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Vegetation Responses to Prescribed Burning in a Mixed-conifer Woodland, Cuyamaca Rancho State Park, California

Bradford D. Martin

Abstract

VEGETATION RESPONSES TO PRESCRIBED BURNING IN A MIXED-CONIFER WOODLAND, CUYAMACA RANCHO STATE PARK, CALIFORNIA

by Bradford D. Martin

This study reports the results of light intensity prescribed burning on the vegetation of 3 jeffrey pine-black oak woodland sites in Cuyamaca Rancho State Park, California. The 1.2 ha, 85 ha, and 6 ha burn plots were measured for tree and shrub density and basal area 6 months, 1½ years, and 2 years following burning for the 3 sites respectively. Each burn site measured was compared against equivalent unburned control plots to help assess the effects of the burning. Density of saplings, seedlings, and herbaceous vegetation was also determined for the woodland understories. Dominance and relative dominance of herbaceous ground cover in meadow areas were obtained to determine the recovery of the bunch grasses.

Tree density and basal area were not affected by the burning except for a slight reduction in the number of trees with very small diameters at breast height (2-8cm). Tree sapling density was greatly reduced in burn plots when compared to control plots. Mean density of tree seedlings also was generally decreased in burn plots except for *Quercus agrifolia*, *Quercus chrysolepis*, and *Quercus kelloggii*, which increased in some study plots in the most recent burn. Density and diversity of herbaceous vegetation were generally increased as a result of the burning. Meadow bunch grasses were recovering well through the thinning of dead grass in bunches. *Muhlenbergia rigens* recovered 143% of the live foliar cover 3 months following one burn.

The greatest change which took place as a result of the burning was a significant reduction in density and basal area of shrubs in the understory. The dominant shrub, Mexican manzanita (*Arctostaphylos pungens*), averaged a 93% density reduction in the burn plots compared to control plots. Other shrubs such as *Arctostaphylos glandulosa*, *Ceanothus leucodermis*, *Ceanothus palmeri*, *Cercocarpus betuloides*, and *Rhamnus californica* were also reduced to a lesser extent.

LOMA LINDA UNIVERSITY

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by

Bradford D. Martin

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Each person whose signature appears below certifies that this thesis in his opinion is adequate, in scope and quality, as a thesis for the degree Master of Arts.

Earl W. Lathrop, Chairman
Earl W. Lathrop, Professor of Biology

David A. Hessinger
David A. Hessinger, Associate Professor of Physiology/Pharmacology

Anthony W. Lewis
Anthony W. Lewis, Assistant Professor of Biology

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INTRODUCTION

"Fire is a good servant, but a poor master."
--Finnish proverb

Today fire is increasingly recognized as a part of the world's ecology. Fire is a physical factor whose periodic occurrence has been of great importanct to man and nature over the centuries (Odum, 1969; Mutch, 1970). Whole biomes, such as those of the grasslands and California chaparrals, have become adapted to periodic fires producing "fire climaxes" (Sauer, 1950; Cooper, 1961; Hanes, 1971). In the distant past, fires occurred naturally in environments without man's interference. Indians and pioneers indicated that natural fires swept over much of the grasslands, chaparrals, and forests of North America (Weaver, 1951; Box, et al., 1967). When a fire started, it would run its course until it went out naturally.

Early fires were caused mainly by lightning, which is still one of the leading causes of forest fires (Weaver, 1957; Granfelt, 1965; Biswell, 1974; Talley and Griffin, 1980). But lightning alone cannot account for all the fires which burned the early natural landscape. Indians used frequent and widespread fires knowledgeably to extend the range of those plants on which they depended. Jeffrey (1961) feels that some of the Albertan prairies were probably anthropogenic in origin rather than natural expression of the physical environment. Indians set burns in order to make hunting easier, to enhance feeding grounds for game, to facilitate the gathering of seeds, bulbs, and berries, and to increase the production of useful plants (Sauer, 1950; Cooper, 1961). Many early explorers who observed the Indians burning noticed how usefully and discretely they used fire. With fire, the Indians kept their forests open, pure, and fruitful (Miller, 1887).

Early settlers also used fire for mining, lumbering, and grazing. Miners used fire to remove slash after cutting trees for mining props and fuel, and to clear the landscape to facilitate their activities. Today some of the best pine stands in California occur in these areas where miners did heavy burning (Biswell, 1974). However, most of the burning done by lumbermen was not beneficial, and many of the heavily cut and burned areas have turned to chaparral (Show and Kotok, 1924).

The destructive fires of the early settlers caused much concern by some thoughtful observers. As a part of the conservation movement legislation was passed in 1872 to prevent the setting of fires. In 1905 the U.S. Forest Service adopted a firm policy of virtual fire exclusion on its lands, with the California Division of Forestry following in 1924 with a policy which covered private lands also (Clar, 1959; Kilgore and Briggs, 1972). Today, modern man has been stopping fire with equipment and machinery, and has suppressed the amount of burning in the environment. But even with the most modern aerial and ground equipment and the best trained firemen, wildfires cannot be totally eliminated. With man's earnest interference, fires do occur at less frequent intervals. However, with these longer time spans between fire, fuels build up to enormous levels and cause fires to become uncontrollable and widespread (Dodge, 1972; Talley and Griffin, 1980). The costs of these wildfires in terms of life, natural resources, and money is very high (Wilson and Dell, 1971).

Investigators in the past few years have realized that the U.S. Forest Service policy of fire exclusion has not been favorable for our environment either. In order to reduce high fuel levels and reintroduce fire into the fire suppressed areas, government agencies and researchers have been conducting prescribed burns (Weaver, 1957; Biswell, 1959, 1960). Prescription burns are for the most part, light intensity fires that are initiated when fuel moistures, humidity, and wind velocity make the fire controllable. Studies have shown that burning involves a major disturbance to vegetation initially, but tends to generate new and fresh plant growth.

In grassland areas, annual and perennial grasses appear to recover very quickly. Usually grasses have 100% recovery within the first or second year (Reynolds and Bohning, 1956; Jameson, 1962; Launchbaugh, 1964; Box, et al., 1967). After a spring burn in a Wisconsin prairie savanna, it was found that grass and forb yield increased three fold with 79% reduction of dead herbage. Not only does herbaceous growth have more productivity, but it is more palatable to herbivores due to its increased water content (Vogl, 1965). Fire has been proposed by Vogl (1974) as being the best method for managing our grassland preserves.

Various studies have revealed that shrubs have invaded into some areas that they did not previously occupy as a result of fire exclusion. When periodic prescribed burns are conducted these shrubs are eliminated and checked from these areas upon which they have encroached (Reynolds and Bohning, 1956; Jameson, 1962; Box, et al., 1967; Dwyer and Pieper, 1967; Blackburn, 1970; Grelen, 1978). Vulnerability of shrubs to fire is due to the thin bark surrounding the trunk. Trees, however, are not affected by light intensity burning because of their thicker bark. In the south-eastern coastal plain, periodic prescribed burns have been found to maintain pine forests in more desirable stages of succession.

Wood quality of these pine trees is also improved as a result of fire (Cooper, 1961; Odum, 1969).

Controlled burns may also enhance communities for wildlife by removing dense vegetation that physically impair habitation by aminals (Vogl, 1973). Fire removes dead plant material, in turn stimulating fresh, palatable growth upon which animals can browse or in which they can hide (Vogl and Beck, 1970; Kessler and Dodd, 1978).

Although research has shown periodic prescribed burning to be beneficial in some locations, each area must be evaluated separately to understand the results of such a program (Biswell, 1974; Sampson, 1944b).

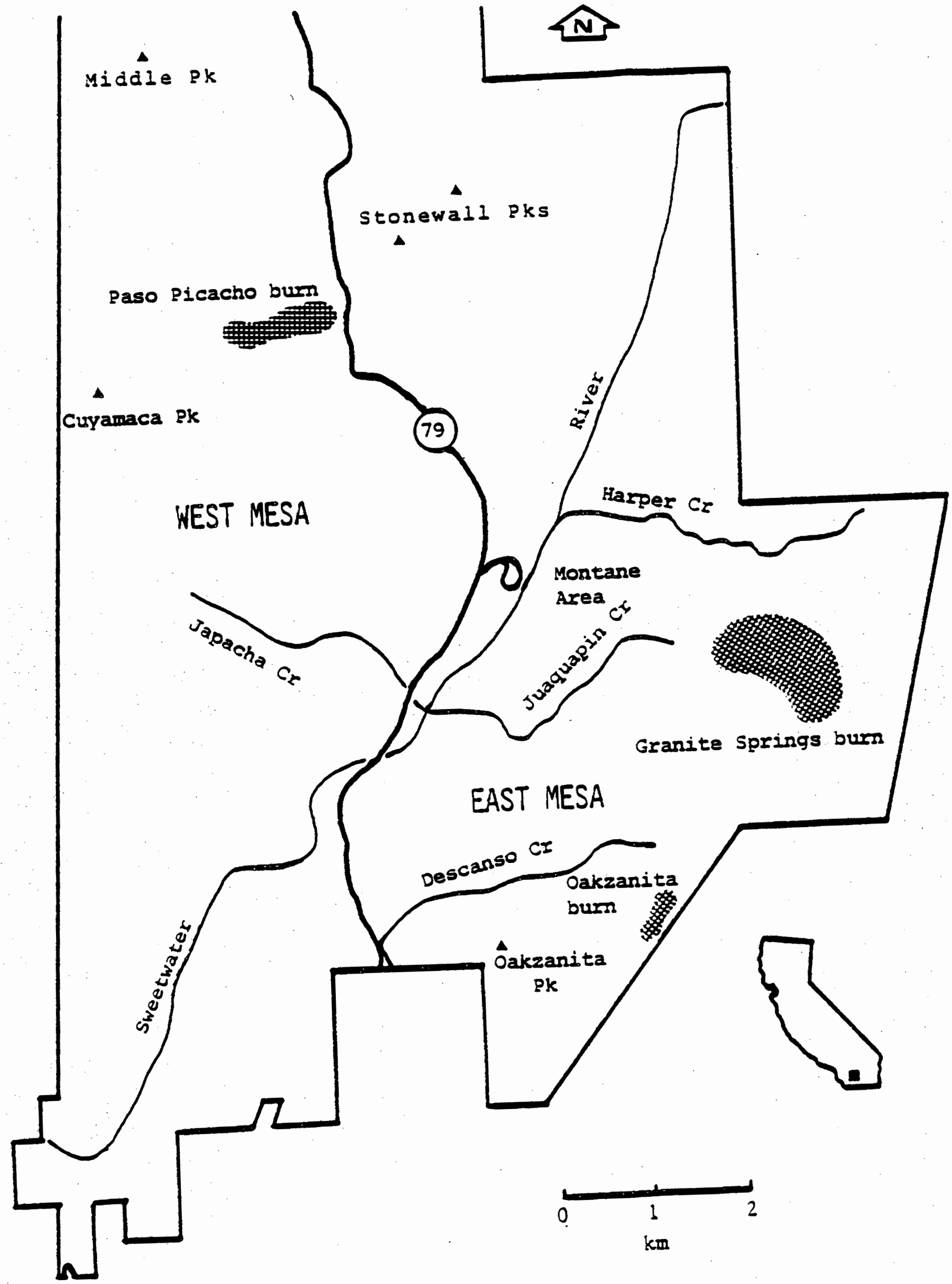
In April 1978, Cuyamaca Rancho State Park started a prescribed burning program in order to reintroduce fire in the park communities. Burning was conducted in the mixed-conifer woodlands of this park, which is located in the Cuyamaca Mountains of eastern San Diego County, California. This location offered an excellent opportunity to study a prescribed burning program.

