots burned in 2007 only. A) XYBI at Little Cedar (CED), B) XYBI at Elliot Reserve (ELL), C) ARCTO3 at CED, and D) ARCTO3 at Santa Ysabel (SYR).

Unlike chamise and the manzanitas, we saw a slight increase in the detection frequencies of the conglomerate *Ceanothus* spp. group. At Little Cedar, *Ceanothus* spp. was reported at a total of eight plots over the course of the study (Appendix 1). At the five plots that burned only in 2003, this species increased slightly from 8.2% (SE = 3.8, n = 5) pre-fire to 15.3% (SE = 4.9, n = 5) post-fire (Figure 36, A). By 2008, *Ceanothus* spp. had dropped completely out of the three plots that burned in both 2003 and 2007. At Elliott Reserve, where *Ceanothus* spp. was not detected before the 2003 fire, we detected it at 5% (SE = 2, n = 2) of the points along the transects (Figure 36, B). Two fire history patterns occurred at Santa Ysabel, plots that did not burn and those burned in 2003. At the unburned plot at Santa Ysabel, the overall frequency of *Ceanothus* spp. decreased from the pre-fire levels and was not detected in either the 2007 or 2008 surveys (Figure 36, C). We saw a very slight increase in *Ceanothus* spp. at the four plots burned in 2003 where the species was not detected pre-fire.

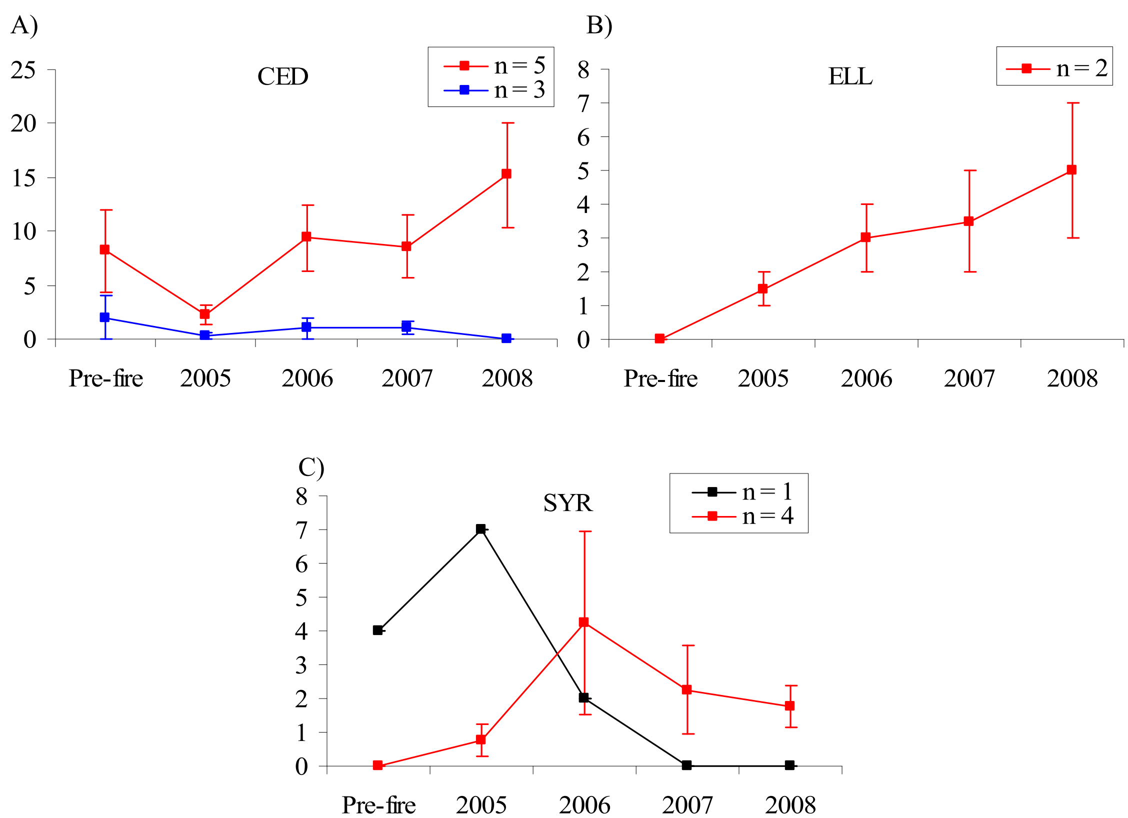

Figure 36. *Ceanothus* spp. detection rates. In all graphs, the x-axes represent the sample year, and the y-axes indicate the average percent of the vegetation transect along which chamise was reported. The number of plots within each site and fire history pattern where chamise was reported is given as n. The values in each graph are the average number of points out of 100 per transect; error bars indicate ±SE. Black shows plots that were unburned; red indicates plots that burned in 2003, and blue is for plots burned in both 2003 and 2007. A) Little Cedar (CED), B) Elliott Reserve (ELL), and C) Santa Ysabel (SYR).

Although Tecate cypress only occurred at Little Cedar, we discuss it here due to the fact that it is a major contributor to the chaparral plots at this site. Pre-fire, Tecate cypress accounted for an average 42% (SE = 16.2, n = 3) cover at Little Cedar (Figure 37). Post-fire, this species was reduced to between 8% and 13% cover at the plots burned in 2003. At the one plot that burned in both 2003 and 2007, cypress was not found pre-fire but has been detected at one point along the 2007 transect at this plot.

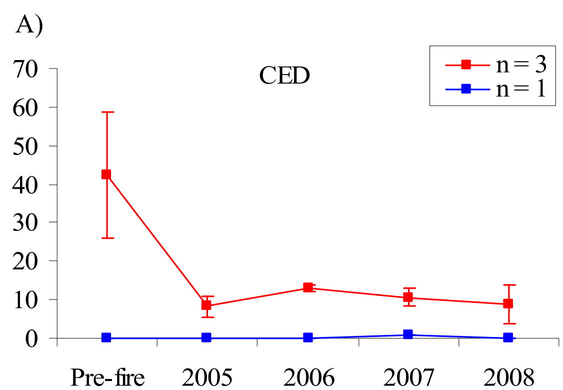

Figure 37. Tecate cypress (*Cupressus forbesii*) detection rates at Little Cedar (CED). The x-axes represent the sample year, and the y-axes indicate the average percent of the vegetation transect along which cypress was reported. The number of plots within each fire history pattern where cypress was reported is given as n in the inset. The values in each series are the average number of points out of 100 per transect; error bars indicate ±SE. Red indicates plots that burned in 2003, and blue is for plots burned in both 2003 and 2007.

As a fire follower, peak rush-rose was not detected at any of the plots pre-fire. After the 2003 fires, this species was found mainly at the chaparral plots at both Little Cedar and Elliott Reserve (Figure 38), but was also found in the burned coastal sage scrub plots at Elliott Reserve. At both sites, the frequency of detection peaked in 2006 when it accounted for an average 18% (SE = 10.6, n = 5) cover at Little Cedar and 10% (SE = 2.9, n = 8) at Elliott Reserve. There has been a slight decline in the detection of this species since 2006.

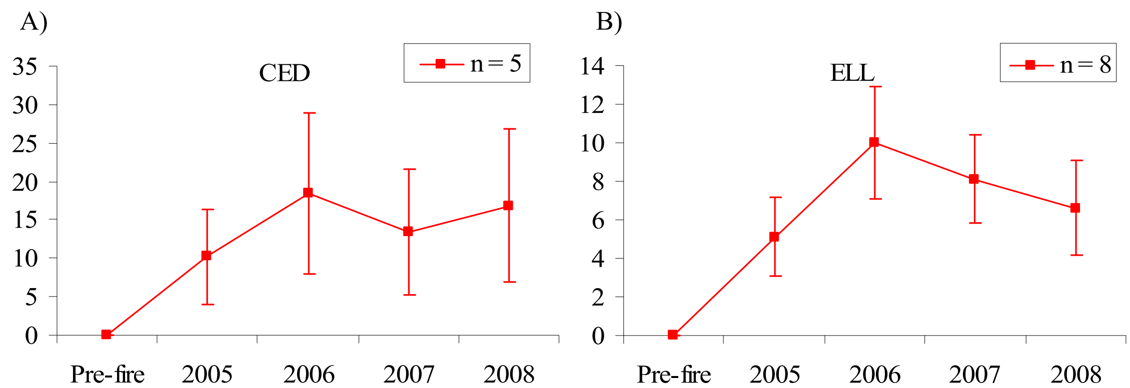

Figure 38. Peak rush-rose (*Helianthemum scoparium*) detection rates. In both graphs, the x-axes represent the sample year, and the y-axes indicate the average percent of the vegetation transect along which peak rush-rose was reported. The number of plots within each site and fire history pattern where peak rush-rose was reported is given as n in the inset. The values in each graph are the average number of points out of 100 per transect; error bars indicate ±SE. Red indicates plots that burned in 2003. A) Little Cedar (CED) and B) Elliott Reserve (ELL).

