THE EFFECT OF FIRE AND FIRE FREQUENCY ON GRASSLAND SPECIES COMPOSITION IN CALIFORNIA'S TULARE BASIN

by

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During the course of this project, I discovored how truly fortunate I am to have such supportive family and friends. They deserve a special note of appreciation. I acknowledge my dear young daughters, Erica and Natalie, who did without their dad for the time I was unable to share with them. Valerie Gunner. Susan Hansen, Jennifer Hansen, and especially my mother, Janice, came to my rescue numerous times on short notice to watch my children, prepare meals, and help with figure designs. Steven Pool's computer wizardry resulted in the excellent graphics.

Special, loving thanks go to my wife, Debra, for her interest in my work, her encouraging support, and superb typing skill. She endured the vagaries and isolation of the Creighton Ranch Preserve during my eight semesters of absences as a commuting graduate student. She waited a long time for "It's almost done" to come true.

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INTRODUCTION

Natural grasslands (Spedding 1971) have intrinsic value as watershed covers and habitat for native plants and animals (Vogl 1979). California's San Joaquin Valley has seen a tremendous loss of natural grassland. In less than two centuries, 5,350,000 acres (2,166,750 ha) were converted to irrigated agriculture, 150,000 acres (60,750 ha) to dry-farmed grain (an artificial grassland), and most of the remainder to grazing land (Smith 1982). The composition of these natural Valley grasslands underwent such rapid change that their former condition will always be open to debate (Wester 1981). The original drought-prone grasslands were overgrazed by too many livestock (Dasmann 1964). Unlike the stable, perennial grasslands of the Great Plains, a strongly fluctuating annual grassland is California's trademark (Beetle 1947). Most experts agree that dry interior valleys like the Tulare Basin (Figure 1), had only scattered perennial grasses. According to Bartolome (1981), "Native annual grasses occupied the spaces between, fluctuating in abundance with the years and the seasons as do the introduced annuals now."

This description is supported by a current account of the Creighton Ranch Preserve by Griggs (1983), in which he lists the native bunch grass, Poa scabrella, as rare in a

Figure 1. Tulare Basin
Map Source: Tulare Basin Protection Plan. Werschkull, et al. 1984.

grassland dominated by Hordeum depressum, a native annual barley.

Fire is important in many vegetation types in California, but there is no information on the frequency of naturally occurring grassland fires prior to the arrival of man in this area. Native peoples of the Valley burned the grassland intermittently for various reasons, but there is no accurate information on fire frequency prior to European settlement. Rapid growth of the human population of the San Joaquin Valley, beginning in the 1850s, ushered in an era of fire suppression which continues to this day. Most fires in the Tulare Basin today are agricultural burns. The long neglected use of fire in native grassland management and preservation (Vogl 1979) has only taken place during the last 20 years in this area. Compared to fire research in forests, the study of grassland burning is still in its infancy.

Sufficient research has been conducted in other grassland regions of the world to make predictive statements about the ecological effects of fire on their local grasslands. Remnant grasslands in the Tulare Basin are rapidly being lost to agriculture and urban development. Less that 2% of the original 268,945 ha of grassland remained in the Tulare Basin in 1983 (Werschkull et al. 1984). The forecast of rapid population growth in this area lends a sense of urgency to grassland protection. Managers of Federal, State and private grassland preserves stand to benefit from knowledge of fire's effect on their particular sites because management practices that duplicate the natural processes inherent to a given region are inexpensive and are the most likely to succeed (Vogl 1979).

A comment by Oberbauer (1982) summarizes the need to protect natural diversity of local grasslands:

> What is really needed is a complete experimental study involving a series of control plots burned at different intervals. Such a program would give a general idea on the impacts that could occur, and also information as to what species may be adversely affected by burning.

The objectives of this study are to determine the effects (beneficial and adverse) of fire and various fire frequencies on: (a) diversity, (b) percent composition of grasses, legumes and forbs (other than legumes), (c) percent composition of native vs. alien species, and (d) percent composition of individual species.