The California State Forest Service conducted light intensity prescription burns in three jeffrey pine-black oak woodlands in the West Mesa and East Mesa areas (Fig. 1).

The Paso Picacho burn was initiated April 24, 1978, with an air temperature of 18°C, a relative humidity of 30%, a fuel moisture of 9-12%, and a wind velocity below 16 km/hr. This burn covered approximately 6 hectares in a mixed-conifer woodland with a chaparral understory.

The Granite Springs burn was conducted on December 11-15, 1978, with an air temperature of 13°C, a relative humidity of 17-37%, a fuel

Fig. 1. Cuyamaca Rancho State Park showing locations of the three prescription burn sites.



N
Middle Pk
Stonewall Pks
Paso Picacho burn
Cuyamaca Pk
79
River
WEST MESA
Harper Cr
Montane
Area
Japacha Cr
Juaquapin Cr
Granite Springs burn
EAST MESA
Descanso Cr
Oakzanita
burn
Oakzanita
Pk
Sweetwater
0
1
2
km

moisture of 7.5%, and a wind velocity of 4-9.6 km/hr. This burn enveloped approximately 85 hectares in a mixed-conifer woodland with a chaparral and grass understory.

The Oakzanita burn was started December 3, 1979, with an air temperature of 18-24°C, a relative humidity of 18-25%, a fuel moisture of 6-8%, and a wind velocity of 0-6.4 km/hr. This burn was approximately 1.2 hectares in a mixed-conifer woodland with a chaparral understory. Parts of a depleted deergrass meadow bordering this woodland were also burned.

A satellite burn near the Oakzanita burn was carried out in a meadow on April 16, 1980 in a pure stand of deergrass (Muhlenbergia rigens). This burn was very small, covering about 0.1 hectares. No measurements of air temperature, fuel moisture, humidity, or wind speed were recorded at this site.

Another satellite deergrass burn near Granite Springs was performed during December 11-15, 1978. Conditions concurring with this burn are the same as the Granite Springs burn.

In the Paso Picacho, Granite Springs, and Oakzanita burn areas, the dominant shrub of the chaparral understory is Mexican manzanita (Arctostaphylos pungens). Figure 2 shows a branch of this shrub which stand 2-3 meters high. Arctostaphylos pungens is a non-sprouting shrub because it lacks a basal burl (Raven, 1966; Munz, 1974). Personnel of Cuyamaca Rancho State Park believe that this shrub is a invader species that is creeping its way into what were grass understories of these mixed-conifer woodlands. Conceivably this shrub is checked by prescription burning, the low intensity burn destroying the vegetative structure, but not breaking the dormancy of the seeds as would likely happen under

Fig. 2. Branch of Mexican manzanita (Arctostaphylos pungens).

2X

wildfire conditions.

In the past, the meadow areas were possibly dominated by deergrass. From overgrazing by cattle and deer in combination with the lack of fire stimulation, these meadows may have become depleted of this species of grass. Since deergrass is a perennial, its growth would probably be stimulated by fire (McClaran, 1981).

This study is testing the hypotheses that there is a significant reduction of shrubs in burned woodland areas as a result of fire and that fire increases productivity of bunch grasses growing in meadow areas. This study may result in information which will help in the management of other burns executed in mixed-conifer woodlands.

METHODS

Information regarding history, dates, and prescriptions of the burns was provided by the personnel of Cuyamaca Rancho State Park. The method used to evaluate the overall effect of the three prescribed burns in the park was by a comparison of vegetation in the burned and control (unburned community equivalent to the burned area) study sites. Woody vegetation was measured by the quadrat method (Cox, 1980). The quadrats, $100m^2$ (10m x 10m) in size (Fig. 3), were randomly placed along transects in the control and burn sites. For the Paso Picacho burn, 26 quadrats were measured in the control area (Fig. 4) and 30 in the burn area (Fig. 5). Twenty-nine quadrats were measured in the control area (Fig. 6) of the Granite Springs site and 33 in the burn area (Fig. 7). Eleven quadrats were measured in the control area (Fig. 8) and 15 in the burn area (Fig. 9) of the Oakzanita study site.

Shrubs and trees at each quadrat were recorded by measuring trunk diameters following methods of Wilson and Vogl (1965). Shrub trunk diameters were measured at ground level, while tree trunk diameters were measured at breast height (DBH). The number of individuals of each species were counted in each quadrat. Since shrubs often have several trunks arising from one common area, an individual shrub was considered to be any plant possessing a burl or trunk distinct from other burls or trunks (Wilson and Vogl, 1965). Mean density is expressed as the number of individuals per hectare (no/ha) and is extrapolated from quadrat data. Basal area was calculated from the diameter of each plant trunk and summed as a percentage of ground covered by each species. Total basal area is the percentage of the total ground surface covered by all

Fig. 3. $100m^2$ quadrat being marked out at the Oakzanita prescription burn site. Photograph was taken in March, 1980.

Fig. 4. View of control area at the Paso Picacho prescription burn site. Photograph was taken north of the Lookout road, July, 1980.

Fig. 5. View of burn area at the Paso Picacho prescription burn site. Photograph was taken south of the Lookout road, July, 1980.

Fig. 6. View of control area at the Granite Springs prescription burn site. Photograph was taken west of the East Mesa fire road near Granite Springs, April, 1981.

Fig. 7. View of burn area at the Granite Springs prescription burn site. Photograph was taken near junction of the East Mesa fire road and the Harvey Moore trail, July, 1980.

Fig. 8. View of control area at the Oakzanita prescription burn site. Photograph was taken west of the East Mesa fire road, April, 1981.

Fig. 9. View of burn area at the Oakzanita prescription burn site. Photograph was taken east of the East Mesa fire road, March, 1980.

shrub and tree species. Relative dominance is the percentage of the total basal area occupied by each species.

Shrub and tree seedlings and saplings species were counted from each $100m^2$ quadrat to determine density and relative dominance. Saplings were considered to be trees or shrubs that had trunk diameters of less than two centimeters excluding seedlings. Seedlings were generally first year plants not exceeding six inches in height.

Similarity of plant types between the control and burn quadrats was computed by Jaccard's coefficient of community similarity (CCj) as described by Brower and Zar (1977). The formula is:

$$CCj = \frac{C}{S_1 + S_2 - C}$$

Where S_1 and S_2 are total basal area or total species in community 1 and 2 respectively, and C equals total basal area or total species common to both communities.

Smaller, one meter square (1m x 1m) quadrats were also used in these woodland areas to measure density and relative dominance of the herbs, seedlings, and small shrubs in the understory. These quadrats were randomly measured along transects within the control and burn areas. Forty-one quadrats were measured in the control area and 40 in the burn area of the Oakzanita burn. For the Paso Picacho burn, 40 quadrats were measured in the control and 120 in the burn area.

Density of the vegetation measured in the $1m^2$ quadrats is expressed as the number of individuals per square meter (no/m^2). Due to the small sampling size, density is not extrapolated to hectares. Relative dominance is the percentage of the total density occupied by each species. Analysis of the differences in the densities of shrubs and trees, sapling shrubs and trees, and seedling shrubs and trees between the control and burn areas was done by "t-testing" as described by Brower and Zar (1977), with level of significance, α=0.05.

Measurements in the grassland meadows which were burned in conjunction with the Oakzanita forest burn were taken for the purpose of testing the recovery of the dominant grass species Muhlenbergia rigens (deergrass). Foliar cover (dominance) and relative dominance of this species were determined for the control (unburned portions of the meadows) and burn areas by use of the point frame (Phillips, 1959; Fig. 10). Foliar cover is expressed as the percentage of ground covered by an individual species. Total foliar cover is the percentage of ground covered by all species. Relative dominance is the percentage of the total cover occupied by each species.

Sampling was done at various dates for comparative purposes. Three hundred point samples (from the point frame) were taken at both the control site and at the burn site for the depleted deergrass meadow of the Oakzanita burn (Figs. 11 and 12) on June 17, 1980 and again on July 16, 1980. In the July measurements, points hitting Muhlenbergia rigens blades were separated as live or dead. From this data, it was possible to determine the amount of dead deergrass removed by the fire.

Quadrat measurements of control and burn areas were taken in both the Oakzanita burn meadow (Fig. 13) and at the Granite Springs site to determine density and basal area of deergrass bunches.

Additional point frame sampling, with totals ranging from 100 to

Fig. 10. The point frame used to measure the grassland vegetation.

Fig. 11. View of control and burn areas at the Oakzanita burn meadow, March, 1980. Burn area is in foreground; control area occupies the remainder of the meadow.

Fig. 12. View of control and burn areas at the Oakzanita burn meadow, July, 1980. Burn area is in foreground; control area occupies the remainder of the meadow.

Fig. 13. View of control and burn areas at the Oakzanita burn meadow, March, 1981. Burn area is in foreground; control area occupies the remainder of the meadow.

150 points each for control and burn sites, were taken at various satellite locations within or near the Oakzanita burn meadow (Figs. 14-16).

Fig. 14. View of the control and burn areas in the small meadow at the north end of the Oakzanita prescription burn, July, 1980. Control area is in the left half of the photograph; burn is in the right half of the photograph.

Fig. 15. View of control and burn deergrass bunches at the satellite burn near the Oakzanita prescription burn, June, 1980. Control bunches are near the edge of the meadow; burn bunches are seen in the foreground.

Fig. 16. View of control and burn deergrass bunches at the satellite burn near the Oakzanita prescription burn, July, 1980. Control bunches are in the background; burn bunches are situated in the foreground.

RESULTS

The vegetative responses to the prescribed burning at Cuyamaca Rancho State Park were studied primarily to see what effect the fire had at each burn location in comparison with equivalent control sites. Shrubs and trees, sapling shrubs and trees, seedling shrubs and trees, and herbaceous vegetation were analyzed separately at each of the three burn areas. Secondary comparisons were also made between the different burn areas with respect to plant responses 2 years, 1½ years, and 6 months after the burn.

EFFECT OF BURNING ON MATURE SHRUBS AND TREES

Paso Picacho burn

Table 1 summarizes the measurements taken June 12, 1980 through July 24, 1980, at the Paso Picacho burn for mean density and relative dominance (based on basal area) of the shrubs and trees in the control and burn area. The fire appears to have reduced the total density of the shrubs and trees in the burn area 15.3%. However, there is no significant difference between the control and burn areas when comparing tree density alone (Table 2). The fewer number of shrubs account for all the density differences observed between the two areas. The fire topkilled and diminished the shrub density 91% in the burn area. This reduction is significantly different even at the 1% level of probability as determined by the "t" test.

When analyzing dominance, it was found that the burn area had a total basal area of 0.64%, while the control had a total basal area of 0.71%. This 8.6% reduction of basal area in the burn is again caused by

Table 1. Mean density and relative dominance (RD, based on basal area) of shrubs and trees in $100m^2$ control and burn quadrats at the Paso Picacho burn, West Mesa, Cuyamaca Rancho State Park. Control K = 26; burn K = 30.