As indicator species for coastal sage scrub environments, we looked at the changes in the frequencies of California sagebrush, California buckwheat, deerweed, laurel sumac, sage, and San Diego sunflower. California sagebrush appears to have fared poorly in the path of the wildfires. Within the three plots at Little Cedar that burned twice, where this species averaged 26% (SE = 3.8, n = 3) cover pre-fire, it has nearly disappeared during the post-fire surveys (Figure 39, A). Even within the plot that only burned in 2003, California sagebrush cover remained low. At Elliott Reserve, this species was comparatively rare pre-fire and has not been detected post-fire. At Rancho Jamul, California sagebrush averaged 15% (SE = 5.3, n = 8) cover pre-fire among the plots that burned twice and has never accounted for more that 1% cover post-fire (Figure 39, C). Cover has remained fairly constant at the unburned plots at Rancho Jamul. Only one unburned plot at Santa Ysabel contained California sagebrush where the percent of the transect containing this species has ranged between 5% and 13% (Figure 39, D).

As seen above for California sagebrush, California buckwheat was heavily impacted by the wildfires. Across all four sites, California buckwheat dropped precipitously among many of the plots that burned (Figure 40). At Little Cedar, Elliott Reserve, and Rancho Jamul, the average cover of this species has declined to nearly zero and remained low throughout the duration of the sampling. At Santa Ysabel however, California buckwheat declined at all plots in 2005 whether the plot burned or not. Additional factors may be involved in the response of this species at Santa Ysabel.

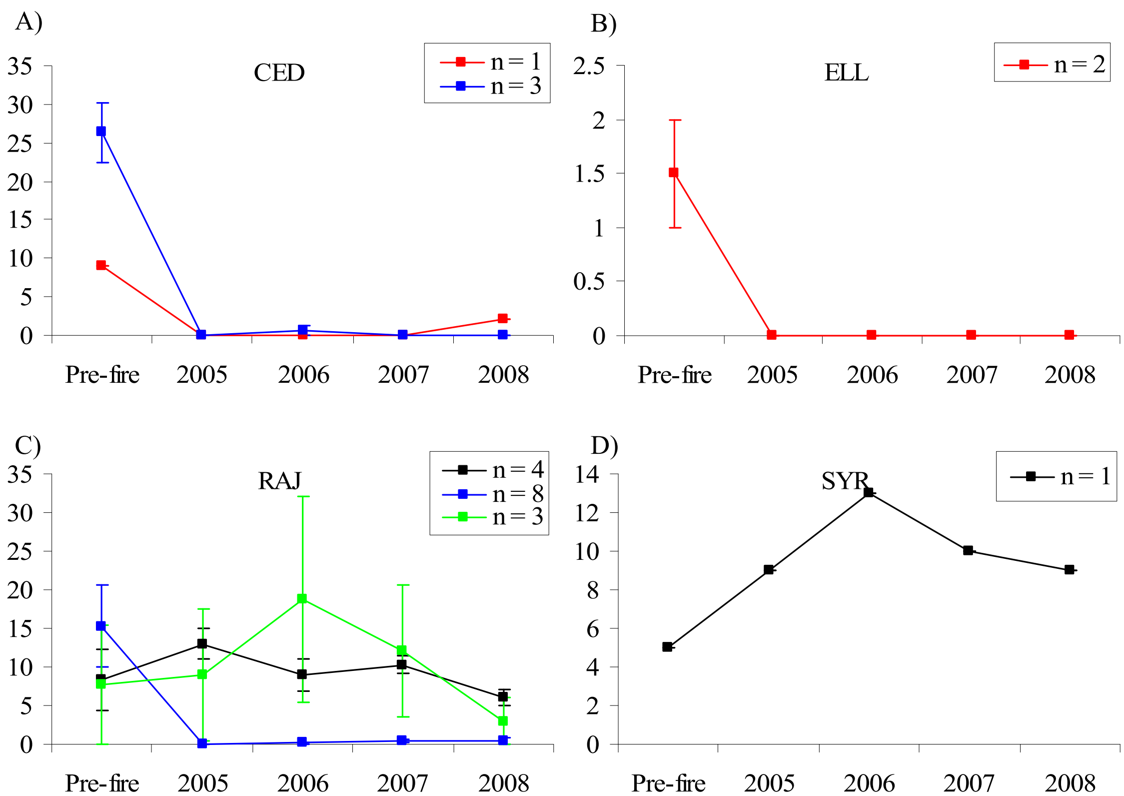

Figure 39. California sagebrush (*Artemisia californica*) detection rates. In all graphs, the x-axes represent the sample year, and the y-axes indicate the average percent of the vegetation transect along which sagebrush was reported. The number of plots within each site and fire history pattern where sage brush was reported is given as n in the inset. The values in each graph are the average number of points out of 100 per transect; error bars indicate ±SE. Black shows plots that were unburned; red indicates plots that burned in 2003; blue is for plots burned in both 2003 and 2007, and green is for plots burned in 2007 only. A) Little Cedar (CED), B) Elliott Reserve (ELL), C) Rancho Jamul (RAJ), and D) Santa Ysabel (SYR).

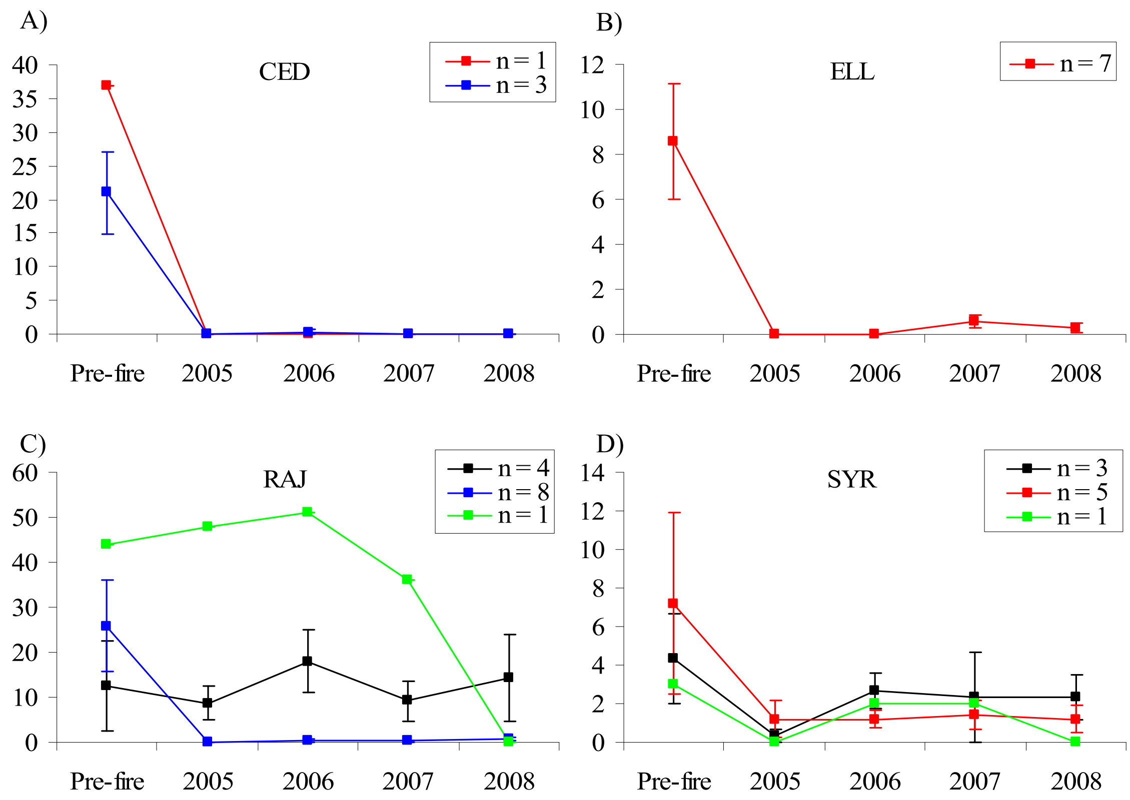

Figure 40. California buckwheat (*Eriogonum fasciculatum*) detection rates. In all graphs, the x-axes represent the sample year, and the y-axes indicate the average percent of the vegetation transect along which buckwheat was reported. The number of plots within each site and fire history pattern where buckwheat was reported is given as n in the inset. The values in each graph are the average number of points out of 100 per transect; error bars indicate ±SE. Black shows plots that were unburned; red indicates plots that burned in 2003; blue is for plots burned in both 2003 and 2007, and green is for plots burned in 2007 only. A) Little Cedar (CED), B) Elliott Reserve (ELL), C) Rancho Jamul (RAJ), and D) Santa Ysabel (SYR).