METHODS

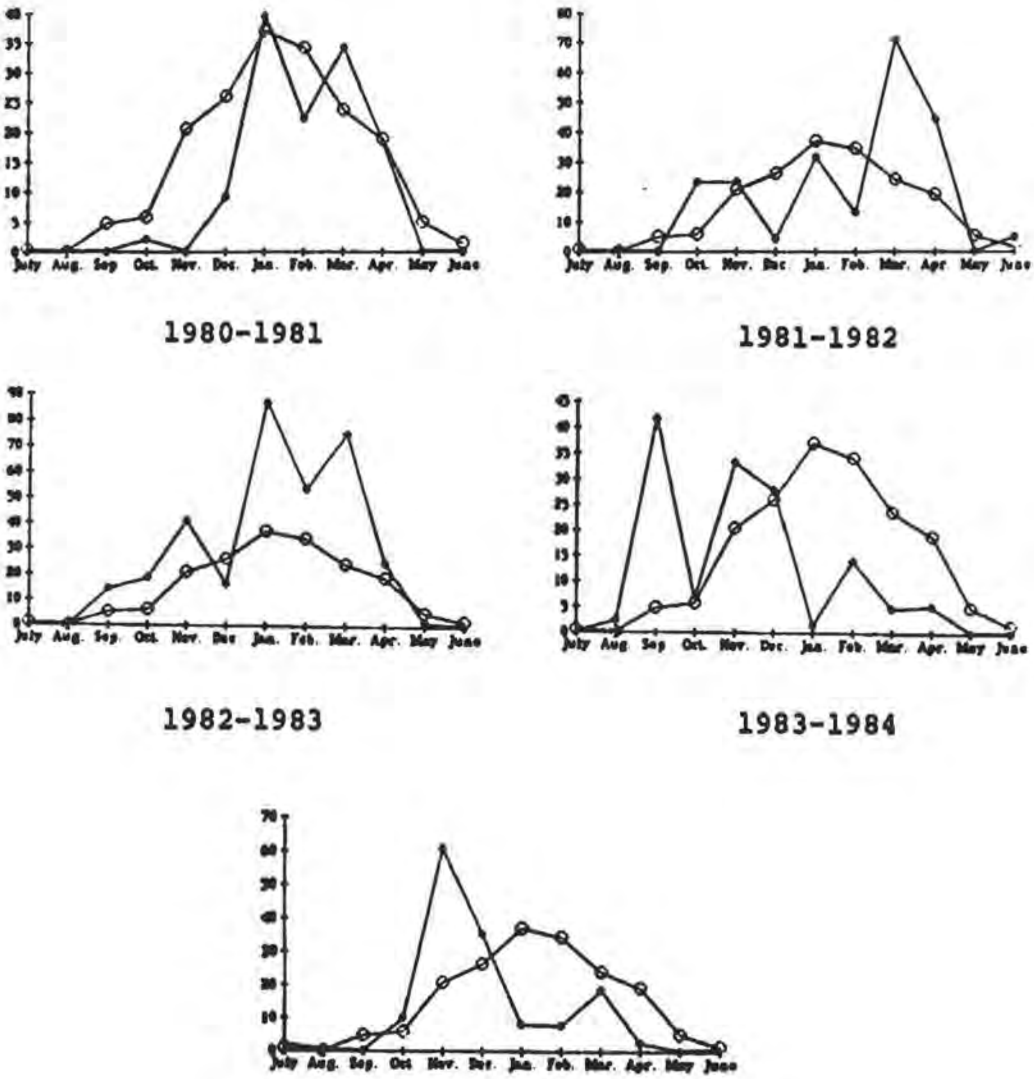
Study Sites

The two sites selected for this study were established at the 1328 ha Creighton Ranch Preserve (CRP) and the 16 ha Pixley Vernal Pools Preserve (PVPP). Both Tulare Basin sites are managed by The Nature Conservancy. PVPP, with 25 to 75 vernal pools, was acquired as a research reserve in 1964 (Bakker 1972). CRP also has a number of vernal pools near its northern border but it was the alkaline grassland surrounding these pools at both sites that was the focus of this study. Alkaline grassland, reduced to less than 3% of its former extent, once covered 91,650 ha in the Tulare Lake Basin (Werschkull et al. 1984). Permanent, private preserves like CRP and PVPP provide excellent remnant examples of this vegetation type for long-term studies.

CRP (36°02'N, 119°28'W) is located on the western edge of Tulare County at an elevation of 70-74 m and comprises portions of 6 sections in T21S, R23E MDB&M. All sampling at CRP was done in Section 22; this high ground at the northern edge of the preserve is above the high water line of nearby Tulare Lake. PVPP (35°59'N, 119°12'W) is located 25 km ESE of CRP at an elevation of 105-107 m. It comprises the NW 1/4 of SW 1/4 Section 30, T22S, R26E MDB&M.

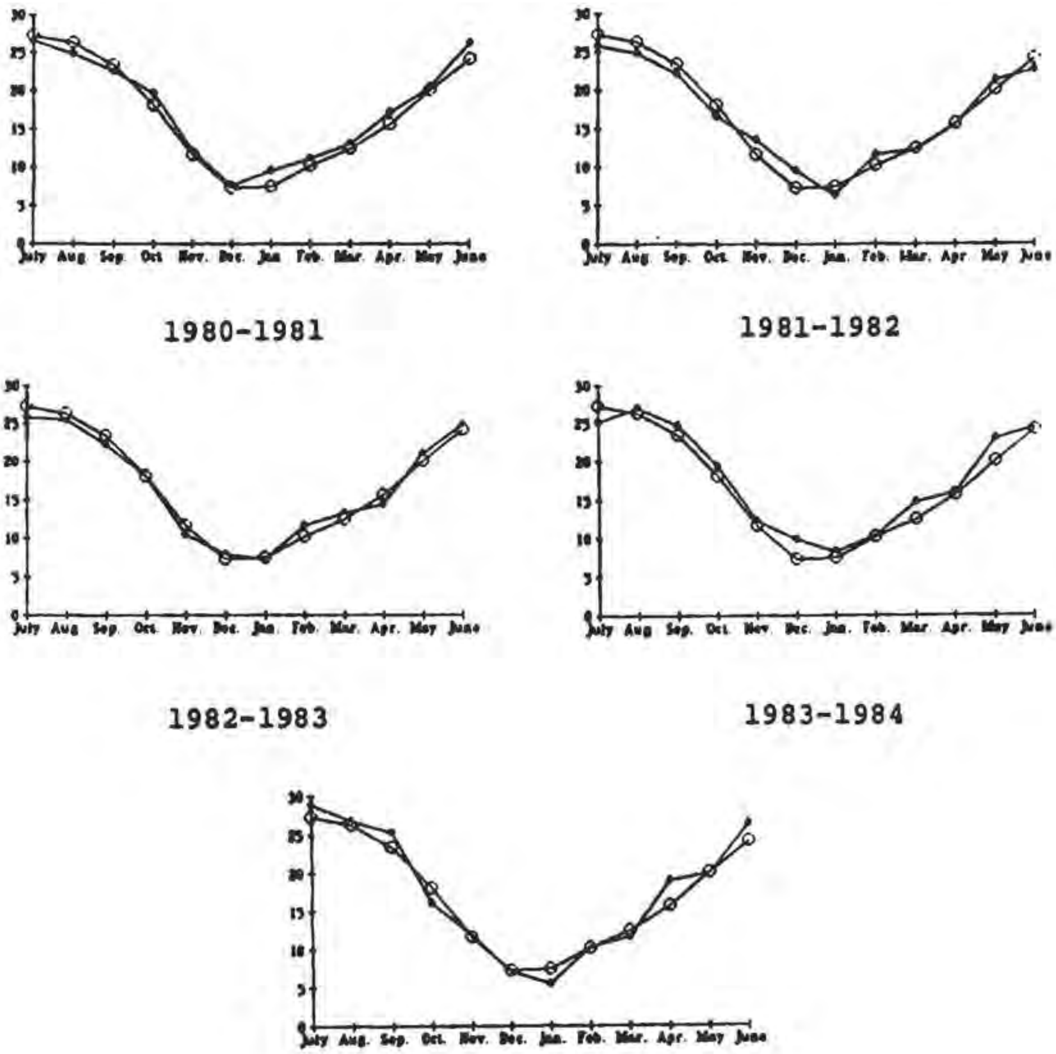
The study area has a Mediterranean climate with long, hot, dry summers and cool, wet winters (Biswell 1956). The rainy season in the Tulare Basin begins in the fall, September to November, when enough precipitation (12.5 mm) occurs to stimulate germination of annual plants (Duncan and Woodmansee 1975). Precipitation usually ends in April, with approximately two-thirds of the annual total falling between December and March (Figure 2). Seasonal totals average about 176 mm, with extremes during this study of 124 to 328 mm. When annual precipitation drops much below the seasonal average of 176 mm, this portion of Tulare Basin experiences a desert climate. Tulare Basin and Mojave Desert rainfall totals are nearly identical, but the Mojave Desert lacks the winter tule fogs which are a characteristic feature of the low-lying Tulare Basin. These dense ground fogs have a moderating climatic influence on local vegetation.