SPECIES		DENSITY (no/ha)	RD (%)
Control			
Abies concolor		4	0.03
Arctostaphylos pungens		438	13.71
Calocedrus decurrens		846	44.28
Ceanothus palmeri		38	2.71
Holodiscus discolor		4	*
Pinus jeffreyi		77	17.14
Quercus chrysolepis		77	4.14
Quercus kelloggii		35	18.00
	TOTAL	1519	
Burn			
Abies concolor		3	0.11
Arctostaphylos pungens		40	2.86
Calocedrus decurrens		760	31.75
Ceanothus palmeri		3	0.05
Pinus flexilis		3	0.11
Pinus jeffreyi		236	46.03
Quercus agrifolia		43	2.06
Quercus chrysolepis		30	1.11
Quercus kelloggii		47	15.87
	TOTAL	1165	

K = number of $100m^2$ plots
* = less than 0.01%

Table 2. Mean density, dominance, and relative dominance of shrubs and trees in $100m^2$ control and burn quadrats at the Paso Picacho burn, Granite Springs burn, and Oakzanita burn, Cuyamaca Rancho State Park.

AREA	DENSITY (no/ha)		DOMINANCE ($\bar{X}$ basal area %)		RELATIVE DOMINANCE (%)	
	control	burn	control	burn	control	burn
Paso Picacho						
Shrubs	480	43	0.12	0.02	16.42	2.96
Trees	1039	1165	0.59	0.62	83.59	97.04
Granite Springs						
Shrubs	31	3	0.005	*	1.44	0.11
Trees	369	345	0.36	0.45	98.56	99.99
Oakzanita						
Shrubs	3529	240	0.25	0.03	54.28	12.45
Trees	374	407	0.22	0.21	46.40	87.55
TOTAL Shrubs	4040	286	0.38	0.05	32.25	3.91
TOTAL Trees	1782	1917	1.17	1.28	67.75	96.09

* = less than 0.001

the fewer number of shrubs in the burn area. This is further indicated by the total tree basal area, which is 0.62% in the burn and 0.59% in the control (Table 2). The basal area similarity of the trees indicate that they are nearly equivalent in both areas and thus not affected by the burn. The total shrub basal area in the burn area was reduced 83.5%, from 0.12% to 0.02%.

The relative dominance of all shrub species in the control area, compared to the tree dominance, is 16.4%, while the burn is only 2.96% (Table 2). The dominant shrub (Arctostaphylos pungens) was reduced significantly ($P < .02$) from 13.71% to 2.86% in the burn area.

Shrubs and trees were separated by size class in Table 3 to show the difference in distribution caused by the fire's removal of the shrubs and smaller sized trees. From comparisons of the total shrubs and trees in each size class, the 2-8 cm. size class is the largest class of shrubs and trees for the control. We would expect the fire to have removed a large number of the shrubs and trees found in this size class because of their small and vulnerable size. This is exactly what is found when looking at the burn area, because the most numerous class of shrubs and trees now lies in the 9-16 cm. size class. The totals in each of the larger size classes are very similar in both control and burn areas. This is due to the increased tree composition in these size classes.

The community coefficients of similarity (CCj) for the control and burn areas at the Paso Picacho burn are shown in Table 4. The low basal area CCj of 0.52 should be expected since the burning of the shrubs would cause a dissimilarity between the control and the burn. When shrubs and trees are analyzed alone, it was found that the shrubs had a

Table 3. Percentages of shrub and tree species by size class in $100m^2$ control and burn quadrats at the Paso Picacho burn, Cuyamaca Rancho State Park. Control K = 26; burn K = 30.

SPECIES	Size class in cm. based on diameter at breast height								
	2-8	9-16	17-24	25-32	33-40	41-48	49-56	57-	TOTAL %
Control									
Abies concolor	0.26								0.26
Arctostaphylos pungens	12.31	8.46	5.38	1.54	0.51	0.26		0.51	28.97
Calocedrus decurrens	17.95	16.92	8.72	4.87	3.85	3.08	0.26	0.77	56.41
Ceanothus palmeri		0.77	0.51	0.77	0.51				2.56
Holodiscus discolor	0.26								0.26
Pinus jeffreyi	1.03	0.51	0.26	0.51	0.51	0.51	0.51	0.26	4.10
Quercus chrysolepis	2.82	1.79		0.51					5.13
Quercus kelloggii		0.26		0.26			1.03	0.77	2.31
SIZE CLASS TOTALS	34.63	28.71	14.87	8.46	5.38	3.85	1.80	2.31	
Burn									
Abies concolor		0.28							0.28
Arctostaphylos pungens	0.57	0.57	1.14	0.85			0.28		3.42
Calocedrus decurrens	19.94	27.06	8.83	4.27	1.42	2.28	0.85	0.57	65.24
Ceanothus palmeri		0.28							0.28
Pinus flexilis		0.28							0.28
Pinus jeffreyi	2.28	6.56	3.42	1.42	2.28		2.28	1.99	20.28
Quercus agrifolia	1.71	0.28	0.57	0.85		0.28			3.70
Quercus chrysolepis		1.71	0.85						2.56
Quercus kelloggii		0.57	0.28	0.28	0.28	1.14	0.85	0.57	3.99
SIZE CLASS TOTALS	24.50	37.59	15.09	7.69	3.98	3.70	4.26	3.13	

K = number of $100m^2$ plots

Table 4. Jaccard's Coefficient of Community Similarity (CCj) for basal area and species composition in $100m^2$ control and burn quadrats at the Paso Picacho burn, Granite Springs burn, and Oakzanita burn, Cuyamaca Rancho State Park.

AREA	CCj (basal area)	CCj (species composition)
Paso Picacho		
Shrubs	0.16	0.66
Trees	0.56	0.71
Shrubs and trees	0.52	0.70
Granite Springs		
Shrubs	0.00	0.00
Trees	0.72	0.66
Shrubs and trees	0.72	0.33
Oakzanita		
Shrubs	0.12	0.25
Trees	0.84	1.00
Shrubs and trees	0.46	0.45

CCj of 0.16, while the trees had a CCj of 0.56. A similarity coefficient of approximately 0.7 is considered an indication that the two communities are virtually identical (Whittaker, 1975). The reason for the only moderately high CCj for the trees is a result of a slight difference in dominance of the trees. When CCj is analyzed for species composition in the control and burn communities, we find something different. This is from the inability of the fire to remove shrub species totally in the burn area. As a result, both the shrubs and trees have high CCj values of 0.66 and 0.71 respectively.

Granite Springs burn

Table 5 summarizes measurements obtained July 10-23, 1980, at the Granite Springs burn for mean density and relative dominance (based on basal area) of the shrubs and trees in the control and burn areas. Comparison of the total density in the control and burn areas show a 13% reduction in the burn. This lessened density is again credited to the shrubs, because tree density is essentially equal in both areas (Table 2). Even with only 13% reduction, shrubs alone were significantly reduced ($P < .05$). The reason for the small reduction in total density, comparing the control and burn sites, is because the control also has a low relative dominance of shrubs (1.44%).

When comparing basal area in the control and burn areas, there is an increase in the burn area (Table 2). This increase is due, simply by chance, to the presence of larger trees in the burn area sampled. The shrubs, however, have a reduced basal area in the burn site, directly attributable to the fire. The relative dominance of the shrubs, like the basal area, was reduced from 1.44% in the control to 0.11% in the burn

Table 5. Mean density and relative dominance (RD, based on basal area) of shrubs and trees in 100m^2 control and burn quadrats at the Granite Springs burn, East Mesa, Cuyamaca Rancho State Park. Control K = 29; burn K = 33.

SPECIES		DENSITY (no/ha)	RD (%)
Control			
Arctostaphylos glandulosa		7	0.36
Arctostaphylos pungens		24	1.08
Pinus jeffreyi		169	50.00
Quercus agrifolia		79	4.12
Quercus kelloggii		121	44.44
	TOTAL	400	
Burn			
Cercocarpus betuloides		3	0.11
Pinus jeffreyi		218	48.89
Quercus kelloggii		127	51.10
	TOTAL	348	

K = number of 100m^2 plots

(Table 2).

All shrubs and trees were separated by size class in Table 6 to reveal the difference in distribution caused by the fire's removal of the shrubs and small trees. A comparison of the total shrubs and trees in each size class indicates that the 2-8 cm. size class again contains the largest number of shrubs and trees in the control, while the largest class in the burn site is the 17-24 cm. size class. Since shrubs have such a low relative dominance, the removal of small trees by the fire accounts for most of this shift in size class.

The community coefficients of similarity for control and burn areas of the Granite Springs burn are shown in Table 4. The high CCj for basal area of 0.72 is a result of the low prevalence of shrubs in both control and burn areas. Even though the shrubs were diminished in the burn, they were of different species and therefore do not alter computations greatly. This is why the CCj for shrubs and trees (0.72) and for trees alone (0.72) are the same. Analysis of CCj for species composition indicates that the low 0.33 value for shrubs and trees is from the lack of common shrubs and few tree species in the control and burn areas. The CCj for shrub species is 0.0, while for the tree species it is a high 0.66. The lack of common shrubs in the control and burn sites indicates slight differences between community types. However, the presence of resprouting Arctostaphylos glandulosa in the burn make the community similarities more evident. The small size of these 1½ year old Arctostaphylos glandulosa resprouts suggest that growth of the shrubs has been slow after the fire.

Table 6. Percentages of shrub and tree species by size class in 100m^2 control and burn quadrats at the Granite Springs burn, Cuyamaca Rancho State Park. Control K = 29; burn K = 33.

SPECIES	Size class in cm. based on diameter at breast height								
	2-8	9-16	17-24	25-32	33-40	41-48	49-56	57-	TOTAL %
Control									
Arctostaphylos glandulosa		0.9	0.9						1.8
Arctostaphylos pungens	2.6	1.7	0.9	0.9					6.1
Pinus jeffreyi	7.8	2.6	6.0	6.0	5.2	6.0	5.2	3.5	42.3
Quercus agrifolia	16.4	0.9			1.7		0.9		19.9
Quercus kelloggii	0.9	0.9	4.3	5.2	7.8	6.0	3.5	1.7	30.3
SIZE CLASS TOTALS	27.7	7.0	12.1	12.1	14.7	12.0	9.6	5.2	
Burn									
Cercocarpus betuloides		0.9							0.9
Pinus jeffreyi	3.5	10.4	15.7	11.3	7.8	3.5	3.5	7.0	62.6
Quercus kelloggii		0.9	3.5	7.0	4.3	8.7	4.3	7.8	36.5
SIZE CLASS TOTALS	3.5	12.2	19.2	18.3	12.1	12.2	7.8	14.8	

K = number of 100m^2 plots

<u>Oakzanita burn</u>

Table 7 presents measurements that were taken March 17, 1980 through July 9, 1980 at the Oakzanita burn for mean density and relative dominance (based on basal area) of the shrubs and trees in the control and burn areas. Woody vegetation of this burn site was reduced 83% when comparing the total density of shrubs and trees in both areas. Since the shrubs have a high relative dominance in the control (54%), we would expect the shrubs to be responsible for the large density reduction (Table 2). When shrubs are examined alone, we find that there was a significant reduction ($P<.01$) in the burn area. The total tree basal areas are the same in both the control and burn sites despite the fact that the tree density in the burn area is slightly higher (8%) than the control due to the trees being of a smaller size class. The basal area of all tree species in the burn area is 0.21%, while 0.22% in the control (Table 2). Total basal area for shrubs and trees taken together in the control was 0.47%, while the burn had only 0.24%. Since the trees alone are equivalent in both areas, the shrubs again cause the noticeable difference in basal area.