In general, the average frequency of deerweed increasd after the fires. At Little Cedar, Rancho Jamul, and Santa Ysabel, the average frequency of deerweed climbed from the rates that we measured pre-fire, but seem to be on the decline over the later portion of our efforts (Figure 41, A, B, and D; Appendix 1). At Elliott Reserve, the average cover of deerweed across all ten sample plots did not appear to increase in the first post-fire sample but has gradually increased each year after that. This apparent delay in response may be linked to the level of isolation of Elliott Reserve from adjacent unburned environments.

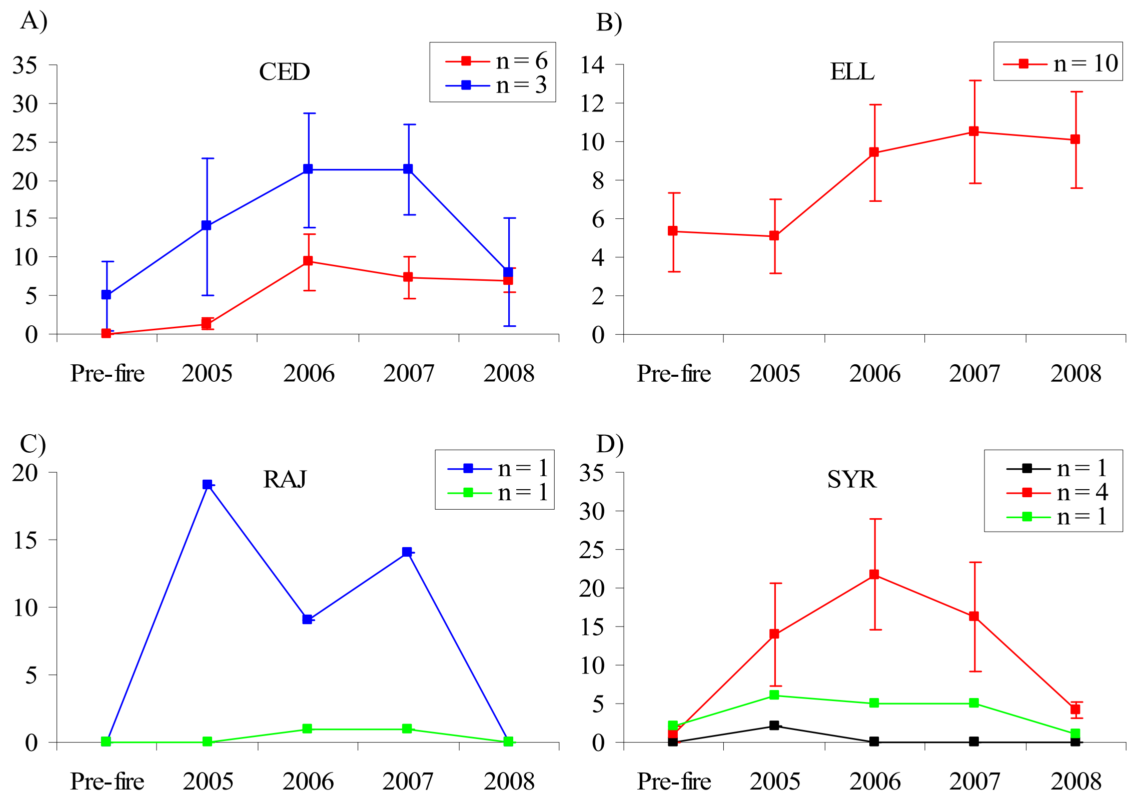

Figure 41. Deerweed (*Lotus scoparius*) detection rates. In all graphs, the x-axes represent the sample year, and the y-axes indicate the average percent of the vegetation transect along which deerweed was reported. The number of plots within each site and fire history pattern where deerweed was reported is given as n in the inset. The values in each graph are the average number of points out of 100 per transect; error bars indicate ±SE. Black shows plots that were unburned; red indicates plots that burned in 2003; blue is for plots burned in both 2003 and 2007, and green is for plots burned in 2007 only. A) Little Cedar (CED), B) Elliott Reserve (ELL), C) Rancho Jamul (RAJ), and D) Santa Ysabel (SYR).

The most dramatic response that we detected for laurel sumac was at the single plot at Rancho Jamul that burned in 2007. Across the four unburned samples at this plot, laurel sumac averaged between 20% and 30% cover each year. After the 2007 fire at this plot, the coverage dropped to 1% (Figure 42, C). Among the other plots, where the pre-fire coverage of laurel sumac was not nearly as high, we saw less of a decline, and sumac levels appear to have remained within the range of variability measured during the pre-fire sample.

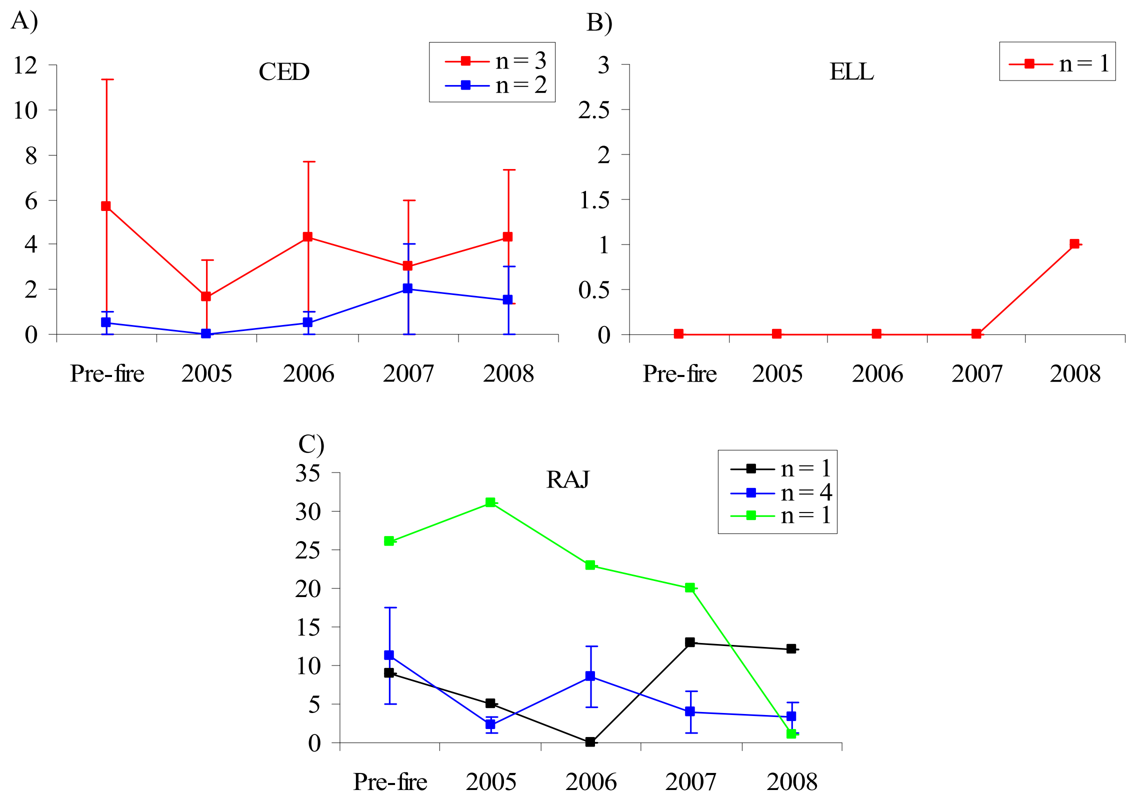

Figure 42. Laurel sumac (*Malosma laurina*) detection rates. In all graphs, the x-axes represent the sample year, and the y-axes indicate the average percent of the vegetation transect along which Laurel sumac was reported. The number of plots within each site and fire history pattern where Laurel sumac was reported is given as n in the inset. The values in each graph are the average number of points out of 100 per transect; error bars indicate ±SE. Black shows plots that were unburned; red indicates plots that burned in 2003; blue is for plots burned in both 2003 and 2007, and green is for plots burned in 2007 only. A) Little Cedar (CED), B) Elliott Reserve (ELL), and C) Rancho Jamul (RAJ).

We saw mixed patterns of response for the conglomerate species group of sage plants (*Salvia* spp.). At Little Cedar and Elliott Reserve, we measured a decline in sage, dropping from 11% (SE = 0, n = 2) and 2% (n = 1), respectively, to 0% among the plots that burned in 2003 only (Figure 43, A and B). At Santa Ysabel, within the five plots that burned in 2003, there seems to have been no change in the frequency of sage across the years. The only apparent change in sage cover at Santa Ysabel was within the one plot that burned in 2007 where the percent of sage cover declined from the pre-fire range of 10% to 12% down to 0% in 2008.