Summer daytime high temperatures frequently exceed 40°C. Freezing temperatures are unusual but can occur at night during the cooler winter months. The warmest part of the year is June through September and the coolest part is December through February (Figure 3). Climatological data were taken from the Corcoran Irrigation District, 9 km west of CRP at 70 m elevation. These data were quite similar to data gathered for two seasons at CRP headquarters. Because PVPP is located on higher ground east of CRP, its



O Average Rainfall in mm.
◆ Actual Rainfall in mm.

Figure 2. Rainfall Averages



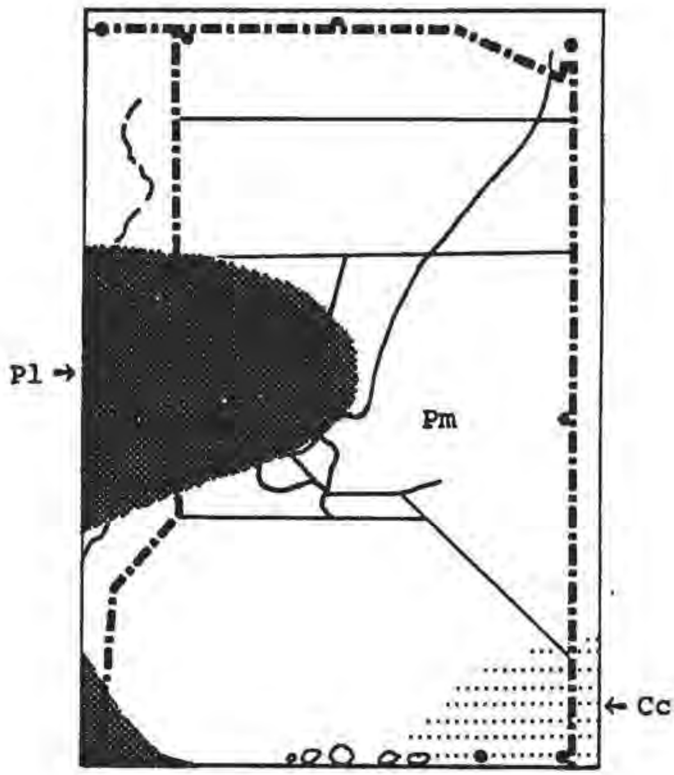
O Average Temperature in C°
◆ Actual Temperature in C°

Figure 3. Temperature Averages

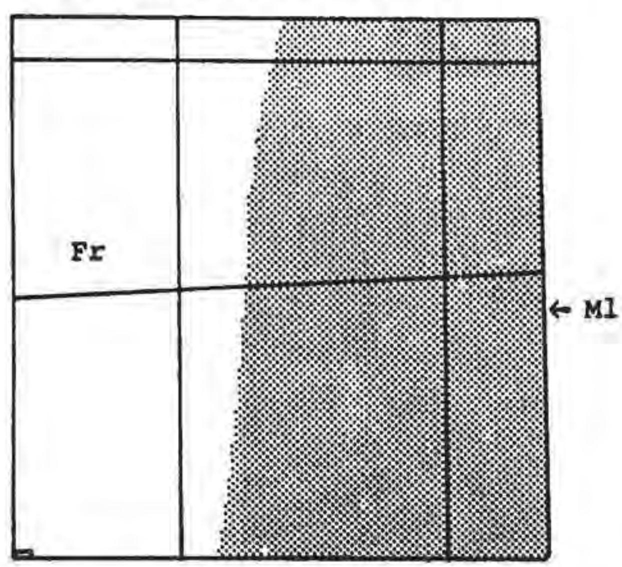
temperatures and rainfall totals are slightly higher on average.

Soils of the Tulare Basin are almost entirely sedimentary, very deep and usually alkaline (Twisselman 1967). Soils on the CRP study site are classified as Chino clay loam, Pond loam, and Pond clay loam. The Pond series soil, when dry, is very compact and hard to penetrate. Surface drainage and subdrainage are very poor. All the Pond soils, especially the finer textured types, contain high accumulations of alkali. Pond loam has a low water holding capacity, owing to its impervious character. The surface is flat with low mounds, which gives it a faint mima topography. The surface soil and subsoil are highly calcareous and impregnated with alkali. Soils on the PVPP study site are classified as Fresno fine sandy loam and Madera loam. The Madera loam is a noncalcareous soil overlying hardpan.

All five loam soils are either calcareous or else they occur atop a calcareous hardpan. Since drainage of these soils is poor, water stands in the depressions, creating vernal pools during wet winters. Soils at the CRP study site are more alkali than those at PVPP and are predominantly clays (Figure 4).