Compared with its high value of 54.28% in the control area, relative dominance drops to 12.45% in the 6 month old burn (Table 2). Even with this tremendous drop in relative dominance, the burn value is still several times higher than the shrubs in the burn areas of Paso Picacho and Granite Springs combined. The few live shrubs that survived the fire in the Oakzanita burn are located within unburned patches or "islands." Due to insufficient ground cover to carry the fire, many shrubs were unburned within these "islands." <u>Arctostaphylos pungens</u> is

Table 7. Mean density and relative dominance (RD, based on basal area) of shrubs and trees in $100m^2$ control and burn quadrats at the Oakzanita burn, East Mesa, Cuyamaca Rancho State Park. Control K = 11; burn K = 15.

SPECIES	DENSITY (no/ha)	RD (%)
Control		
Arctostaphylos glandulosa	28	1.00
Arctostaphylos pungens	3318	48.40
Ceanothus leucodermis	18	0.20
Ceanothus palmeri	18	0.80
Cercocarpus betuloides	9	0.08
Eriogonum fasciculatum	73	0.20
Pinus jeffreyi	209	17.50
Quercus agrifolia	137	23.20
Quercus dumosa	10	1.50
Quercus kelloggii	28	5.70
Rhamnus californica	55	2.10
TOTAL	3885	
Burn		
Arctostaphylos pungens	233	12.43
Cercocarpus betuloides	7	0.02
Pinus jeffreyi	107	24.22
Quercus agrifolia	273	49.22
Quercus kelloggii	27	14.11
TOTAL	647	

K = number of $100m^2$ plots

by far the dominant plant in this control area with a relative dominance of 48.2% (Table 7). The fire was very successful in significantly reducing ($P < .01$) this shrub by lowering its dominance by 93%, compared to the control.

Some of the shrubs species found in the control were not also found in the burn sites when measured. However, subsequent observations were made to see if those missing species were present in the burn before the fire. In this inspection, crown sprouts of *Arctostaphylos glandulosa*, *Ceanothus leucodermis*, *Ceanothus palmeri*, *Cercocarpus betuloides*, *Penstemon heterophyllus*, and *Rhamnus californica* were found. Of the sparse smaller trees that were topkilled by the fire, almost all are resprouting at the base (Fig. 17).

The community coefficients of similarity for the control and burn areas at the Oakzanita burn are shown in Table 4. The low basal area CCj for shrubs and trees should be expected, since the burning of the dominant shrubs would cause dissimilarity between the control and burn. When considered alone, we would expect a low value for the shrubs and a high value for the trees. This is precisely what exists with a 0.12 CCj for shrubs and 0.84 CCj for trees. When CCj is evaluated for species composition in the control and burn communities, we see this same pattern again with 0.25 for shrubs and 1.0 for the trees. These high coeffecients of similarity for the trees in both areas imply that the control quadrats were identical to those of the burn.

EFFECTS OF BURNING ON SAPLING SHRUBS AND TREES

Paso Picacho burn

Fig. 17. Sprouting occurring 15 months after a young *Quercus agrifolia* was topkilled by the Oakzanita prescription burn. Photograph was taken March, 1981.

Mean density and relative dominance (based on density) of sapling shrubs and trees from $100m^2$ quadrats measured during June 12, 1980 through July 24, 1980, are summarized in Table 8 for control and burn plots at the Paso Picacho burn. Sapling density was reduced 94% in the burn area compared to the control. This was shown to be significant at the 1% level of probability. This extreme reduction should be expected because of the susceptibility of all small woody vegetation to fire. Sapling trees would be expected to react to fire in the same manner as do shrubs, with high reductions in their numbers. Compared with each other, none of the sapling species appear to have superior mechanisms for immediate fire survival. However, Calocedrus decurrens saplings compromise over 89% of the saplings in both the control and burn areas. Both Calocedrus decurrens and Quercus chrysolepis show significant reduction ($P < .02$) of saplings in the burn.

Mean densities of sapling shrubs and trees from $1m^2$ quadrat measurements taken July 16-22, 1980, are presented in Table 9. In each of the three burn samples there was a mean reduction of 82.6% of the total shrubs and tree saplings, compared to the control. Fewer shrub and tree species were also found in the burn site. This reduction is important when realizing that most of these shrubs were small and fast growing species. Eriogonum fasciculatum and Rhus trilobata display slight increases in the burn site, possibly indicating stimulated growth by the fire.

Granite Springs burn

Mean density and relative dominance (based on density) of sapling shrubs and trees from $100m^2$ quadrats measured July 10-23, 1980, are

Table 8. Mean density and relative dominance (RD, based on density) of sapling shrubs and trees in $100m^2$ control and burn quadrats at the Paso Picacho burn, West Mesa, Cuyamaca Rancho State Park. Control K = 26; burn K = 30.

SPECIES		DENSITY (no/ha)	RD (%)
Control			
Abies concolor		4	0.23
Calocedrus decurrens		1562	89.62
Ceanothus palmeri		23	1.32
Pinus jeffreyi		8	0.46
Quercus agrifolia		15	0.86
Quercus chrysolepis		104	5.96
Quercus kelloggii		27	1.55
	TOTAL	1743	
Burn			
Calocedrus decurrens		97	97.00
Quercus agrifolia		3	3.00
	TOTAL	100	

K = number of $100m^2$ plots

Table 9. Mean density of sapling shrubs and trees in a mixed-conifer woodland following the Paso Picacho prescription burn of April 24-30, 1978, West Mesa, Cuyamaca Rancho State Park.

SITE	K[a]	R[b]	DENSITY (no/m^2)		% CHANGE[c]
Control	40	4	1.74		
A) burn	40	3	0.78		-55.2
B) burn	40	0	0.00		-100.0
C) burn	40	1	0.13		-92.5
				$\overline{X}$	-82.6

a = number of $1m^2$ plots sampled per site
b = number of species per site
c = test - control ÷ control x 100%

listed in Table 10 for control and burn areas at the Granite Springs burn. Total sapling density was significantly reduced ($P<.01$) in the burn when compared with the control. *Pinus jeffreyi*, comprising 85% of the total saplings found at this control location, was reduced significantly ($P<.01$) in the burn. It was also the only sapling tree species encountered in the burn. *Cercocarpus betuloides* appears to have reseeded itself quite well in the burn area during the 1½ years following the burn.

Oakzanita burn

In Table 11, $100m^2$ quadrat measurements taken March 17, 1980 through July 1, 1980, for mean density and relative dominance (based on density) of sapling shrubs and trees are presented for the control and burn areas of the Oakzanita burn. Sapling trees show a significant reduction ($P<.05$) in the burn, even though sapling density was low in the control.

Table 12 summarizes measurements obtained July 9, 1980, for mean density and relative dominance (based on density) of sapling shrubs and trees confronted in $1m^2$ quadrat measurements at the Oakzanita burn. An 88% increase of total sapling density was found in the burn when compared with the control. However, all of these saplings were shrubs and presumable have grown since the fire. There was also an enhancement in the number of species of sapling shrubs and trees occurring in the burn. *Eriogonum fasciculatum* and *Rhus trilobata* are the only species that are common to both control and burn plots. In both cases the density of these shrub saplings increased in the burn. *Eriogonum fasciculatum* was the dominant sapling shrub and comprised approximately 50% of the total density in both the control and burn plots.

Table 10. Mean density and relative dominance (RD, based on density) of sapling shrubs and trees in $100m^2$ control and burn quadrats at the Granite Springs burn, East Mesa, Cuyamaca Rancho State Park. Control K = 29; burn K = 33.

SPECIES		DENSITY (no/ha)	RD (%)
Control			
Pinus jeffreyi		72	84.71
Quercus agrifolia		10	11.76
Quercus kelloggii		3	3.53
	TOTAL	85	
Burn			
Cerocarpus betuloides		3	50.00
Pinus jeffreyi		3	50.00
	TOTAL	6	

K = number of $100m^2$ plots

Table 11. Mean density and relative dominance (RD, based on density) of sapling shrubs and trees in $100m^2$ control and burn quadrats at the Oakzanita burn, East Mesa, Cuyamaca Rancho State Park. Control K = 11; burn K = 15.

SPECIES		DENSITY (no/ha)	RD (%)
Control			
Pinus jeffreyi		9	16.67
Quercus agrifolia		36	66.67
Quercus kelloggii		9	16.67
	TOTAL	54	
Burn			
Cercocarpus betuloides		7	100.00
	TOTAL	7	

K = number of $100m^2$ plots

Table 12. Mean density and relative dominance (RD, based on density) of sapling shrubs and trees in $1m^2$ control and burn quadrats at the Oakzanita burn, East Mesa, Cuyamaca Rancho State Park. Control K = 41; burn K = 40.

SPECIES	DENSITY (no/m^2)	RD (%)
Control		
Eriogonum fasciculatum	0.15	55.56
Eriogonum wrightii	0.05	18.52
Rhamnus californica	0.05	18.52
Rhus trilobata	0.02	7.41
TOTAL	0.27	
Burn		
Eriogonum fasciculatum	1.10	47.21
Lonicera subspicata	0.02	0.86
Rhus trilobata	0.10	4.29
Rosa californica	0.22	9.44
Symphoricarpos parishii	0.82	35.19
Toxicodendron diversiloba	0.07	3.00
TOTAL	2.33	

K = number of $1m^2$ plots

EFFECT OF BURNING ON SEEDLING SHRUBS AND TREES

Paso Picacho burn

Mean density and relative dominance (based on density) of seedling shrubs and trees from 100m^2 quadrat measurements taken June 12, 1980 through July 24, 1980, at the Paso Picacho burn are listed in Table 13. From these data one can see a 62% reduction of the total seedling density within the burn. Nevertheless, the bulk of this decrease is attributed to the significant reduction ($P < .01$) of *Calocedrus decurrens* in the burn site. Seedlings of *Arctostaphylos pungens* and *Ceanothus palmeri* showed a considerable increase in the burn area (approximately 85%).

Quercus agrifolia and *Quercus chrysolepis* both had moderate increases in the burn. This seems paradoxical for *Quercus chrysolepis* because less than half as many mature trees of this species appear in the burn as compared to the control. The 79% increase of *Quercus agrifolia* seedlings in the burn might be credited to the absence of mature trees of this type in the control. Even with the absence of mature trees there were numerous seedlings of *Quercus agrifolia* in the control.

The incidence of *Quercus kelloggii* and *Pinus jeffreyi* seedlings was reduced in the burn slightly. This again is possibly from a species preference for germination in unburned soils (i.e. *Calocedrus decurrens*). This partiality for unburned soils is further substantiated by the existence of considerably greater numbers of mature trees of *Quercus kelloggii* and *Pinus jeffreyi* in the burned areas. One might logically think that the presence of more trees in one area would result in an increase of seedlings in that same area. Nevertheless, this was not

Table 13. Mean density and relative dominance (RD, based on density) of seedling shrubs and trees in $100m^2$ control and burn quadrats at the Paso Picacho burn, West Mesa, Cuyamaca Rancho State Park. Control K = 26; burn K = 30.