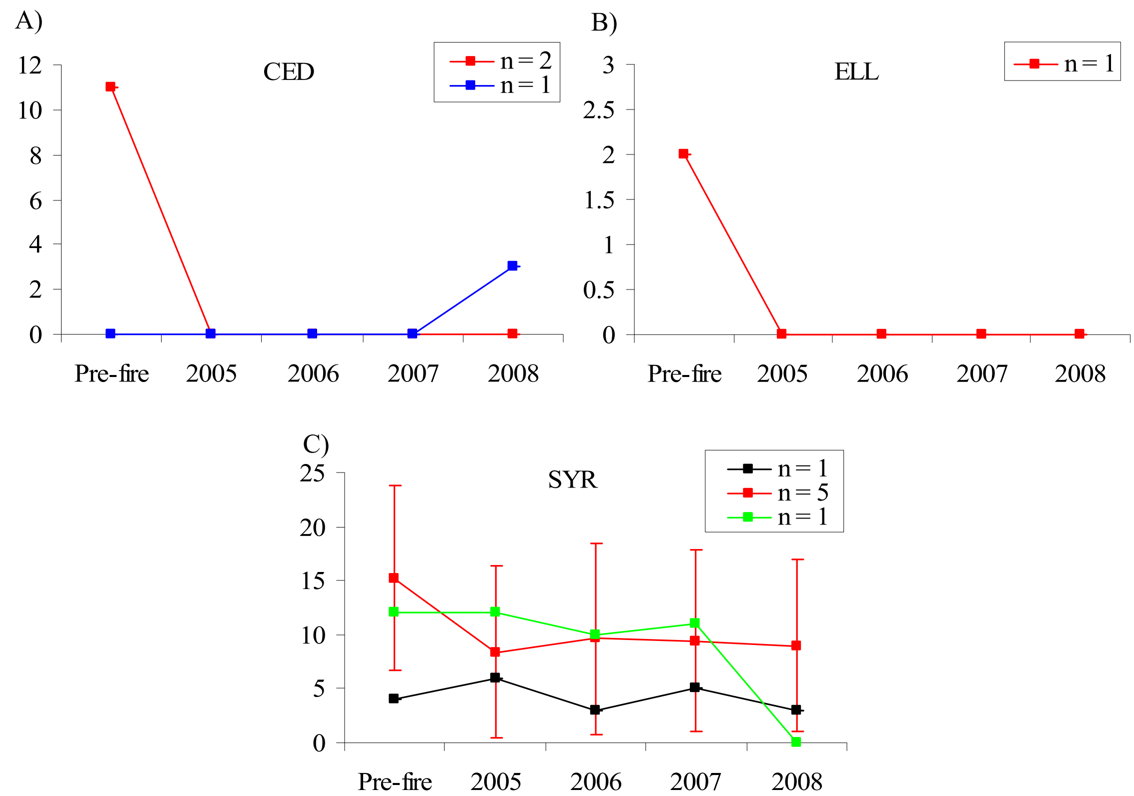

Figure 43. Sage (*Salvia* spp.) detection rates. In all graphs, the x-axes represent the sample year, and the y-axes indicate the average percent of the vegetation transect along which sage was reported. The number of plots within each site and fire history pattern where sage was reported is given as n in the inset. The values in each graph are the average number of points out of 100 per transect; error bars indicate ±SE. Black shows plots that were unburned; red indicates plots that burned in 2003; blue is for plots burned in both 2003 and 2007, and green is for plots burned in 2007 only. A) Little Cedar (CED), B) Elliott Reserve (ELL), and C) Santa Ysabel (SYR).

We only detected the San Diego sunflower at Little Cedar and Rancho Jamul over the entire length of our efforts. At both sites, the average cover of this species declined within plots that burned (Figure 44). Across the plots that either burned once or twice, the San Diego sunflower declined to nearly zero detections along each survey transect and has remained consistently low. Within the two plots that remained unburned for the duration of our efforts, the average cover represented by the San Diego sunflower remained at nearly 30% each year data were collected.

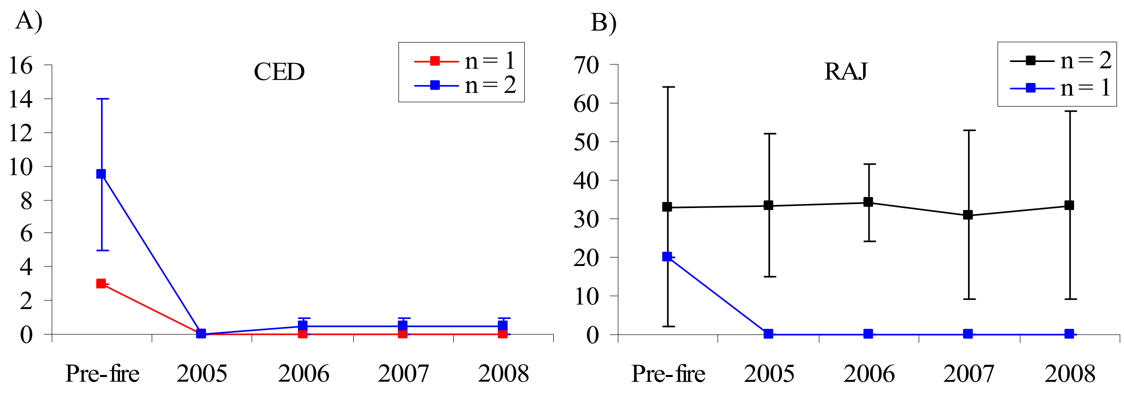

Figure 44. San Diego sunflower (*Viguiera laciniata*) detection rates. In all graphs, the x-axes represent the sample year, and the y-axes indicate the average percent of the vegetation transect along which the San Diego sunflower was reported. The number of plots within each site and fire history pattern where the San Diego sunflower was reported is given as n in the inset. The values in each graph are the average number of points out of 100 per transect; error bars indicate ±SE. Black shows plots that were unburned; red indicates plots that burned in 2003, and blue is for plots burned in both 2003 and 2007. A) Little Cedar (CED) and B) Rancho Jamul (RAJ).

As previously noted, the many exotic grass species were combined into a single category, "non-native grass". The average coverage of non-native grasses as a composite group has most likely been unchanged at Little Cedar, Rancho Jamul, and Santa Ysabel (Figure 45, A, C, and D). At these three sites, the annual average cover of non-native grass has been consistent with the pre-fire range of variability. Elliott Reserve was the exception to the pattern. At Elliott Reserve, the data indicate that there was a downward trend in the frequency of non-native grass, declining from the pre-fire average of 62% (SE = 4.4, n = 10) down to the lowest post-fire rate of 19% (SE = 3.4, n = 10) in 2007 (Figure 45, C).

With the exception of the three plots at Rancho Jamul that burned in both 2003 and 2007, native needlegrass (*Nassella* spp.) represented only a small portion of the average annual cover at the study plots. Native needlegrasses were reported at 34% (SE = 17.5, n = 3) of the transect points at the three repeat-burn plots at Rancho Jamul before any fire impacts (Figure 46, C). After the second fire at these plots in 2007, the 2008 average cover for native needlegrasses was only 9% (SE = 7.9, n = 3). At Little Cedar and Elliott Reserve, native needlegrass cover reached a maximum in 2006 and has declined during the two subsequent years of sampling (Figure 45, A and B). The percent of native needlegrass cover at Santa Ysabel has not differed much from the pre-fire levels (Figure 46, D).