Creighton Ranch Preserve



Pixley Vernal Pools Preserve

Pond loam (Pl) Pm = Pond clay loam Madera loam (Ml)
Chino clay loam (Cc) Fr = Fresno fine sandy loam

Figure 4. Soil Maps

Vegetation is of the California annual type (Heady 1958). California Natural Diversity Data Base classifies this Tulare Basin vegetation sub-type as alkaline grassland (Werschkull et al. 1984) based on species composition, soil, and climate. Vegetation at both study sites consists almost entirely of native and alien grasses and forbs (Appendix A). Since climatic conditions at both sites are nearly identical, differences in soil type may be responsible for the higher percent cover of grasses at PVPP and the higher percent cover of forbs at CRP. Dominant plant species at both sites are Bromus mollis, Bromus rubens, Hordeum depressum, and Hordeum leporinum (Table 1).

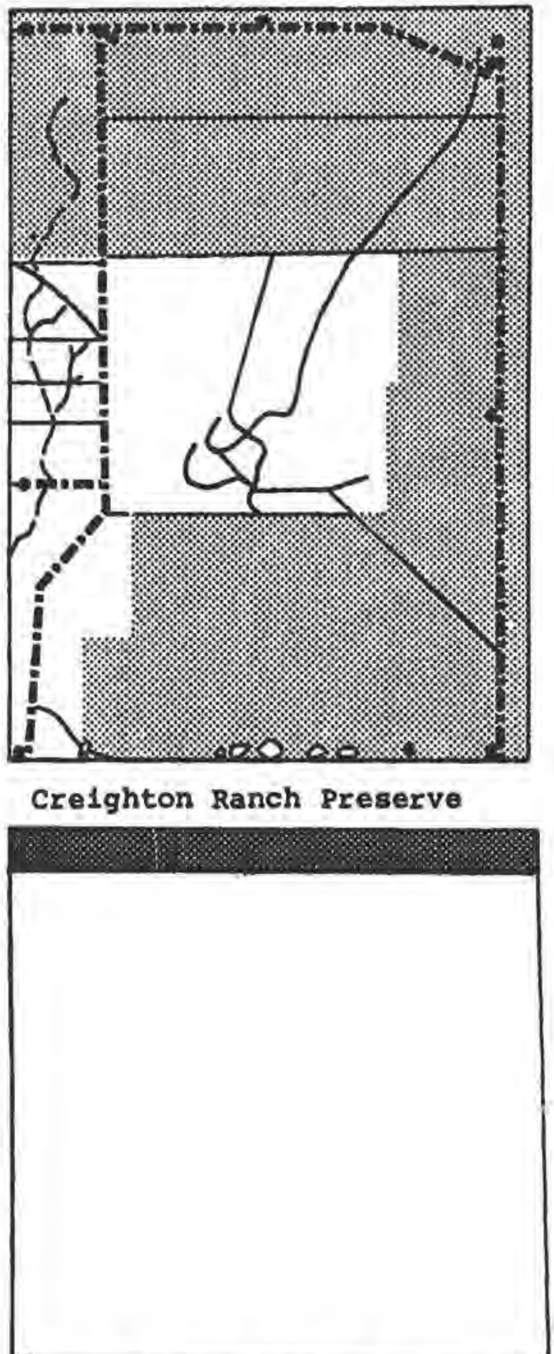
Table 1. Plant Species in Control Plots: Percent Composition.

CRP		PVPP	
*Hordeum depressum	38%	*Bromus mollis	34%
Hordeum geniculatum	15%	*Hordeum leporinum	21%
*Bromus mollis	12%	*Bromus rubens	20%
*Hordeum leporinum	9%	*Hordeum depressum	8%
*Bromus rubens	4%	Vulpia Myuros	6%
	78%		89%

The five most abundant species from each preserve are listed in descending order of abundance. Abundance is calculated as percent composition of data points from all control plots at a given preserve. Species common to both preserves are indicated with an asterisk (*).

Prior to its establishment as a wildlife preserve in 1964, PVPP was never plowed or disced, but a strip of land 31.4 m wide along the northern border (Figure 5) was leveled. According to Jack Zaninovich, an authority on local botany and PVPP history, this leveling probably occurred during the 1930s. Wildfire of unknown origin burned the property ca. 1973. Since no grazing had occurred at PVPP since 1964, that fire was the only major known disturbance at the preserve during the 15-year interval between its establishment and the beginning of this study.

The Nature Conservancy began managing CRP in 1980. Prior disturbance at the study site, Section 22, was associated with cattle grazing operations and a system of groundwater wells and irrigation structures (Figure 5). From 1876 to February, 1980, cattle grazing provided most of the income on grasslands at CRP. An average of 300 to 600 cattle, 900 maximum, grazed the property during wet months. A system of check levees was constructed between 1915 and 1937, approximately 1929, to disperse and control water for irrigated pasture. Cattle loading fences and chutes still stand in the northeast corner of the study site. A system of low levees was constructed in the early 1940s to create a few irregularly shaped waterfowl hunting impoundments. Groundwater pumps, canals and maintenance roads were installed in 1945-1946 to collect and transport irrigation water to the south. A number of dry depressions where



Creighton Ranch Preserve

Pixley Vernal Pools Preserve

old (ca. 1929) check levees (spaced ca. 12 m apart)

• groundwater pump   irrigation canal   low levees

dry reservoir   leveled land

Figure 5. Maps of Historical Disturbance

topsoil was borrowed for levee construction, are located along the southern edge of the site. After 134 years of grazing, CRP is by far the more disturbed of the two sites; intact "cow pies" were still present in the spring of 1986 after the completion of this study. Despite the disturbance, species composition at CRP is similar to that at PVPP.

Prescribed Burning

Prescribed burns were conducted at PVPP during the fall, August to October, in 1980, 1981, and 1983 (Figure 6). A fire of unknown origin burned part of the CRP study site in June, 1981. Prescribed burns were conducted at CRP during the fall, August to October in 1982, 1983, and 1984 (Figure 7). Burns were scheduled in the fall because this is when maximum dryness of the mulch layer (Hedrick 1948) coincides with relative humidity that is higher and temperatures that are cooler than during the summer. This means that fuels are driest and burning conditions are safer at about the time of the first fall rains. Fire behavior data are in Appendix B.