SPECIES		DENSITY (no/ha)	RD (%)
Control			
Arctostaphylos pungens		4	0.09
Calocedrus decurrens		3096	72.90
Ceanothus palmeri		31	0.72
Pinus jeffreyi		8	0.19
Quercus agrifolia		27	0.64
Quercus chrysolepis		169	3.98
Quercus kelloggii		912	21.47
	TOTAL	4247	
Burn			
Arctostaphylos pungens		30	1.87
Calocedrus decurrens		287	17.89
Ceanothus palmeri		250	15.58
Pinus jeffreyi		3	0.18
Quercus agrifolia		137	8.54
Quercus chrysolepis		197	12.28
Quercus kelloggii		700	43.64
	TOTAL	1604	

K = number of $100m^2$ plots

found to be the case in the burn location of Paso Picacho.

Table 14 summarizes the mean density of shrub and tree seedlings obtained from $1m^2$ quadrat measurements taken during July 16-22, 1980, in the Paso Picacho burn. All three of the burn samples show a sizeable decrease in seedling density (44.4%) in contrast to the control. These results seem in agreement with the decreases found in the $100m^2$ quadrat measurements.

Granite Springs burn

Mean density and relative dominance (based on density) of seedlings occurring in the $100m^2$ quadrats during July 10-23, 1980, at the Granite Springs burn are presented in Table 15. There was a 76% reduction in total seedling density within the burn area. Although no mature *Ceanothus palmeri* shrubs were present in the burn, a few seedlings of this type were growing there. Mean densities of *Pinus jeffreyi* and *Quercus kelloggii* were significantly reduced ($P < .02$) in the burn areas, 81% and 66% respectively, even though there were more mature trees of these species in the burn. Density of seedlings of *Quercus agrifolia* were significantly reduced ($P < .01$) in the burn plots. This reduction is most likely caused by the complete absence of mature trees of this type in the burn area.

Oakzanita burn

Table 16 presents mean density and relative dominance (based on density) of seedlings growing in $100m^2$ quadrats measured March 17, 1980 through July 9, 1980, at the Oakzanita burn. No significant difference in density of seedlings was found for any of the shrubs and tree species.

Mean seedling density and relative dominance (based on density)

Table 14. Mean density in post-fire establishment of shrubs and tree seedlings in a mixed-conifer woodland following the Paso Picacho prescription burn of April 24-30, 1978, West Mesa, Cuyamaca Rancho State Park.

SITE	K[a]	R[b]	DENSITY (no/m^2)		% CHANGE[c]
Control	40	6	1.39		
A) burn	40	3	0.53		-61.9
B) burn	40	4	0.81		-41.7
C) burn	40	4	0.98		-29.5
				$\bar{X}$	-44.4

a = number of $1m^2$ plots sampled per site
b = number of species per site
c = test - control ÷ control x 100%

Table 15. Mean density and relative dominance (RD, based on density) of seedling shrubs and trees in $100m^2$ control and burn quadrats at the Granite Springs burn, East Mesa, Cuyamaca Rancho State Park. Control K = 29; burn K = 33.

SPECIES		DENSITY (no/ha)	RD (%)
Control			
Pinus jeffreyi		48	2.66
Quercus agrifolia		710	39.31
Quercus kelloggii		1048	58.03
	TOTAL	1806	
Burn			
Ceanothus palmeri		6	1.35
Pinus jeffreyi		9	2.02
Quercus agrifolia		79	17.71
Quercus kelloggii		352	78.92
	TOTAL	446	

K = number of $100m^2$ plots

Table 16. Mean density and relative dominance (RD, based on density) of seedling shrubs and trees in $100m^2$ control and burn quadrats at the Oakzanita burn, East Mesa, Cuyamaca Rancho State Park. Control K = 11; burn K = 4.

SPECIES	DENSITY (no/ha)	RD (%)
Control		
Arctostaphylos pungens	82	2.00
Pinus jeffreyi	18	0.44
Quercus agrifolia	3909	95.34
Quercus kelloggii	91	2.22
TOTAL	4100	
Burn		
Arctostaphylos pungens	25	0.29
Ceanothus palmeri	75	0.88
Quercus agrifolia	5375	62.87
Quercus kelloggii	3075	35.96
TOTAL	8550	

K = number of $100m^2$ plots

from $1m^2$ quadrat measurements taken July 9, 1980, are summarized in Table 17. In this particular area there was a substantial increase (41%) of total seedling density in the burn. Almost all of this total density enrichment is from the prodigious abundance (425% increase) of *Quercus agrifolia* seedlings in the burn plots. Seedlings of all species, Except *Pinus jeffreyi*, exhibited greater density in the burn. *Arctostaphylos pungens* and *Ceanothus palmeri* again show a density increase in the burn as was observed at the Paso Picacho area. The 71% density increase of *Quercus kelloggii* in the burn appears contradictory to what is described at the Paso Picacho and Granite Springs locale.

EFFECT OF BURNING ON HERBACEOUS VEGETATION

Paso Picacho burn

Table 18 lists the mean density of herbaceous plants growing in $1m^2$ quadrats at the Paso Picacho burn measured July 16-22, 1980. There was a considerable increase of herb density within each of the burn samples. The mean percent change of density for the three burn samples was 107.7%. The diversity of the herbaceous vegetation was also greatly enhanced in the burn plots. Burn sample sites B and C contain more than twice as many species as the control does. Burning in this specific area seems to have enriched the amounts and types of herbaceous vegetation even though this effect was measured more than 2 years after the burn.

Oakzanita burn

Table 19 summarizes the mean density of understory herbs in $1m^2$ quadrats at the Oakzanita burn measured July 9, 1980. The total density

Table 17. Mean density and relative dominance (RD, based on density) of seedling shrubs and trees in $1m^2$ control and burn quadrats at the Oakzanita burn, East Mesa, Cuyamaca Rancho State Park. Control K = 41; burn K = 40.

SPECIES		DENSITY (no/m^2)	RD (%)
Control			
Pinus jeffreyi		0.02	1.72
Quercus agrifolia		1.07	92.24
Quercus kelloggii		0.07	6.03
	TOTAL	1.16	
Burn			
Arctostaphylos pungens		0.02	0.34
Eriogonum fasciculatum		0.07	1.18
Ceanothus palmeri		0.10	1.69
Quercus agrifolia		5.62	94.77
Quercus kelloggii		0.12	2.02
	TOTAL	5.93	

K = number of $1m^2$ plots

Table 18. Mean density of herbaceous ground cover in a mixed-conifer woodland following the Paso Picacho prescription burn of April 24-30, 1978, West Mesa, Cuyamaca Rancho State Park.

SITE	K^a	R^b	DENSITY (no/m^2)		% CHANGE[c]
Control	40	11	3.06		
A) burn	40	12	4.54		48.4
B) burn	40	24	7.32		139.2
C) burn	40	23	7.21		135.6
				$\bar{X}$	107.7

a = number of $1m^2$ plots sampled per site
b = number of species per site
c = test - control ÷ control x 100%

Table 19. Mean density of herbaceous ground cover in a mixed-conifer woodland following the Oakzanita prescription burn of December 3, 1979, East Mesa, Cuyamaca Rancho State Park.

SITE	K[a]	R[b]	DENSITY (no/m^2)	% CHANGE[c]
Control	41	21	17.55	
Burn	40	30	13.62	-22.3

a = number of $1m^2$ plots sampled per site
b = number of species per site
c = test - control ÷ control x 100%

of herbs was reduced 22% in the burn, with a concomitant increase in diversity. Thirty species of herbaceous plants were encountered in the burn understory as compared to the 21 species in the control. Although total density was greater in the control, 50% of this density was due to the dominant species (Solidago californica) which was reduced 39% as a result of the burn. Other dominant herbs of the control (Galium andrewsii, Leptodactylon pungens, Mimulus guttatus) were also decreased substantially in the burn.

Mean values of dominance and relative dominance for herbaceous ground cover in the meadow area of the Oakzanita burn during June and July 1980, are presented in Tables 20 and 21. Muhlenbergia rigens is by far the dominant plant in the control area. Approximately 50% of each deergrass bunch in the control was dead, leaving approximately 50% live foliar cover. The burn area reveals the elimination of dead deergrass as a result of fire. Muhlenbergia rigens showed a 51% recovery of live foliar cover in July, 1980. Little or no difference in recovery between the months of June and July 1980 indicates that growth was perhaps slow during this month. Table 22 summarizes the $1m^2$ quadrat measurements taken March 12, 1981 for mean values of dominance and size of deergrass bunches. There are over three times the number of deergrass clumps (bunches) per m^2 in the burn as compared to the control. However, the bunches in the control have over five times as much area as do the burn bunches. Thus, when examining the control bunches, dominance is considerably higher here than in the burn, but since half of this dominance is dead herbage, it can be considered that the deergrass recovered 91% only 15 months after burning.

Table 20. Mean values of dominance (D) and relative dominance (RD) for herbaceous ground cover in meadow at Oakzanita burn, East Mesa, Cuyamaca Rancho State Park, as measured with a point frame on June 17, 1980. Control K = 300; burn K = 300.

SPECIES		D (% Foliar Cover)	RD (%)
Control			
Achillea millefolium		1.67	1.70
Ambrosia psilostachya		2.00	2.10
Bromus tectorum		0.33	0.36
Clarkia purpurea		0.33	0.36
Lotus purshianus		0.67	0.71
Muhlenbergia rigens		53.00	56.80
Poa pratensis		13.33	14.30
Sidalcea malvaeflora		4.67	5.00
Solidago californica		2.67	2.90
Trifolium bifidum		1.30	1.40
Vulpia myuros		13.30	14.30
	TOTAL	93.30	
Burn			
Achillea millefolium		0.67	1.04
Clarkia purpurea		2.67	4.17
Epilobium paniculatum		0.30	0.52
Juncus sp.		0.67	1.04
Lotus pershianus		2.67	4.17
Muhlenbergia rigens		16.00	25.00
Poa pratensis		4.30	6.77
Sidalcea malvaeflora		3.00	5.21
Solidago californica		9.00	14.06
Trifolium bifidum		2.30	3.65
Vulpia myuros		22.00	34.38
	TOTAL	64.00	

K = number of points measured

Table 21. Mean values of dominance (D) and relative dominance (RD) for herbaceous ground cover in meadow at Oakzanita burn, East Mesa, Cuyamaca Rancho State Park, as measured with a point frame on July 16, 1980. Control K = 300; burn K = 300.

SPECIES	D (% Foliar Cover)	RD (%)
Control		
Achillea millefolium	2.67	3.11
Ambrosia psilostachya	1.00	1.20
Juncus sp.	1.00	1.20
Clarkia purpurea	0.67	0.78
Delphinium parryi	0.33	0.38
Epilobium paniculatum	0.33	0.38
Gnaphalium palustre	1.33	1.55
Lotus purshianus	5.67	6.62
Muhlenbergia rigens (live)	30.33	35.49
Muhlenbergia rigens (dead)	28.00	32.69
Orthocarpus attenuatus	0.33	0.38
Poa pratensis	5.67	6.62
Sidalcea malvaeflora	1.67	1.95
Solidago californica	2.33	2.72
Vulpia myuros	4.33	5.05
TOTAL	85.66	
Burn		
Achillea millefolium	1.00	1.48
Clarkia purpurea	1.67	2.48
Delphinium parryi	0.33	0.49
Epilobium paniculatum	0.33	0.49
Gnaphalium palustre	1.00	1.48
Lotus purshianus	4.66	6.92
Melica imperfecta	6.00	8.91
Muhlenbergia rigens (live)	15.33	22.70
Poa pratensis	1.67	2.49
Poa scabrella	1.67	2.49
Sidalcea malvaeflora	3.66	5.43
Sitanion hystrix	1.00	1.48
Solidago californica	7.67	11.39
Trifolium bifidum	1.00	1.40
Vulpia myuros	20.33	30.19
TOTAL	67.32	

K = number of points measured

Table 22. Mean values for the recovery of *Muhlenbergia rigens* in meadow at Oakzanita burn, East Mesa, Cuyamaca Rancho State Park, from $1m^2$ quadrat measurements taken March 12, 1981. Control K = 15; burn K = 15.