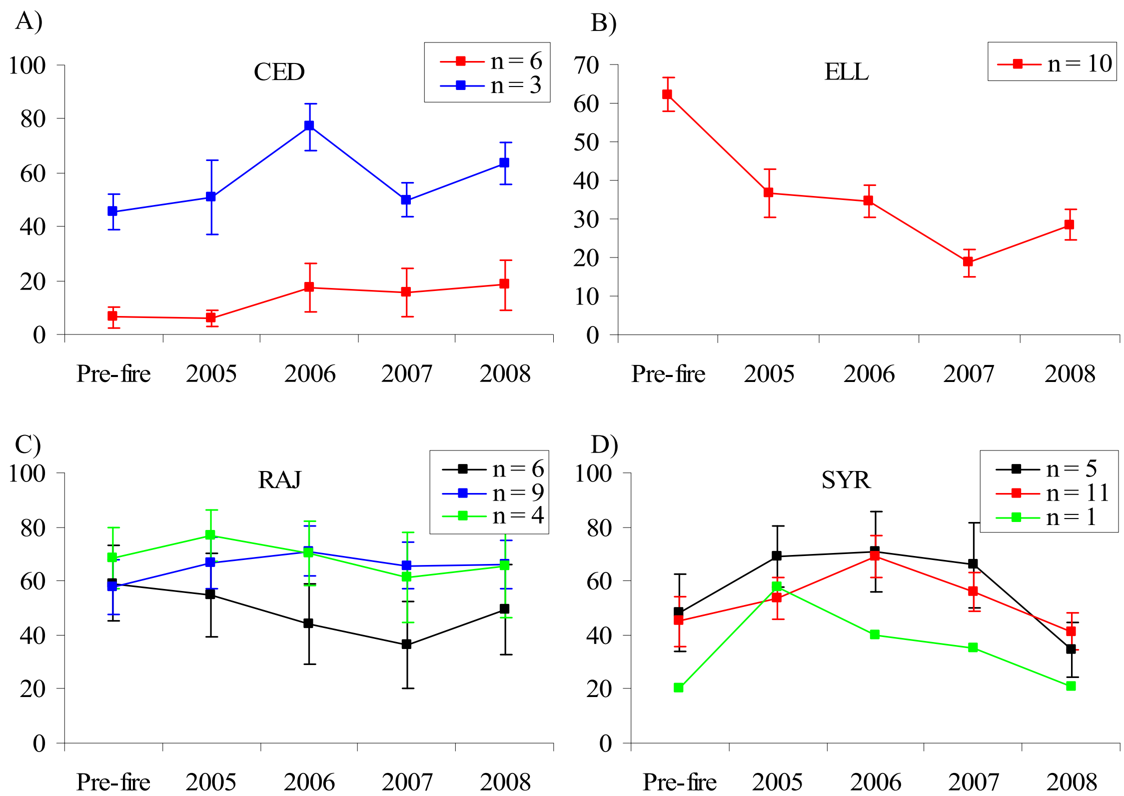

Figure 45. Non-native grass detection rates. In all graphs, the x-axes represent the sample year, and the y-axes indicate the average percent of the vegetation transect along which non-native grass was reported. The number of plots within each site and fire history pattern where non-native grass was reported is given as n in the inset. The values in each graph are the average number of points out of 100 per transect; error bars indicate ±SE. Black shows plots that were unburned; red indicates plots that burned in 2003; blue is for plots burned in both 2003 and 2007, and green is for plots burned in 2007 only. A) Little Cedar (CED), B) Elliott Reserve (ELL), C) Rancho Jamul (RAJ), and D) Santa Ysabel (SYR).

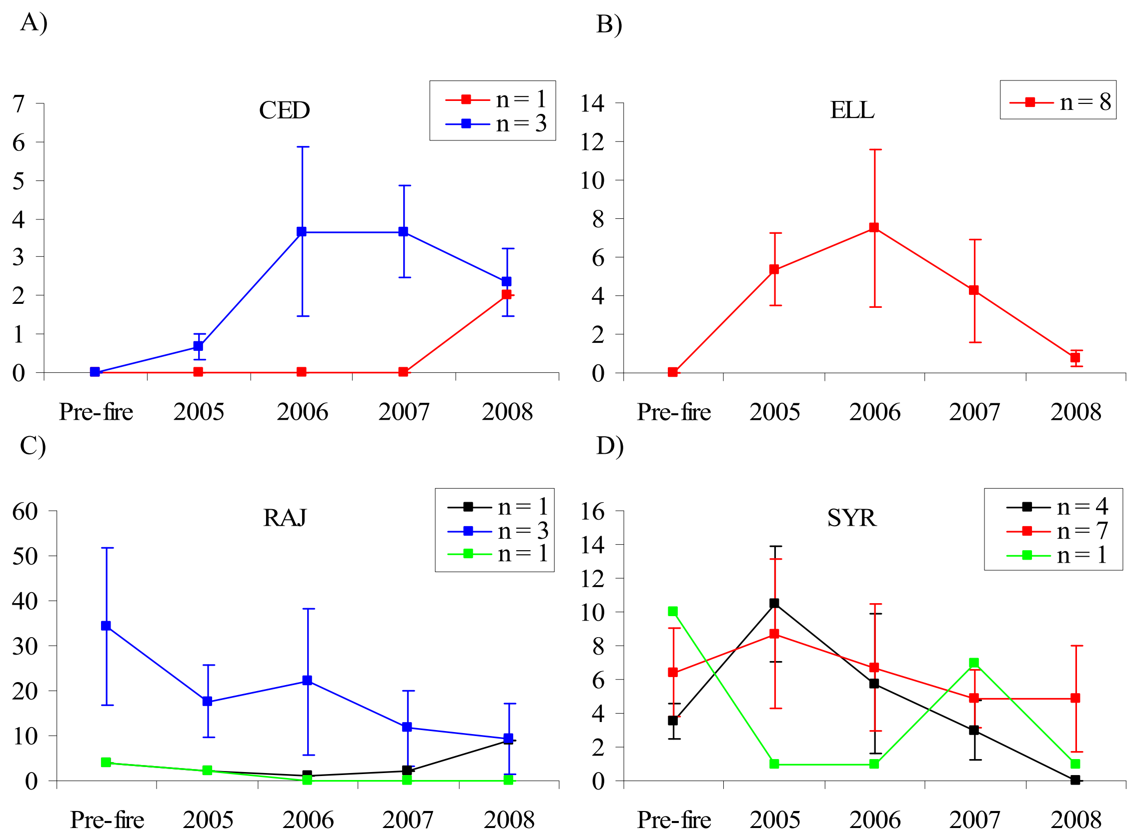

Figure 46. Native needlegrass (*Nassella* spp.) detection rates. In all graphs, the x-axes represent the sample year, and the y-axes indicate the average percent of the vegetation transect along which native needlegrass was reported. The number of plots within each site and fire history pattern where native needlegrass was reported is given as n in the inset. The values in each graph are the average number of points out of 100 per transect; error bars indicate ±SE. Black shows plots that were unburned; red indicates plots that burned in 2003; blue is for plots burned in both 2003 and 2007, and green is for plots burned in 2007 only. A) Little Cedar (CED), B) Elliott Reserve (ELL), C) Rancho Jamul (RAJ), and D) Santa Ysabel (SYR).

We looked at two species groups representing the woodland and riparian plots, oaks and pines. Oaks only occurred at two plots at Elliott Reserve where they averaged a pre-fire cover rate of 8% (SE = 3, n = 2) (Figure 47, A). The lowest measured rate of cover for oaks at Elliott Reserve was in 2008 when the average was 2% (SE = 0, n = 2). Only one plot at Rancho Jamul had any oak coverage which ranged between 70% and 80% for the duration of the study (Figure 46, B). At Santa Ysabel, three plots with oaks remained unburned, and six burned in 2003. Across both fire history patterns, oak coverage remained in the 15% to 20% range across all five sample years (Figure 46, C). Pines only occurred on two of our study plots; both were at Santa Ysabel. On these two plots, the pre-fire average cover was 49% (SE = 15, n = 2) (Figure 47, D). In the first post-fire sample year, pines still accounted for 29% (SE = 9, n = 2) of the cover at these plots. Gradually, the burned pines died completely or toppled over resulting in a final 1.5% (SE = 1.5, n = 2) pine cover.