Vegetation Sampling

Relative cover was sampled each year at PVPP (1981 to 1985) and CRP (1982 to 1985) during March (during April in 1985). Burned and unburned plots representing all the various treatments were sampled using the step-point method

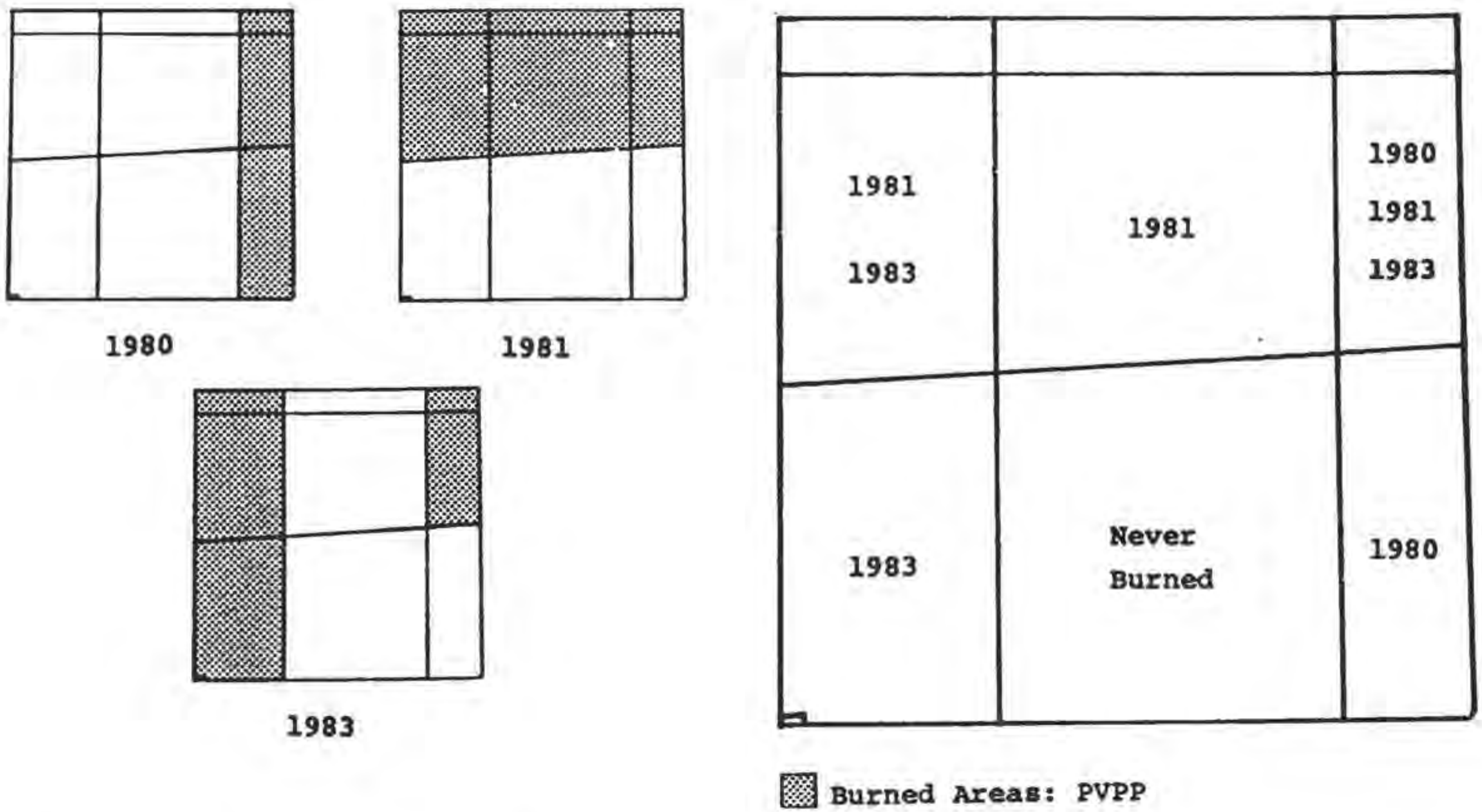


Figure 6. Burn History: PVPP

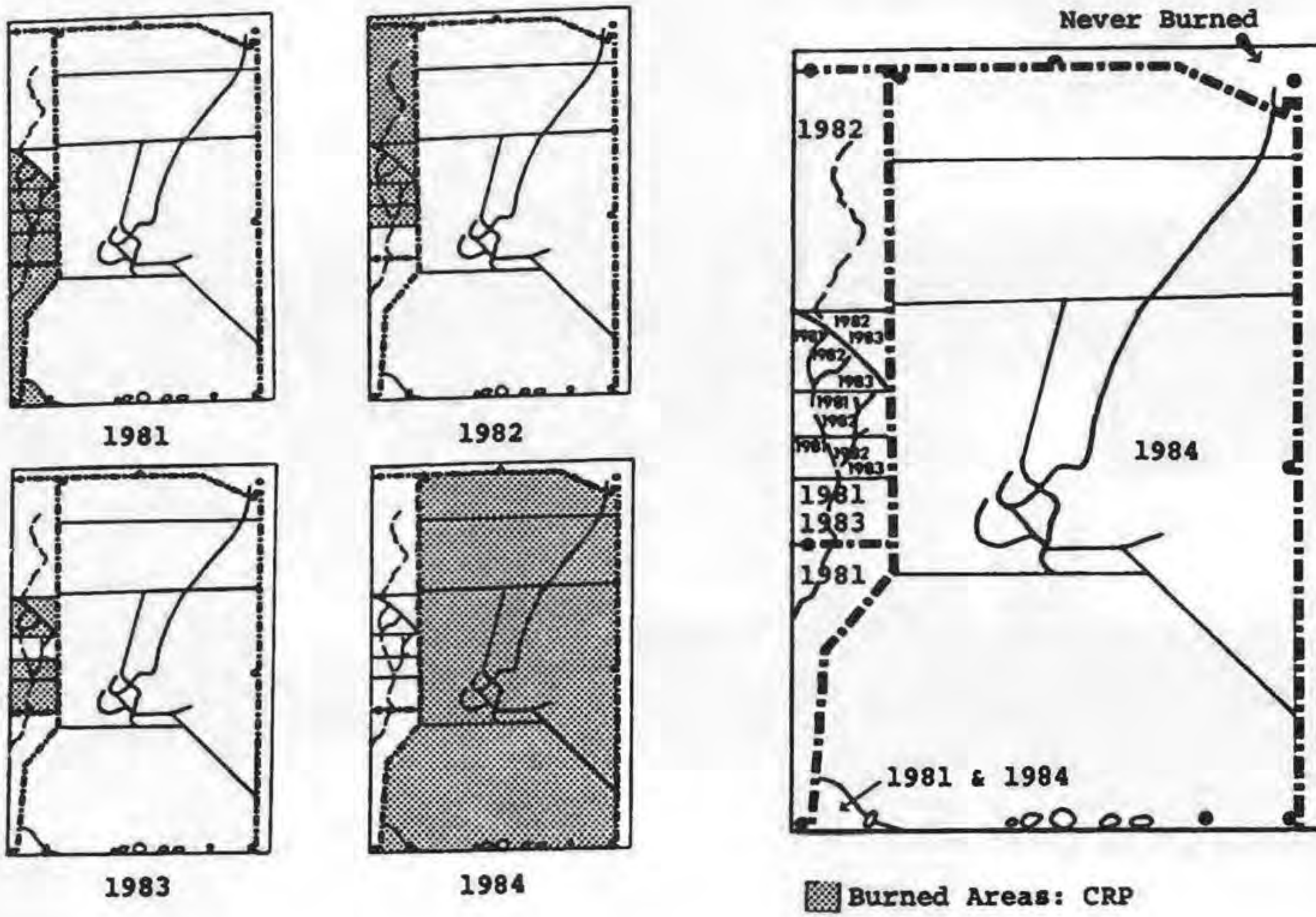


Figure 7. Burn History: CRP

as described by Evans and Love (1957). The plant at the tip of the pointer or the plant rooted nearest the point where the pointer touched the ground was recorded as a hit. Using this method, it was possible to determine the percent composition (relative cover) for each plant species sampled in each treatment plot. A minimum of three transects of 100 points each were conducted in each treatment plot. Species-sample size curves were generated in 1981 at PVPP (Figure 8) and in 1982 at CRP (Figure 9) to determine the number of transects required to adequately sample the species composition of a treatment plot. After running one transect of 100 points, the number of different species in it was counted. Additional transects were run, and the number of newly encountered species was tabulated. This was continued until no additional species were added. Since burn treatments covered areas of varied size, a species-area graph was also generated to determine whether a relationship existed between species number and the size of a treatment plot (Figure 10). When time allowed, more than three transects per treatment were conducted.

Field forms consisted of a list of species present with columns for each transect within a treatment plot. At PVPP, three burns and five sampling seasons generated 17 different burn treatments and five unburned controls. At CRP, four burns and four sampling seasons generated 17 different burn treatments and four unburned controls (Appendix C).