SITE	CLUMPS (no/plot)	AREA/CLUMP (m^2)	TOTAL BASAL AREA (m^2)	DOMINANCE (% Basal Area)
Control	4.13	0.017	1.05	7.0
Burn	12.93	0.003	0.48	3.2

K = number of $1m^2$ plots

Mean values of dominance and relative dominance for herbaceous ground cover in a small meadow at the north end of the Oakzanita burn are presented in Table 23. There was a sharp change in the dominance and species of herbs in the control and burn areas in this meadow. The dominant plant in the control was Vulpia myuros, while the burn contained mostly the perennial, Melica imperfecta (RD of 92.7%).

Satellite burns

Mean values for the recovery of Muhlenbergia rigens in the satellite prescription burn (April 4, 1980) near the Oakzanita burn are presented in Tables 24, 25, and 26, with measurements taken in May, June, and July 1980, respectively. Muhlenbergia rigens recovered 21% by May 1980, 90% by June 1980, and 143% by July 1980 (Fig. 18). This clearly demonstrates the ability of deergrass to recover very rapidly after a fire.

Mean values for the recovery of Muhlenbergia rigens in the other satellite burn (December 1978) located near Granite Springs are summarized in Table 27. Within these $150m^2$ quadrats, there were more than three times as many deergrass clumps in the burn in contrast with the control. The control bunches, however, have over four times the area per bunch as do the burn bunches. Assuming that half of the control dominance is dead herbage, the burn has recovered 145% of the live foliar cover within 1½ years following burning. In all instances, burning increases the number of clumps and reduces the size of each clump. This elimination of dead grass would allow increased productivity to occur in the burned areas.

Table 23. Mean values of dominance (D) and relative dominance (RD) for herbaceous ground cover in small north meadow of the Oakzanita burn, East Mesa, Cuyamaca Rancho State Park, as measured with a point frame on July 16, 1980. Control K = 100; burn K = 100.

SPECIES		D (% Foliar Cover)	RD (%)
Control			
Avena barbata		1.00	1.85
Bromus tectorum		1.00	1.85
Lupinus bicolor		1.00	1.85
Vulpia myuros		51.00	94.44
	TOTAL	54.00	
Burn			
Melica imperfecta		76.00	92.70
Sidalcea malvaeflora		1.00	1.22
Vulpia myuros		5.00	6.10
	TOTAL	82.00	

K = number of points measured

Table 24. Mean values for the recovery of *Muhlenbergia rigens* in a satellite burn near the Oakzanita burn, East Mesa, Cuyamaca Rancho State Park, from $20m^2$ quadrat measurements taken May 5, 1980. Control K = 1; burn K = 1.

SITE	CLUMPS (no/plot)	AREA/CLUMP (m^2)	TOTAL BASAL AREA (m^2)	DOMINANCE (% Basal Area)
Control	23	0.199	4.59	22.95
Burn	490	0.001	0.49	2.45

K = number of $20m^2$ plots

Table 25. Mean values of dominance (D) and relative dominance (RD) for herbaceous ground cover in a satellite burn near the Oakzanita burn, East Mesa, Cuyamaca Rancho State Park, as measured with a point frame on June 26, 1980. Control K = 100; burn K = 100.

SPECIES		D (% Foliar Cover)	RD (%)
Control			
Muhlenbergia rigens		41.00	100.00
	TOTAL	41.00	
Burn			
Ambrosia psilostachya		11.00	21.57
Muhlenbergia rigens		37.00	72.55
Vulpia myuros		3.00	5.88
	TOTAL	51.00	

K = number of points measured

Table 26. Mean values of dominance (D) and relative dominance (RD) for herbaceous ground cover in a satellite burn near the Oakzanita burn, East Mesa, Cuyamaca Rancho State Park, as measured with a point frame on July 16, 1980. Control K = 150; burn K = 150.

SPECIES		D (% Foliar Cover)	RD (%)
Control			
Ambrosia psilostachya		3.33	3.55
Muhlenbergia rigens (live)		44.00	46.98
Muhlenbergia rigens (dead)		45.00	48.00
Rosa californica		0.66	0.70
Sidalcea malvaeflora		0.66	0.70
	TOTAL	93.65	
Burn			
Ambrosia psilostachya		2.00	2.78
Muhlenbergia rigens (live)		63.33	87.96
Muhlengergia rigens (dead)		6.00	8.33
Solidago californica		0.67	0.93
	TOTAL	72.00	

K = number of points measured

Fig. 18. Curve for recovery of the live foliar cover of *Muhlenbergia rigens* following fire. Measurements were taken May 5,1980, June 26, 1980, and July 16, 1980.

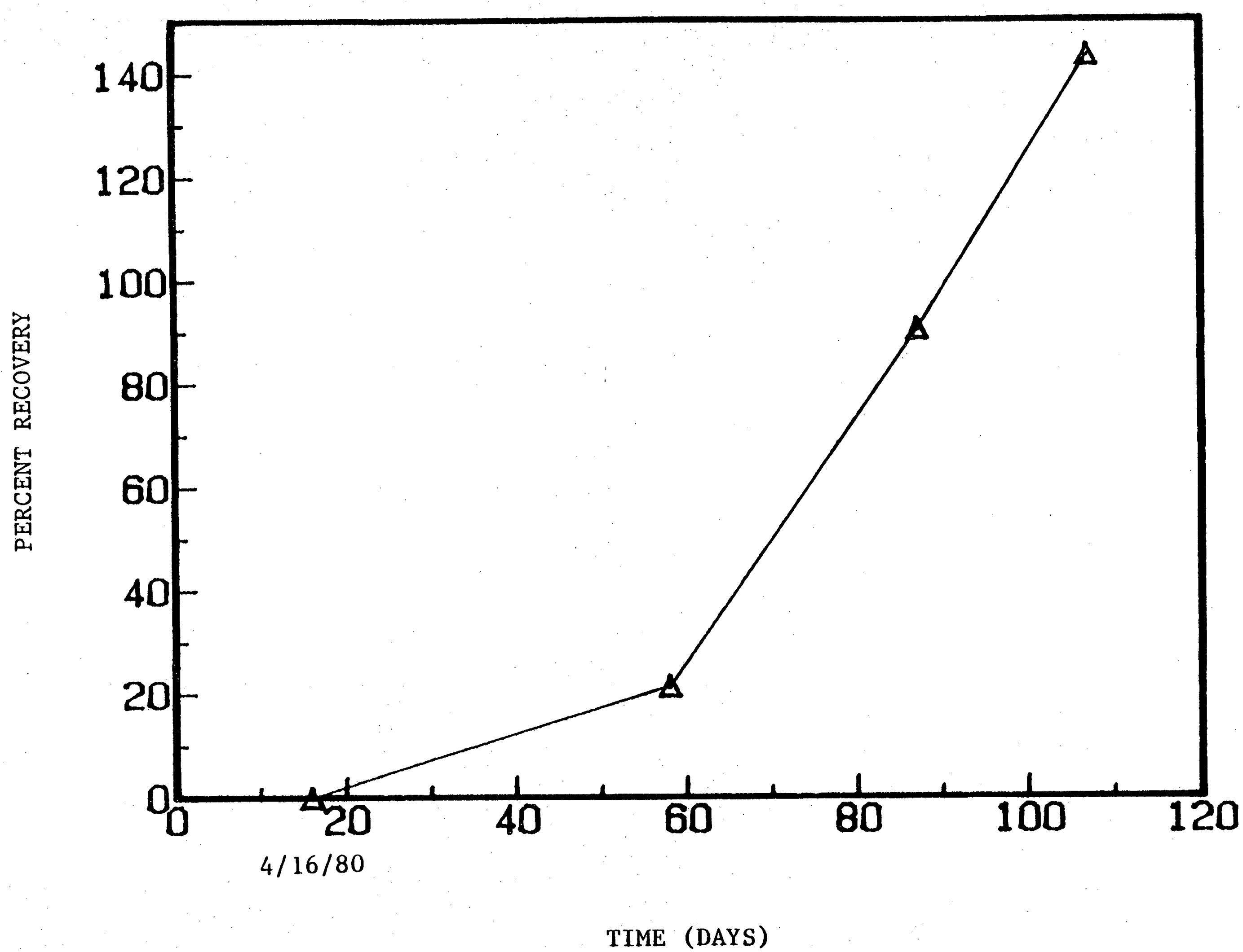

PERCENT RECOVERY
0
20
40
60
80
100
120
140
0
20
40
60
80
100
120
4/16/80
TIME (DAYS)

Table 27. Mean values for the recovery of *Muhlenbergia rigens* in a satellite burn near Granite Springs, East Mesa, Cuyamaca Rancho State Park, from $150m^2$ quadrat measurements taken June 11, 1980. Control K = 1; burn K = 1.

SITE	CLUMPS (no/plot)	AREA/CLUMP (m^2)	TOTAL BASAL AREA (m^2)	DOMINANCE (% Basal Area)
Control	194	0.060	11.72	7.82
Burn	593	0.014	8.04	5.39

K = number of $150m^2$ plots

SUMMARY COMPARISONS BETWEEN THE BURN AREAS

In each of the three study locations in the park, mature shrubs were significantly reduced by the prescribed burning. Total reduction of shrub density and basal area was 93% and 87% respectively (Table 2). Almost all of this reduction is accounted for by the dominant shrub Arctostaphylos pungens. This decrease in shrubs is important considering that there is still significantly fewer shrubs in the burn area 2 years following a fire. Mature trees, however, were not significantly affected by the fire at any of the 3 locations. Total density and basal area of the trees for all 3 burns are very similar (Table 2).

Sapling shrubs and trees were significantly reduced as a result of fire in each burn area. Total reduction in density of saplings for all areas was found to be 94%. Two years following fire, the Paso Picacho burn alone exhibits a 94% reduction.

Seedling shrubs and trees (in each area) decreased considerably in the burn areas at Paso Picacho and Granite Springs, while greatly increasing in the burn at Oakzanita. When total seedling density for all areas is analyzed the control and burn areas are virtually equal.

Mean density of herbaceous vegetation at the Paso Picacho burn increased 107%, while at the Oakzanita burn it decreased 22%. The 107% increase 2 years after fire is important. However, the discrepancy between the two burns might be due to the great abundance of Solidago californica in the control at the Oakzanita burn. Even though the density decreased in the burn area of Oakzanita, the diversity of herbaceous plants in the burn areas of both locations was greatly enriched as a result of fire. There are almost twice as many species of herbs in the burn at the Paso Picacho area when compared to the control. Also, 33% more species were growing in the burn area of Oakzanita when compared to the control.