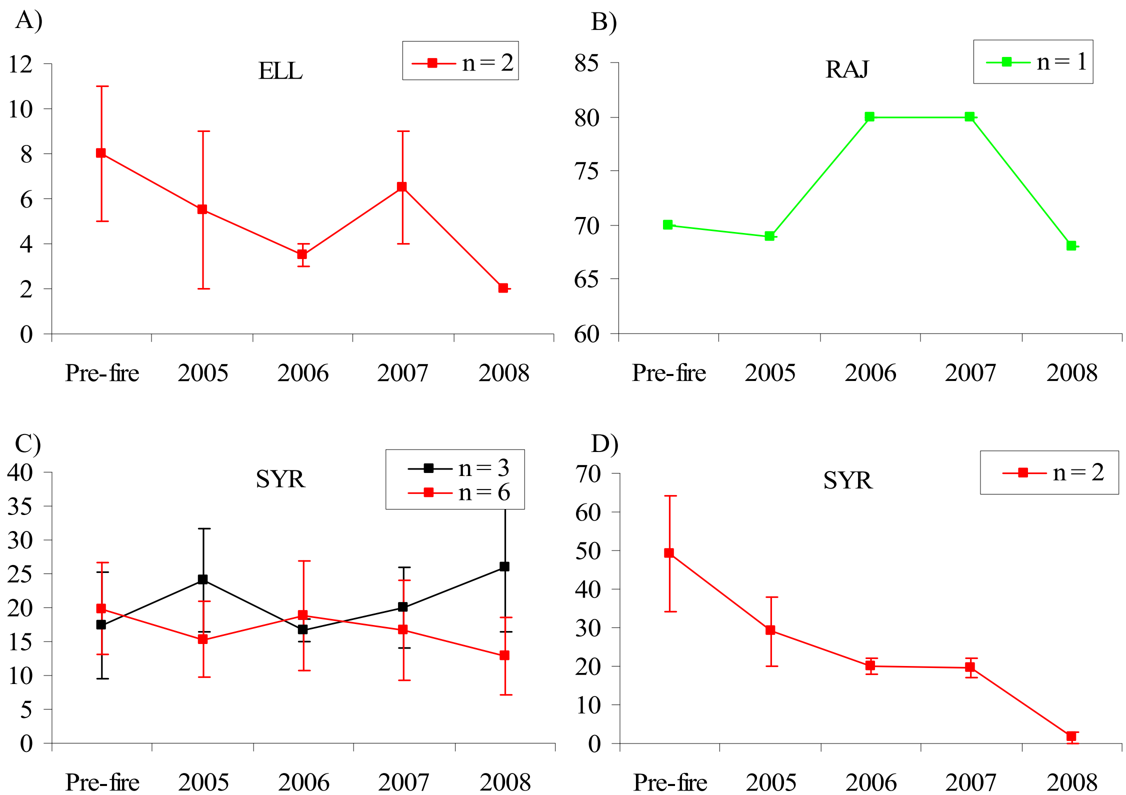

Figure 47. Oak (*Quercus* spp.) and pine (*Pinus* spp.) detection rates. In all graphs, the x-axes represent the sample year, and the y-axes indicate the average percent of the vegetation transect along which oaks or pines were reported. The number of plots within each site and fire history pattern where oaks or pines were reported is given as n in the inset. The values in each graph are the average number of points out of 100 per transect; error bars indicate ±SE. Black shows plots that were unburned; red indicates plots that burned in 2003, and green is for plots burned in 2007 only. Oak detection rates at A) Elliott Reserve (ELL), B) Rancho Jamul (RAJ), and C) Santa Ysabel (SYR); and D) pine detection rates at SYR.

Discussion

Vegetation Structure Response to Fire

Based on the pre-fire vegetation surveys conducted at each plot, along with the four years of post-fire samples, the vegetation structure, as measured as the percent of shrub and tree coverage, was most changed in the two shrubland classifications chaparral and coastal sage scrub. With the exception of the plots at Santa Ysabel, shrub and tree cover declined across most of our study plots in these two vegetation types, dropping from pre-fire highs of 60% to 80% (Figure 10, Figure 12, and Figure 13) down to nearly 0% in the most dramatic instances. The most severe loss of structure was within the coastal sage scrub plots at Rancho Jamul. Within plots 7, 11, and 21, the loss of cover occurred following the 2003 fires. Plot 19 at Rancho Jamul was able to maintain nearly 50% of the pre-fire cover until the plot burned again in 2007 (Appendix 1). Afterward, shrub and tree cover dwindled to the same levels as measured at plots 7, 11, and 21.

Drawing from the results for the individual species, the loss of shrub and tree cover in our coastal sage scrub plots may have been heavily dependent upon the decline of California buckwheat and California sagebrush. While California sagebrush maintained a relatively constant level of cover at the unburned plots, the burned plots experienced a different pattern (Figure 39). The highest levels of California sagebrush cover that we measured were at plot 19 and 36 at Rancho Jamul. The pre-fire sample from plot 19 contained 38% California sagebrush, and our 2006 sample from plot 36 had California sagebrush at 45% of the transect points. The highest post-fire level of sagebrush was at plot 6 at Rancho Jamul in the 2008 sample when sagebrush covered 9% of the transect. In many cases, California sagebrush was completely absent from the post-fire samples. Despite the dramatic decline, there has been some minor recovery for this species, but only very minor. Much of what has been stated for California sagebrush also applies to California buckwheat. Both of these species have been reported previously to re-sprout from the seed bank following fire. Zedler et al. (1983) reported seedlings of both species following a fire in 1979 in the canyons adjacent to Little Cedar, but reported that California buckwheat seedlings were much less abundant than California sagebrush seedlings. Zedler et al. (1983) indicated that the cover of California sagebrush may have increased following the first fire at their study site due to the high level of seedling emergence. Our results for California sagebrush seem to be inconsistent with Zedler et al. (1983); we saw little recovery of this species even out to the fourth post-fire year.

Within the chaparral plots, the loss of shrub and tree cover could be attributed to the initial declines detected in chamise but potentially has been mitigated by the increases found in ceanothus and peak rush-rose and the re-sprouting of chamise. While chamise cover dropped precipitously at most of our burned study plots, the species has been steadily recovering as would be expected. Chamise typically re-sprouts from the burned stumps following fire events. However, at the Little Cedar plots where chamise occurred alongside Tecate cypress, the chamise has not re-grown, either from basal sprouting or seed germination. Perhaps the fire levels in these areas were sufficient to not only top kill the chamise but also powerful enough to compromise the below ground reserves. At these Little Cedar plots the pre-fire chamise has been replaced by *Ceanothus*.

At Little Cedar and Elliott Reserve, shrub and tree cover within chaparral and coastal sage scrub plots appears to be making a gradual recovery, slowly climbing towards the pre-fire levels. The exceptional note would be the plots at Little Cedar that burned twice. The level of shrub and tree cover was increasing within these three plots until the 2008 samples which were collected the year after the 2007 Harris Fire (Figure 10). Shrub and tree cover had shown little evidence of recovery at Rancho Jamul (Figure 13). For the chaparral and coastal sage scrub vegetation communities, post-fire recovery can take several years and is likely dependent upon fire return intervals and precipitation patterns (Keeley and Keeley 1981).

Within the plots that we identified as woodland/riparian environments, only those with pines have shown a decline in shrub and tree cover. At Santa Ysabel plots 20 and 22, the gradual decline in the percent of the plots covered by pines may be at a turning point. While the large adults that made up much of the pre-fire canopy have died and subsequently toppled over, seedlings have started to appear in the landscape. At the times of our surveys, the pine seedlings were still relatively small and only contributed to a small portion of the total cover. Several more years of growth will be required before these seedlings provide the level of structure provided by the previous generation.

Those plots dominated by grass and oaks changed little with respect to shrub and tree cover. The grassland plots had only low levels of cover to begin with and do not appear to have changed in response to the fires. Many of the oaks that burned during these fires survived and continue to provide similar levels of cover as measured pre-fire.

Shrub and Tree Species Richness

We saw mixed results for our index of shrub and tree species richness. In chaparral plots, we measured a slight increase at Little Cedar and Elliott Reserve, but detected no change at Santa Ysabel which already had the highest average level of species richness for this vegetation type (Figure 14, Figure 15, and Figure 17). Coastal sage scrub study plots that burned twice appear to have been more heavily impacted than those only burned one time. At both Little Cedar and Rancho Jamul, the plots burned in both years lost species richness when compared to the plots only burned in 2003 or 2007 (Figure 14 and Figure 16). Those plots only burned once tended to retain species richness levels similar to that measured in the pre-fire samples (Figure 14 and Figure 16). The response of the coastal sage plots at Santa Ysabel may be harder to interpret; there was only one plot that burned, and one that remained unburned (Figure 17).

Again, our survey efforts detected relatively little change in the grassland and woodland/riparian plots with regards to this variable. Shrub and tree species richness was already predictably low in the grasslands (Figure 16 and Figure 17). Woodland/riparian plots generally were dominated by just a few species of shrubs and trees pre-fire which continued to be the case in the post-fire samples.

Canopy Height

While canopy height tended to decrease in most instances, the greatest decline that we measured occurred in the pine plots at Santa Ysabel. At plots 20 and 22 at Santa Ysabel, the pre-fire average canopy heights were over 4- and 6-m, respectively (Figure 21). By the 2008 sample, these had withered down to only 0.28- and 0.18-m, respectively. As mentioned above, there is potential that as the seedling pines mature over the next couple of years, canopy height will increase.

In the shrublands, we saw three patterns of response in the measured canopy height, an immediate decline, a gradual decline, and no response. Our results indicated that there was an immediate decline in the canopy height in the chaparral plots at Little Cedar and Elliott Reserve. In both of these, the 2005 samples were substantially lower than the pre-fire levels and have remained lower or dipped even further below the pre-fire averages (Figure 18 and Figure 19). Gradual loss of canopy height was seen in the results for chaparral and woodland/riparian plots at Santa Ysabel (Figure 21) and in coastal sage scrub at Little Cedar, Elliott Reserve, and Rancho Jamul. As of the 2008 samples, there did not appear to be any substantial recovery in canopy height in those conditions where it was lost. No change in average canopy height was detected in the woodland/riparian plots at Rancho Jamul. The average canopy height in the grassland plots at Rancho Jamul and Santa Ysabel fluctuated up and down but may be inaccurate due to the nature of the annual growing pattern of grasses, tall in early spring through summer and then dead and slumped over in fall.

Substrate Frequencies

Although the substrate type leaf litter was the most frequently observed result, we focused on the results for sandy soil. Reviewing the results as a whole, it appeared that there were complications with the substrate category leaf litter. As per the protocol, leaf litter could refer to fallen leaves and other loose materials or it may have indicated dead, matted grass materials. In many instances, the pre-fire leaf litter was indeed fallen leaves which were consumed in the fires. Post-fire, much of the reported leaf litter was dead matted grasses. As a result, there was often little change in the frequency or depth of leaf litter as a substrate category. In some cases, based on our protocol, the frequency and depth of leaf litter increased following the fire contrary to what we had expected to see in the results.