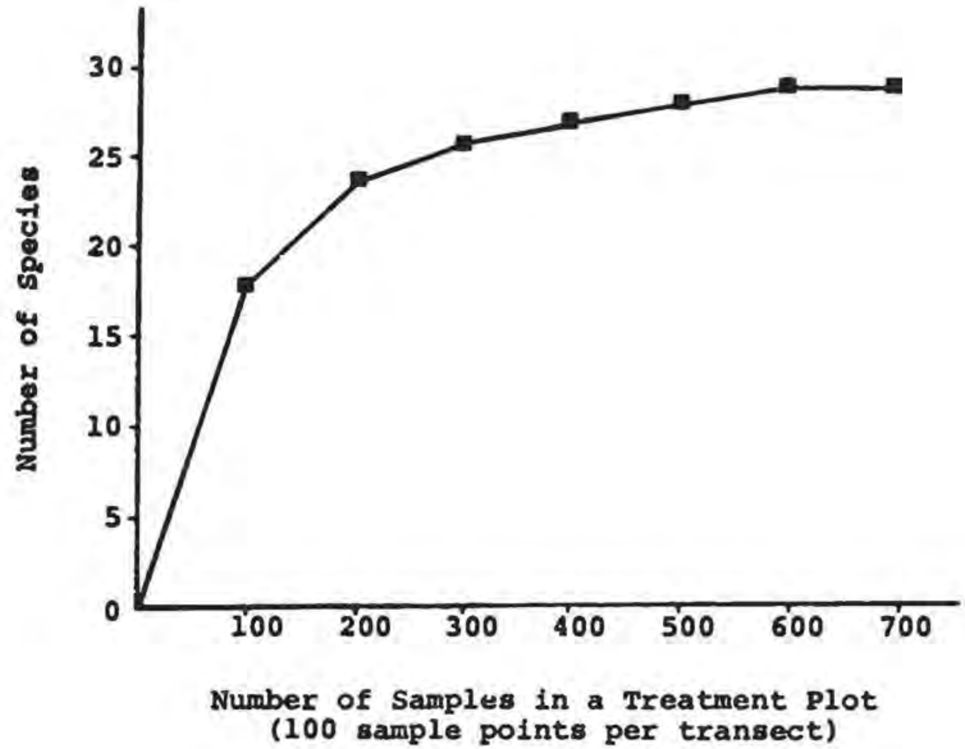


Figure 8. Species-Sample Size Curve: PVPP 1981

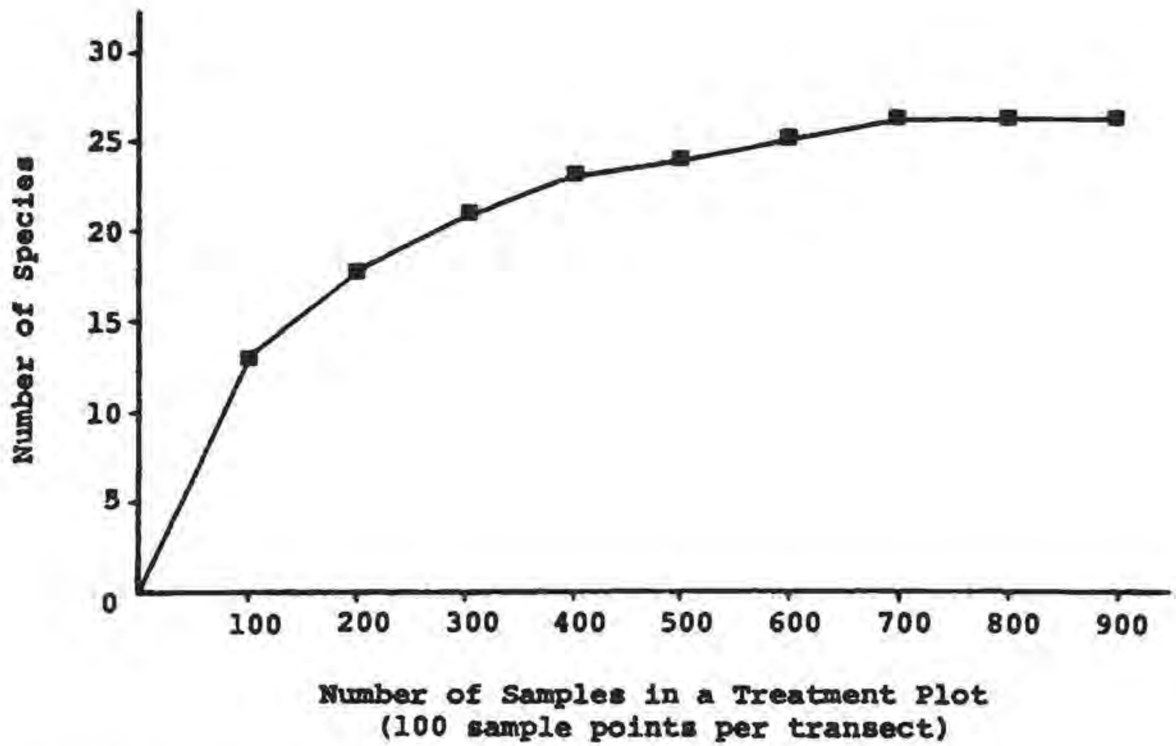


Figure 9. Species-Sample Size Curve: CRP 1982

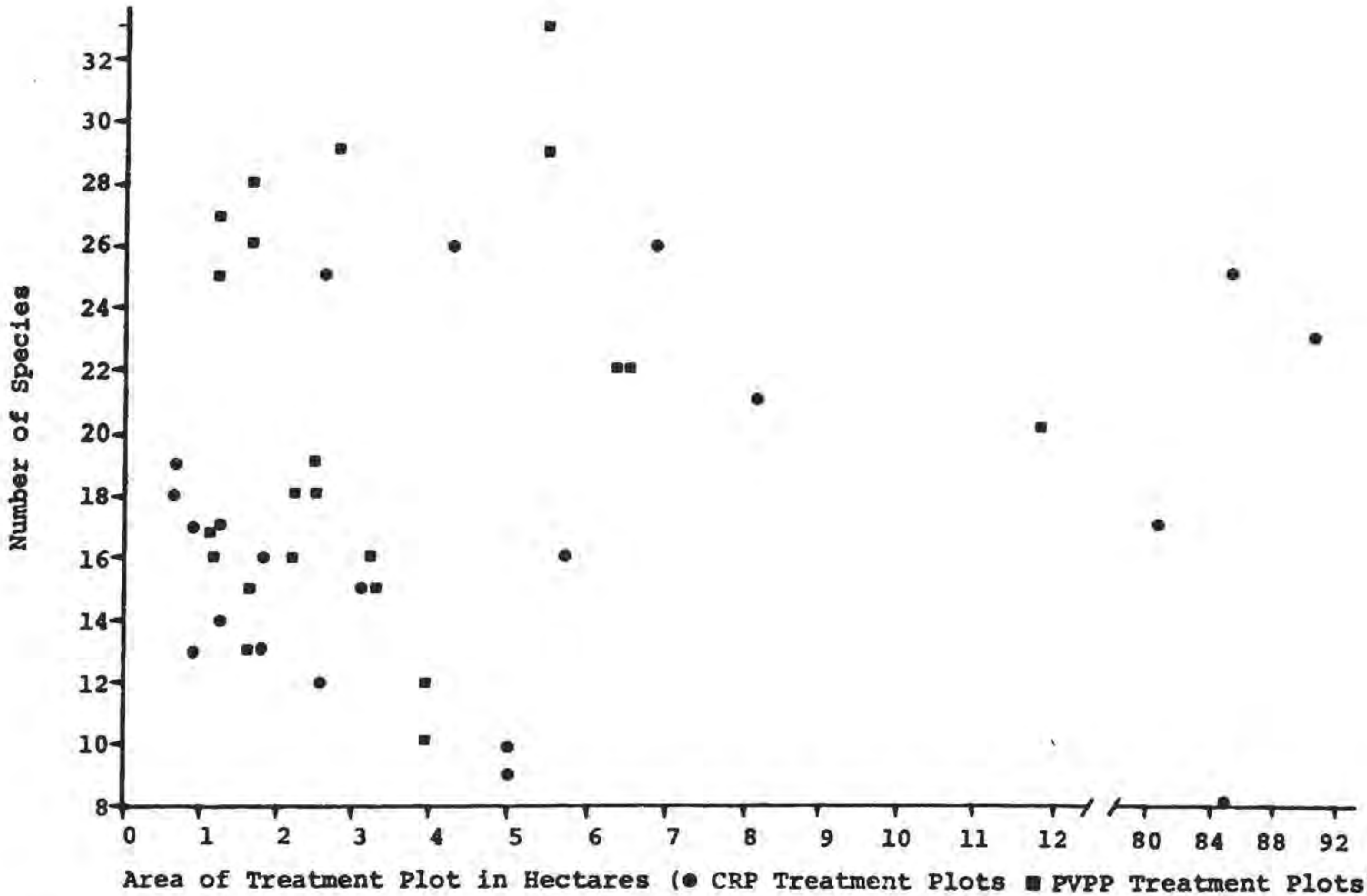


Figure 10. Species-Area Graph

Data Analysis

All transect data for each species was calculated as a proportion of total composition, P_i. A statistical summary, compiled for each treatment, included the following descriptive statistics for each species: total P_i per treatment, $\bar{X}P_i$ (P_i per treatment/number of transects), standard deviation, standard error, and coefficient of variability. The $\bar{X}P_i$ figure represents the percentage composition for a given species in a treatment; the figure used to compare response of a given species to various fire frequencies.