SUMMARY COMPARISONS BETWEEN DEERGRASS BURNS

The satellite deergrass burn near Granite Springs indicates recovery of Muhlenbergia rigens to be 145% of live foliar cover only 1½ years following fire. The Oakzanita burn meadow has 91% recovery of live foliar cover only 15 months after burning. The highest rate of recovery, however, was seen at the satellite burn near the Oakzanita burn. Muhlenbergia rigens recovered 143% of the live foliar cover only 3 months following the fire at this site.

DISCUSSION

The results of this study are helpful to the understanding of the effects of fire on vegetation. Stone (1965) stated that drastic changes in composition of many plant communities in national parks have occurred over the last 50 years due to fire-exclusion policies. Prescription (controlled) burning should help forests and other communities to restore and maintain their natural composition.

THE MIXED-CONIFER WOODLANDS

The possibility that shrubs are invading the woodland areas of Cuyamaca Rancho State Park as a result of fire exclusion is supported by previous research. Biswell (1974) states that some non-sprouting shrubs (*Ceanothus spp*. and *Arctostaphylos spp*.) move slowly into stands of resident grasses in woodland areas. If sufficient rain falls and if grass density is not to great, a few seedlings will survive each year around mature shrubs (Schultz et al., 1955). Eventually these shrubs will completely invade areas previously occupied by grass. Non-sprouting shrubs, however, are very sensitive to fire. Frequent fires in these shrub invaded areas could possibly reestablish the original grassland understory. If aggressive non-sprouting shrubs are not checked by fire, they lead the way for less aggressive sprouting shrubs (Biswell, 1974).

A 93% reduction of *Arctostaphylos pungens* as a result of prescription burning was seen in the burn areas of this study. Biswell and Schultz (1958) also found a 93% reduction of manzanita from a prescription burn conducted in a ponderosa pine forest. However, the present study did not find the numerous manzanita seedlings the following year after the burn as reported by Biswell and Schultz. Arctostaphylos pungens seedlings were very infrequent in all control and burn areas of Cuyamaca Rancho State Park. Unlike other species of manzanita (Vogl and Schorr, 1972), Arctostaphylos pungens does not produce numerous seedlings as a result of prescribed burning.

The reduction of less dominant shrub species (Arctostaphylos glandulosa, Ceanothus leucodermis, Ceanothus palmeri, Cercocarpus betuloides, Quercus dumosa, Rhamnus californica) in the burn areas should also be expected from these prescribed burns. Unlike Arctostaphylos pungens, however, these shrubs are sprouters and therefore are recovering slightly (Figs. 19, 20, & 21). The presence of Ceanothus leucodermis, Ceanothus palmeri, and Cercocarpus betuloides might improve site conditions by increasing soil nitrogen (Hellmers and Kelleher, 1959; Vlamis et al., 1964). Considerable increases of Ceanothus palmeri seedlings found in burn areas indicate stimulated germination by fire (Went et al., 1952; Stone and Juhren, 1953; Quick, 1959).

The ability of mature trees to withstand the low intensity fire of a prescribed burn was demonstrated in this study. No significant difference in tree density or basal area was found between the control and burn areas. Vogl and Schorr (1972) assumes that frequent burning in the upper elevations of the San Jacinto Mountains would favor pines over the manzanita chaparral. Periodic burning in the mixed-conifer woodlands of Cuyamaca Rancho State Park could also favor the pine and oak trees over Arctostaphylos pungens.

Seedlings of Pinus jeffreyi decreased in density in each of the Cuyamaca burn areas when compared with the controls. Biswell and

Fig. 19. Sprouting _Arctostaphylos glandulosa_ only 15 months after being topkilled by the Oakzanita prescription burn. Photograph was taken in March, 1981.

Fig. 20. Sprouting _Ceanothus palmeri_ only 15 months after being topkilled by the Oakzanita prescription burn. Photograph was taken March, 1981.

Fig. 21. Sprouting *Rhamnus californica* only 15 months after being topkilled by the Oakzanita prescription burn. Photograph was taken March, 1981.

Schultz (1958) found that multiple, prescribed burns done during spring in ponderosa pine can result in large numbers of pine seedlings in burned areas. Possibly, additional burning in mixed-conifer woodlands of Cuyamaca Rancho State Park during spring (instead of winter) would assist pine seedling growth. Vlamis et al. (1956) found that pine seedlings growing in burned soils showed nearly 50% increases in weight over the seedlings growing in unburned soils. Pine seedlings tend to establish themselves after a burn in "hot spots" where burning was intense. These spots are free from competition of grasses long enough to allow seedlings to survive subsequent fires (Weaver, 1951).

Seedlings of Calocedrus decurrens were significantly reduced in the burn area of the Paso Picacho burn when compared to the control. The seedlings of this species of tree clearly prefer unburned soils.

There was an increase of herbaceous ground cover in the burn sites of woodland understories at Paso Picacho. Biswell (1974) states that increases of this nature may be caused by consumed shrub cover, removal of phytotoxins, a seed bed high in nutrients, and reduced competition with the shrubs result from fire.

THE GRASSLAND VEGETATION

The effect of fire on the grasses and herbaceous plants of meadow areas in this study have shown that these non-woody plants recover very quickly after burning. Initially there was a complete removal of the above ground parts of this type of vegetation in burned areas which resulted from the burning of the highly accumulated dead plant matter. Compaction of dead vegetation in grasslands is not as great as woodland areas, therefore decomposition is less. The high levels of dead flammable herbage before burning is attributed to the low decomposition and rapid growth of these herbaceous plants (Vogl, 1974). The fires of the grasslands tend to be flashy, with the heat well above the ground. Soil surface temperatures of these fires seldom rise above 100° C, which is much less than the temperatures found in forest fires (Daubenmire, 1968).

The increased productivity of Muhlenbergia rigens found in burned areas of this study corresponds to results of previous research. Most studies report growth increases of grassland vegetation within 1 or 2 years after burning (Dix and Bulter, 1954; Kelting, 1957; Duvall, 1962; Kucera and Ehrenreich, 1962; Hilmon and Hughes, 1965; Hulbert, 1969; Lloyd, 1972). The increased production of deergrass is probably caused by the removal of dead litter. Other studies point out that denudation of grassland study sites, whether caused by clipping or burning, resulted in increased productivity (Duvall, 1962; Hulbert, 1969; Lloyd, 1972). Deergrass growth could also have been stimulated by the blackened soil after burning. After a fire, the blackened and unshaded soil is considerably warmer in comparison to unburned areas. This would allow foliage to grow earlier in the season and increase total production (Kelting, 1957; Kucera and Ehrenreich, 1962; Hilmon and Hughes, 1965; Daubenmire, 1968).

The substantially higher recovery rate of live foliar cover found at the satellite deergrass burn near the Oakzanita burn (143% in 3 months) could be due to the date that the burn was conducted. There is a fair amount of evidence that prescribed burns in grasslands are more beneficial when applied in the spring time. Hilmon and Hughes (1965) found late winter or early spring burns were more productive than fall or early winter burns. The Oakzanita burn meadow and the satellite deergrass burn near Granite Springs were both burned during winter, while the satellite deergrass burn near Oakzanita was burned in early spring. Prescribed burning done during fall or early winter can also allow problems with erosion due to the denuded soil during the rainy season (Trlica and Schuster, 1969).

Figure 22 shows that the burned deergrass sites of this study appear to have more seedstalks than unburned sites. Other studies related to burning in grasslands indicate increased new growth of grass inflorescences as a result of fire stimulation (Biswell and Lemon, 1943; Dix and Bulter, 1954; Kucera and Ehrenreich, 1962; Hilmon and Hughes, 1965).

Animals often prefer the fresh forage of burned areas because of the higher protein and mineral content of post-burn grass shoots (Kelting, 1957; Hilmon and Hughes, 1965; Daubenmire, 1968; Penfound, 1968). Older and coarse bunches of Muhlenbergia rigens are less palatable to deer, or other grazers, than the new foliage of younger clumps created by burning (Crampton, 1974). The rate of recovery for mulch structure of grasses is usually 100% within 1 to 4 seasons (Dix, 1960; Duvall, 1962). Therefore, burning every few years would rejuvinate fresh growth of deergrass.

Balls (1962) states that the Indian tribes of southern California used Muhlenbergia rigens extensively in making the foundation of their coiled basketwork. A small bunch of deergrass was bound with a strand of squaw bush (Rhus trilobata) to form a coil in the basket being made.

Fig. 22. Seedstalk production of Muhlenbergia rigens 12 months following fire. Control bunches are located in the foreground; burn bunches are situated in the center of photograph. Photograph was taken in March, 1981.

Sometimes Indian women would travel 20 miles to gather this grass, which had to be collected when it is not too green nor overripe. North American Indians used fire to facilitate collection and increase production of useful plants (Sauer, 1950; Biswell, 1974). It is quite possible that the Cuyamaca Indians also burned meadow and woodland areas to increase fresh production of *Muhlenbergia rigens* and *Rhus trilobata*.

CONCLUSION

The results of this study verified the hypotheses that woodland shrubs were significantly reduced as a result of prescribed burning and that bunch grass productivity was also stimulated by fire.

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APPENDICES

Appendix A: Plants of Cuyamaca Rancho State Park.

Family/Genus and Species	Common Name
Agavaceae	
Yucca schidigera	Mohave Yucca
Yucca whipplei	Our Lord's Candle
Amaryllidaceae	
Bloomeria crocea	Golden Stars
Brodiaea orcuttii	Brodiaea
Dicholestemma pulchellum	Wild-Hyacinth
Anacardiaceae	
Rhus laurina	Laurel Sumac
Rhus ovata	Sugar Bush
Rhus trilobata	Squaw Bush
Toxicodendron diversiloba	Poison-Oak
Apiaceae	
Apium graveolens	Celery
Lomatium vaseyi	
Osmorhiza chilensis	Sweet-Cicely
Sanicula bipinnatifida	Purple Sanicle
Asclepiadaceae	
Asclepias albicans	Milkweed
Asclepias eriocarpa	Milkweed
Asclepias fascicularis	Milkweed
Aspidiaceae	
Athyrium filix-femina	Lady Fern

Appendix A cont'd.

Family/Genus and Species	Common Name
Asteraceae	
Achillea millefolium	Yarrow
Agoseris heterophylla	Mountain Dandelion
Agoseris retrorsa	Mountain Dandelion
Ambrosia psilostachya	Western Ragweed
Artemisia douglasii	Sagebrush
Artemisia dracunculus	Sagebrush
Artemisia ludoviciana	Sagebrush
Artemisia tridentata	Basin Sagebrush
Baccharis glutinosa	Mule Fat
Chaenactis glabriuscula	
Chrysothamnus nauseosus	Rabbit-Brush
Cichorium intybus	Chicory
Cirsium tioganum	Thistle
Conyza canadensis	Horseweed
Corethrogyne filaginifolia	
Erigeron foliosus	Fleabane
Eriophyllum confertiflorum	Golden-Yarrow
Gnaphalium californicum	Cudweed
Gnaphalium microcephalum	Cudweed
Gnaphalium palustre	Cudweed
Gnaphalium ramosissimum	Cudweed
Grindelia hallii	Gum-Plant

Appendix A cont'd.