Sandy soil was more consistently collected and had little potential to be confounded with other substrate types. Sandy soil indicated that no other substrate type was present and served as a measure of bare ground. Due to the increased evaporation associated with exposed soils and the reduced ability of water to penetrate such, burned plots have significantly lower soil moisture levels than unburned sites (Christensen and Muller 1975). As Heisler et al. (2004) found, the loss of above ground vegetation may result in increased soil surface temperatures at burned plots. The loss of soil moisture, surface cover, and near-soil surface structure, combined with increased surface temperatures, has likely made the habitat unsuitable for certain species of plants and animals while at the same time making it more suitable for others.

Vegetation Community Similarities

Using the similarity dendrograms to look at the levels of community similarity within samples, we saw how the vegetation at the plots within a study site compared to each other and how these similarities may have shifted following the fires. At Little Cedar the post-fire samples tended to be most closely matched to the pre-fire sample from the same group of plots (Figure 30). For example, all eight post-fire samples from plots 7 and 8 were most like each other at a shared similarity of 58%. This cluster of burned samples was then most similar to the pre-fire samples at the same plots at a shared similarity of 42%. Reviewing the data indicates that the separation of the post-fire samples from the pre-fire results was largely based on the presence of peak rush-rose and deerweed after the fire (neither species was found during the initial transect surveys) and the decline of chamise pre-fire to post-fire. While all samples from plots 7 and 8 fell within the same node of the dendrogram, there was still a potential difference between the pre-fire and post-fire communities. A similar pattern of separation between the pre-fire and post-fire samples appeared in the results for plots 1 and 2, except that in this case the division appears to be driven by the decline in chamise, Tecate cypress, and *Salvia* spp. and an increase in *Ceanothus* spp., deerweed, and non-native grass. The most notable shift in vegetation community at Little Cedar was observed at plot 4 (Figure 30). The first samples after each fire at plot 4, samples C4-1.2 and C4-2.1, were most similar to the non-native grass samples from Rancho Jamul. The samples from the third and fourth years after the 2003 fires were grouped with burned coastal sage scrub node (node D) so it may be possible that the vegetation at plot 4 will recover again, moving away from the high shared similarity with grassland samples.

One of our plots at the Elliott Reserve (plot 10) also seems to have shifted away from a coastal sage scrub shrubland towards a grassland community. All of the post-fire samples from plot 10 grouped within the grassland node of the dendrogram (Figure 31, node B). The amount of cover of non-native grass accounted for 73% of the within node similarity. The lack of California buckwheat in the post-fire samples from plot 10 helped to differentiate these from the pre-fire sample. The lack of peak rush-rose in the post-fire samples from plot 10 separated them from the rest of the samples from the other burned shrubland plots. The fire follower, peak rush-rose, was also the main contributor in the differences between the burned chaparral and coastal sage samples (node F; average abundance = 10.1%, SE = 1.3) and the unburned samples of each vegetation type (nodes D and E; 0% in both).

We saw the greatest shifts in community similarity between samples at Rancho Jamul. The similarity levels of several samples moved away from shrublands to become more like the grassland plots. The post-fire samples from burned coastal sage scrub (plots 7, 11, 19, and 21) were most like the grassland samples. The vegetation at plot 11 has most likely been detrimentally altered for the long term. The post-fire samples from this plot are deeply imbedded in the grassland node (Figure 32, node E). The short return interval between the 2003 and 2007 fires have rendered these former shrublands nearly devoid of any shrub and tree cover. Only plot 7 has shown any indication of recovering towards the pre-fire, unburned state. It may be interesting to follow what happens at plot 2 over the next several years. The non-USGS efforts at this plot to remove non-native grass has resulted in this plot being unlike any other samples that we have collected during our fire related efforts in San Diego County. Within the unburned coastal sage scrub cluster of the dendrogram (Figure 32, node B) there was potentially one further division, samples with San Diego sunflowers and those without. All of the samples from plots 10 and 35 together with the pre-fire sample from plot 19 contained samples of the San Diego sunflower. The remainder of the samples from unburned coastal sage scrub at Rancho Jamul did not contain this species. San Diego sunflower was absent from all post-fire samples at plot 19 which helps to explain the removal of these samples from the unburned coastal sage scrub cluster.

The only notable change in vegetation community at Santa Ysabel was within one of the plots originally classified as woodland/riparian, more specifically a pine woodland. The pre-fire sample and the majority of the post-fire samples from plot 22 placed it within a group consisting entirely of samples characterized by the presence of pines (Figure 31, node E). The results from the fifth post-fire year indicate that plot 22 was no longer a pine forest but had become more similar to samples collected at grassland plots (node F). Otherwise, little change in vegetation community was detected at Santa Ysabel.

Individual Species Responses

Fire can have both direct and indirect impacts on individual species. Besides direct mortality from the fires, vegetation may be impacted by subsequent post-fire changes in habitat suitability. We believe that direct mortality played a large role in the observed species declines, killing many of the shrubs in both chaparral and coastal sage scrub environments, namely California sagebrush and California buckwheat. We suspect the indirect effects of the fire, such as decreases in the level of shrub and tree cover, were largely responsible for the changes we observed in the abundance and distribution of fire follower species such as peak rush-rose.

The coastal sage scrub and chaparral plots both lost substantial amounts of shrub and tree cover. The fire also removed all downed wood and leaf litter cover in these plots leaving sparse shrubs and vast amounts of open ground. These conditions appear to have been suitable for the fire follower species. Our results indicated that peak rush-rose was absent from the pre-fire samples, but came to represent as much as 47% cover within an individual sample at Little Cedar and an average of nearly 10% to15% of the post-fire samples at Little Cedar and Elliott Reserve (Figure 38). Additionally, *Ceanothus* appears to have responded positively to the newly opened environments at Little Cedar, Elliott Reserve, and Santa Ysabel. At plots 1 and 2 at Little Cedar, *Ceanothus* has replaced chamise as the second most abundant cover species.

Perhaps the greatest examples of direct mortality were observed in the average percent cover measured for California sagebrush and California buckwheat. Both of these species appeared to have declined dramatically immediately after the first fire at a plot and have shown little evidence of post-fire regeneration. One of the few instances where we saw an increase in cover of California sagebrush was at plot 2 at Rancho Jamul which had no reported sagebrush pre-fire but where sagebrush cover was detected as high as 10% cover post-fire. However, plot 2 at Rancho Jamul did not burn and so this increase is not a response to fire, but is more likely an indication of the restoration efforts at this plot by an organization outside of the USGS. In most other instances, where we had detected California sagebrush pre-fire we did not find any after the plots burned, even up to four years later (Figure 39). We have detected small levels of California buckwheat post-fire at the burned plots, but levels are still low compared to the pre-fire cover of this species (Figure 40).

We also saw declines in several other species, but unlike California sagebrush and California buckwheat, we feel that these species are poised to recover from the impacts of the fires. In general, chamise declined immediately after the fires, but there have been indications that it survived or has re-sprouted (Figure 34). Only at plots 1 and 2 at Little Cedar has chamise not shown any recovery. Chamise is adapted to regenerate after fire by sprouting new growth from the basal material, drawing from underground resources. At Little Cedar plots 1 and 2, we would suggest that the long term build up of Tecate cypress growth and leaf litter contributed to a more intense fire condition on these plots (BARC = 4, Table 1) resulting in the total die-off of the chamise, both above and below ground. Plot 3 at Little Cedar was the only other plot with chamise to experience a level 4 severity rating, except that it had much lower levels of cover of both chamise and Tecate cypress.

The declines in Tecate cypress detected as a result of our efforts should be taken with a measure of reserve. Tecate cypress, like chamise, is well adapted to life with fire, and in fact, requires fire as part of its life cycle. In many cases, the seed cones of the Tecate cypress remain closed until a fire event triggers them to open and release their contents. Following the fires, we have observed many Tecate cypress seedlings along the transects at the study plots, and they have continued to grow over the four years of post-fire survey efforts (Figure 48). However, as of this time, they only contribute a fraction of the cover provided by the mature, previous generation and may require several more years of uninterrupted growth before they are capable of producing their own seed cones.

Based on the findings of our vegetation surveys to date, the pines at Santa Ysabel would appear to be another species heavily impacted by the fires. Our most recent survey efforts indicate that the two pine plots should be characterized as grassland environments.

However, as with Tecate cypress, there are many seedlings in these two plots which may mature and re-establish these plots as pine woodlands.

Figure 48. Tecate cypress seedlings growing around a burned chamise plant at Little Cedar.

Caveats

While we were able to show variations in unburned and burned plots within vegetation communities, changes in individual species cover rates, and shifts in the overall community structure, there are several potential confounding factors that may have influenced our results and warrant discussion. Natural fluctuations in seasonal weather patterns and the responses of vegetation to these patterns, may lead to biases in the detection and cover results (Whelan 1995). For instance, pre-fire samples were collected at different times among our sites. The pre-fire data for Little Cedar and Elliott Reserve were collected in the years 1995 and 1996 (Table 3). We began collecting pre-fire data for Rancho Jamul and Santa Ysabel in 2001 and 2002, respectively, both relatively dry years. The post-fire data for all sites began in 2005, a rather wet year. The last three years of post-fire sampling occurred during drought years, which may have hindered the recovery process. Additionally, there may have been slight variations in the placement of the transect line from year to year as well as site fatigue (the impact to a site from repeated visits).

Community Conversion

Based on the first four years of post-fire research, the vegetation communities in burned coastal sage scrub have become more similar to that of grasslands, especially across the three lower elevation sites of Little Cedar, Elliott Reserve, and Rancho Jamul (Figure 30, Figure 31, and Figure 32). The burned chaparral plots, while still different than the pre-fire communities after four years of re-growth, did not appear to be as heavily impacted by the fires as was observed in the coastal sage scrub plots. Very few burned chaparral plots shared a high level of similarity with any grassland samples. Neither the grassland nor the woodland/riparian plots appeared to have experienced any shifts in community, most of the species present before the fires were also contributing to the community afterwards. Continuing to study these burned plots and the recovery processes of the vegetation will serve to tell us whether the vegetation communities follow the same trends as Zedler et al. (1983) and Keeley (2005) have reported previously for chaparral and coastal sage scrub shrub lands. Under repeated short return interval fire events, the potential exists that the vegetation will transition to grassland communities and not rebound to those of unburned chaparral and coastal sage scrub. As our efforts continue over the years subsequent to the data presented here, it will be of great interest to see if the communities in these burned shrublands return to that of the unburned and pre-fire state.

Conclusion

The southern California wildfires of 2003 and 2007 impacted the vegetation community structure in chaparral and coastal sage scrub study plots. We detected shifts in species richness and community composition in these vegetation types where the fires substantially reduced the cover of shrub and tree species. No changes in species richness or community composition were measured in grasslands or woodland/riparian plots where vegetative structure was not substantially affected from the fires.

We measured changes in cover of individual species in the post-fire burned study plots. In coastal sage scrub and chaparral, we detected increases in the percent cover of peak rush-rose and *Ceanothus*, and a decreased rate of cover for California sagebrush and California buckwheat. Most importantly, the vegetation communities in burned coastal sage scrub were more similar to those of grasslands. We will continue to monitor these communities to document the longer term effects in light of the more frequent fire regime in southern California.

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Appendix 1. Photo series.

A)

B)

C)

Photo series 1. Plant species observed at Little Cedar. A) Deerweed (*Lotus scoparius*) and *Ceanothus* spp. in bloom near plot 8. B) Chaparral-pea (*Pickeringia montana*) grew near plot 2. C) Whipple's yucca (*Yucca whipplei*) grew near the transect at plot 7.

Appendix 1 (continued). Photo series.

A)

B)

C)

Photo series 2. Although categorized as a BARC level 1 (no burn) after the 2007 Harris Fire, A) Plot 4, B) Plot 5, and C) Plot 6 at Little Cedar clearly showed signs of fire related damage.

Appendix 1 (continued). Photo series.

A)

B)

C)

D)

Photo series 3. Several plots at Rancho Jamul burned in the 2007 Harris Fire after burning only four years earlier in the 2003 Otay Fire. A) Plot 11, classified as a coastal sage scrub plot based on the pre-fire survey, had few shrubs remaining. B) After the 2007 fire, the results from the 2008 vegetation survey at plot 19 indicated that it was becoming more like the non-native grasslands. C) Plot 21 immediately after the 2007 fire and then D) the subsequent spring.

Appendix 1 (continued). Photo series.

A)

B)

Photo series 4. Woodland/riparian plots at Rancho Jamul changed little after the fires. A) This oak woodland plot, although burned in the 2007 Harris Fire, appeared much as it did pre-fire. B) Burned sycamore and riparian areas were similar to the unburned conditions within a year of the fire.

Appendix 2. Species names. The common and scientific names of plant species mentioned throughout the text or that were used in the preparation of the similarity diagrams, as well as the U.S. Department of Agriculture code for each species as was used in the data collection process are listed. "X" indicates that the species was used in the generation of the dendrogram for the given study site. Study sites are Little Cedar (CED), Elliott Reserve (ELL), Rancho Jamul (RAJ), and Santa Ysabel (SYR).

Common Name	Scientific Name	USDA Code[1]	Study Site			
			CED	ELL	RAJ	SYR
Chamise	*Adenostoma fasciculatum*	ADFA	X	X		X
California sagebrush	*Artemisia californica*	ARCA11	X	X	X	X
Manzanita	*Arctostaphylos* spp.	ARCTO3	X			X
Wild oats[a]	*Avena* spp.	AVENA				
Brome grass[a]	*Bromus* spp.	BROMU				
California-lilac	*Ceanothus* spp.	CEANO	X	X		X
Bushrue, coast spice bush	*Cneoridium dumosum*	CNDU		X		
Tecate cypress	*Cupressus forbesii*	CUFO2	X			
Bermudagrass[a]	*Cynodon* spp.	CYDA				
California buckwheat	*Eriogonum fasciculatum*	ERFA2	X	X	X	X
Yerba santa	*Eriodictyon trichocalyx*	ERTR7	X			
Eucalyptus	*Eucalyptus* spp.	EUCAL		X		
Nit grass[a]	*Gastridium* spp.	GASTR				
Saw-toothed goldenbush	*Hazardia squarrosa*	HASQ2	X	X		
Peak rush-rose	*Helianthemum scoparium*	HESC2	X	X		
Barley[a]	*Hordeum* spp.	HORDE				
Goldenbush	*Isocoma menziesii*	ISME5		X	X	
Beardless wildrye	*Leymus triticoides*	LETR5				X
Ryegrass[a]	*Lolium* spp.	LOLIU				
Honeysuckle	*Lonicera* spp.	LONIC				X
Deerweed, California broom	*Lotus scoparius*	LOSC2	X	X	X	X
Chaparral mallow	*Malacothamnus fasciculatus*	MAFA	X			
Laurel sumac	*Malosma laurina*	MALA6	X		X	
Melica, oniongrass	*Melica* spp.	MELIC				X
Wishbone bush	*Mirabilis californica*	MICA6			X	

Appendix 2 (continued).

Common Name	Scientific Name	USDA Code[1]	Study Site CED	ELL	RAJ	SYR
Monkeyflower	*Mimulus* spp.	MIMUL	X	X		
Deergrass	*Muhlenbergia rigens*	MURI2				X
Needlegrass	*Nassella* spp.	NASSE	X	X	X	X
Non-native grass		NNG[b]	X	X	X	X
(Montana) Chaparral-pea	*Pickeringia montana*	PIMO5	X			
Pine	*Pinus* spp.	PINUS				X
Western sycamore	*Platanus racemosa*	PLRA			X	
Bluegrass[a]	*Poa* spp.	POA				
Coast live oak[c]	*Quercus agrifolia*	QUAG				
Engelmann/mesa Oak[c]	*Quercus engelmannii*	QUEN				
Oak	*Quercus* spp.	QUERC		X	X	X
Spiny redberry	*Rhamnus crocea*	RHCR	X			
Holly-leaved redberry	*Rhamnus ilicifolia*	RHIL				X
Lemonadeberry	*Rhus integrifolia*	RHIN2		X		
Willow	*Salix* spp.	SALIX			X	
White sage[d]	*Salvia apiana*	SAAP2				
Sage	*Salvia* spp.	SALVI	X	X		X
Spike-moss	*Selaginella* spp.	SELAG				
Creeping snowberry, trip vine	*Symphoricarpos mollis*	SYMO				X
Poison-oak	*Toxicodendron diversilobum*	TODI				X
San Diego sunflower	*Viguiera laciniata*	VILA3	X		X	
Annual fescue[a]	*Vulpia* spp.	VULPI				
Mission manzanita	*Xylococcus bicolor*	XYBI	X	X		
Our Lord's candle, Whipple's yucca	*Yucca whipplei*	YUWH	X			
		Count of Species	21	17	12	18

[a] These species were not used directly in the generation of any dendrograms, but were combined under "Non-native grass: NNG".

[b] "NNG" is not a U.S. Department of Agriculture species code, but is a conglomerate of multiple non-native grass species.

[c] These species were not used directly in the generation of any dendrograms, but were combined under "Oak: QUERC".

[d] This species was not used directly in the generation of any dendrograms, but was combined with other species within the genus *Salvia* under "Sage: SALVI".

[1] (USDA 2007)