Family/Genus and Species	Common Name
Asteraceae cont'd	
Gutierrezia bracteata	Matchweed
Gutierrezia sarothrae	Matchweed
Haplopappus arborescens	
Haplopappus cuneatus	
Haplopappus parishii	
Haplopappus pinfolius	Pine-Bush
Haplopappus squarosus	
Helenium bigelovi	Sneezeweed
Helianthus gracilentus	Sunflower
Hymenothrix wrightii	
Hypochoeris radicata	Cat's Ear
Lasthenia chrysostoma	Goldfield
Madia elegans	Tarweed
Matricaria matricarioides	Pineapple Weed
Microseris linearfolia	
Perezia microcephala	
Senecio ganderi	Groundsel
Solidago californica	California Goldenrod
Stephanomeria virgata	
Wyethia ovata	
Berberidaceae	
Berberis pinnata	Barberry

Appendix A cont'd.

Family/Genus and Species	Common Name
Betulaceae	
Alnus rhombifolia	White Alder
Boraginaceae	
Amsinckia intermedia	Fiddleneck
Cryptantha affinis	
Plagiobothrys nothofulvus	Popcorn Flower
Brassicaceae	
Arabis pulchra	Rock-Cress
Arabis sparciflora	Rock-Cress
Barbarea orthoceras	Winter-Cress
Brassica nigra	Black Mustard
Erysimum capitatum	Wallflower
Lepidium virginicum	Peppergrass
Rorippa nasturtium-aquaticum	Water-Cress
Thysanocarpus curvipes	Lace-Pod
Cactaceae	
Echinocereus engelmannii	Hedgehog Cactus
Opuntia phaecantha	Cholla
Caprifoliaceae	
Lonicera subspicata	Honeysuckle
Sambucus caerulea	Elderberry
Sambucus mexicana	Elderberry
Symphoricarpos mollis	Snowberry

Appendix A cont'd.

Family/Genus and Species	Common Name
Caprifoliaceae cont'd	
<u>Symphoricarpos parishii</u>	Snowberry
Caryophyllaceae	
<u>Silene laciniata</u>	Catchfly
Chenopodiaceae	
<u>Chenopodium album</u>	White Pigweed
<u>Chenopodium fremontii</u>	Goosefoot
Convolvulaceae	
<u>Calystegia fulcrata</u>	Morning-Glory
Cornaceae	
<u>Cornus occidentalis</u>	Dogwood
Crassulaceae	
<u>Dudleya pulverulenta</u>	Live-Forever
Cucurbitaceae	
<u>Cuscuta sp.</u>	Dodder
<u>Marah macrocarpus</u>	Wild Cucumber
Cupressaceae	
<u>Calocedrus decurrens</u>	Incense-Cedar
Cyperaceae	
<u>Carex sp.</u>	Sedge
<u>Cyperus niger</u>	Umbrella Sedge
<u>Scirpus acutus</u>	Hard-Stem Bulrush
<u>Scirpus microcarpus</u>	Bulrush

Appendix A cont'd.

Family/Genus and Species	Common Name
Datiscaceae	
Datisca glomerata	
Equisetaceae	
Equisetum laerigatum	Horsetail
Ericaceae	
Arctostaphylos glandulosa	Eastwood Manzanita
Arctostaphylos pungens	Mexican Manzanita
Rhododendron occidentale	Western Azalea
Euphorbiaceae	
Eremocarpus setigerus	Turkey-Mullein
Euphorbia polycarpa	Spurge
Fabaceae	
Astragalus deanei	Locoweed
Astragalus oocarpus	Locoweed
Lathyrus splendens	Pride of California
Lotus argophyllus	Bird's Foot Trefoil
Lotus purshianus	Bird's Foot Trefoil
Lotus scoparius	Deerweed
Lupinus adsurgens	Lupine
Lupinus agardhianus	Lupine
Lupinus bicolor	Lupine
Lupinus concinnus	Lupine
Lupinus densiflora	Lupine

Appendix A cont'd.

Family/Genus and Species	Common Name
Fabaceae cont'd	
Lupinus excubitus	Lupine
Lupinus latifolius	Lupine
Lupinus polycarpus	Lupine
Psoralea macrostachya	Psoralea
Psoralea rigida	Psoralea
Thermopsis macrophylla	False Lupine
Trifolium albopurpureum	Clover
Trifolium bifidum	Clover
Trifolium ciliolatum	Clover
Trifolium tridentatum	Clover
Vicia americana	Vetch
Fagaceae	
Quercus agrifolia	Coast Live Oak
Quercus chrysolepis	Canyon Oak
Quercus dumosa	Scrub Oak
Quercus kelloggii	California Black Oak
Quercus x morehus	Oracle Oak
Quercus wislizenii	Interior Live Oak
Garryaceae	
Garrya veatchii	Silk-Tassel Bush
Gentianaceae	
Frasera parryi	Green Gentian

Appendix A cont'd.

Family/Genus and Species	Common Name
Geraniaceae	
Erodium cicutarium	Filaree
Hydrophyllaceae	
Nemophila menziesii	Baby Blue-Eyes
Phacelia cicutaria	
Phacelia distans	Wild-Heliotrope
Phacelia heterophylla	
Phacelia imbricata	
Hypericaceae	
Hypericum anagalloides	
Hypericum formosum	
Iridaceae	
Iris missouriensis	Iris
Sisyrinchium bellum	Blue-Eyed Grass
Juncaceae	
Juncus phaeocephalus	Rush
Juncus sp.	Rush
Lamiaceae	
Marrubium vulgare	Horehound
Mentha pulegium	Pennyroyal
Monardella hypoleuca	
Monardella macrantha	
Salvia apiana	White Sage

Appendix A cont'd.

Family/Genus and Species	Common Name
Lamiaceae cont'd	
Salvia sonomensis	Sage
Stachys rigida	Hedge-Nettle
Trichostema parishii	Bluecurls
Liliaceae	
Calochortus albus	Fairy Lantern
Calochortus dunnii	Mariposa Lily
Calochortus invenustus	Mariposa Lily
Calochortus splendens	Mariposa Lily
Chlorogalum parviflorum	Soap Plant
Lilium humboldtii	Humboldt Lily
Linaceae	
Linum lewisii	Flax
Malvaceae	
Sidalcea malvaeflora	Checker
Onagraceae	
Boisduvalia densiflora	
Clarkia purpurea	
Clarkia rhomboidea	
Epilobium paniculatum	Willow Herb
Oenothera hookeri	Evening-Primrose
Camissonia hirtella	
Camissonia ignota	

Appendix A cont'd.

Family/Genus and Species	Common Name
Onagraceae cont'd	
Zauschneria californica	California-Fuschia
Orchidaceae	
Habenaria elegans	Rein Orchid
Paeoniaceae	
Paeonia californica	Peony
Papaveraceae	
Dicentra chrysantha	Golden Ear-Drops
Eschscholzia californica	California Poppy
Pinaceae	
Abies concolor	White Fir
Pinus coulteri	Coulter Pine
Pinus flexilis	Limber Pine
Pinus jeffreyi	Jeffrey Pine
Plantaginaceae	
Plantago pusilla	Plantain
Platanaceae	
Platanus racemosa	Sycamore
Poaceae	
Agropyron parishii	Wheat Grass
Avena barbata	Slender Wild Oats
Briza minor	Quakinggrass
Bromus diandrus	Ripgutgrass

Appendix A cont'd.

Family/Genus and Species	Common Name
Poaceae cont'd	
Bromus marginatus	Brome Grass
Bromus mollis	Soft Chess
Bromus rubens	Foxtail Chess
Bromus tectorum	Cheatgrass
Calamagrostis densa	Reedgrass
Deschampsia danthonioides	Tufted Hairgrass
Elymus glaucus	Ryegrass
Festuca confusa	Fescue
Festuca octoflora	Fescue
Melica imperfecta	Melic
Muhlenbergia rigens	Deergrass
Poa pratensis	Kentucky Bluegrass
Poa scabrella	Bluegrass
Polypogon monspeliensis	Beardgrass
Sitanion hystrix	Squirreltail
Sporobolus airoides	Dropseed
Stipa coronata	Speargrass
Stipa lepida	Speargrass
Stipa pulchra	Speargrass
Vulpia myuros	Fescue
Vulpia bromoides	Fescue

Appendix A cont'd.

Family/Genus and Species	Common Name
Polemoniaceae	
Collomia grandiflora	
Eriastrum saphirinum	
Gilia angelensis	Gilia
Gilia capitata	Gilia
Leptodactylon pungens	
Linanthus androsaceus	
Linanthus bellus	
Linanthus nuttallii	
Polygonaceae	
Eriogonum elongatum	Buckwheat
Eriogonum fasciculatum	California Buckwheat
Eriogonum gracile	Buckwheat
Eriogonum wrightii	Buckwheat
Rumex crispus	Curly Dock
Portulaceae	
Claytonia perfoliata	Miner's-Lettuce
Pteridaceae	
Pellaea mucronata	Bird's Foot Fern
Pityrogramma triangularis	Goldenback Fern
Pteridium aquilinum	Bracken
Ranunculaceae	
Aquilegia formosa	Columbine

Appendix A cont'd.

Family/Genus and Species	Common Name
Ranunculaceae cont'd	
Clematis ligusticifolia	Clematis
Delphinium hesperium	Larkspur
Delphinium parryi	Larkspur
Thalictrum occidentale	Meadow-Rue
Thalictrum polycarpum	Meadow-Rue
Rhamnaceae	
Ceanothus cuneatus	Buck Brush
Ceanothus greggii	California-Lilac
Ceanothus leucodermis	Chaparral Whitethorn
Ceanothus palmeri	Palmer Ceanothus
Ceanothus tomentosus	California-Lilac
Rhamnus californica	Coffeeberry
Rhamnus crocea	Buckthorn
Rhamnus ilicifolia	
Rosaceae	
Adenostoma fasciculatum	Chamise
Cercocarpus betuloides	Mountain-Mahogany
Cercocarpus minutiflorus	Mountain-Mahogany
Fragaria vesca	Strawberry
Heteromeles arbutifolia	Toyon
Holodiscus discolor	Ocean Spray
Potentilla glandulosa	Cinquefoil

Appendix A cont'd.

Family/Genus and Species	Common Name
Rosaceae cont'd	
Potentilla gracilis	Cinquefoil
Prunus ilicifolia	Holly-Leaved Cherry
Prunus virginiana	Western Choke Cherry
Rosa californica	California Rose
Rubus glaucifolius	
Rubus ursinus	California Blackberry
Rubiaceae	
Galium andrewsii	Bedstraw
Galium angustifolium	Bedstraw
Galium aparine	Bedstraw
Salicaceae	
Salix gooddingii	Willow
Salix lasiolepis	Arroyo
Saxifragaceae	
Lithophragma affine	Woodland-Star
Ribes roezlii	Sierra Gooseberry
Scrophulariaceae	
Antirrhinum coulterianum	Snapdragon
Castilleja stenantha	Paint-Brush
Cordylanthus filifolius	Bird's-Beak
Keckiella ternata	Straw
Mimulus cardinalis	Monkey-Flower

Appendix A cont'd.

Family/Genus and Species	Common Name
Scrophulariaceae cont'd	
Mimulus guttatus	Monkey-Flower
Penstemon centranthifolius	Scarlet Bugler
Penstemon heterophyllus	Beard-Tongue
Scrophularia californica	Figwort .
Verbascum thapsus	Common Mullein
Solanaceae	
Datura meteloides	Jimsonweed
Solanum parishii	Nightshade
Typhaceae	
Typha latifolia	Cat-Tail
Urticaceae	
Urtica holosericea	Nettle
Violaceae	
Viola lobata	Violet
Viscaceae	
Arceuthobium californicum	
Phoradendron villosum	Mistletoe