A diversity summary compiled for each treatment included the following parameters for each treatment and for each transect within a treatment: H' (Shannon's diversity index), species number (the species richness component of diversity), maximum H' (the highest possible H' for the number of species present in the sample), minimum H' (the lowest possible H' for the number of species present in the sample), and equitability (the evenness component of diversity). The Shannon index measures heterogeneity (richness and evenness).

All comparisons of diversity were restricted to results from a given site in a given year. The number of transects in a given treatment varied. Treatments with more transects (more sample points) were likely to encounter more rare species (thus influencing H'). Comparisons of diversities refer to $\bar{X}H'$ (mean diversity of all the transects in a given treatment) rather than total H' for the treatment. Since H' is a relative value, it is not directly comparable from one treatment to another (Chambers and Brown 1983). In order to make direct comparisons of treatments, two different similarity indices were used. Indices of similarity (IS) provide direct, appropriate comparisons of the results of different treatments (burns vs. control or burn vs. burn).

Indices of similarity were calculated using percent similarity and Spatz's modification of Jaccard's index; a more reliable comparison of different treatments (Chambers and Brown 1983). IS was calculated using both indices to compare between treatment and within treatment similarities. If average within treatment similarities (IS between transects within a given treatment) were greater than between treatment similarities, this would indicate that there were major differences in percent composition between treatments. Diversity and IS formulae are in Table 2. Relative cover, calculated by treatment, was partitioned among grasses, legumes and forbs (other than legumes). Further categorizing into annuals vs. perennials and natives vs. aliens allowed for more detailed analysis of each category's response to a given treatment.

All these analyses were done to test the hypothesis that fire or fire frequency is the variable which affects species diversity and species composition. This was done while

Table 2. Formulae: Diversity and Similarity Indices

Shannon's Diversity Index: H'

$$H' = \sum_{i=1}^{s} p_i \log p_i \qquad (p_i = \frac{n_i}{N})$$

Log base ten was used in all calculations of H'.

Percent Similarity: PS_{ab}

$$PS_{ab} = 100 - 0.5 \sum_{i=1}^{s} \left| a_i - b_i \right|$$

a_i = importance value of species i in A

b_i = importance value of species i in B

Spatz' Similarity Index: IS_{sp}

$$IS_{sp} = R \times \frac{MC}{MA + MB + MC} \times 100$$

where

R = The smaller values of the species or life-forms common to both areas are first divided by the greater values. These fractions are then added up and the sum is divided by the total number of species in both areas.

MC = The sum of the values of all species or life-forms common to both areas.

MA = The sum of the values of all species or life-forms in one area.

MB = The sum of the values of all species or life-forms in the second area.

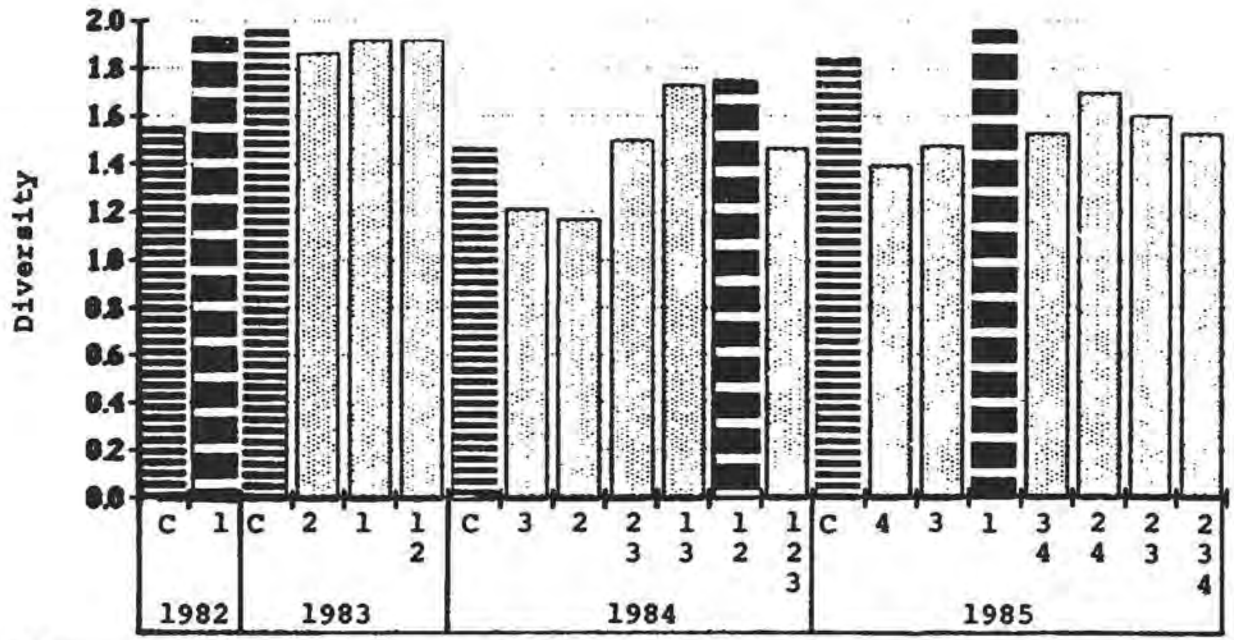
assuming uniformity of soil, elevation, exposure, temperature, and precipitation at a given treatment plot. No replicates existed for any given treatment. Since no significance tests could be run on these results, no statistics were generated for analyses. The strength of this study was in its ability to isolate the effect of fire on grassland species diversity and composition. This was possible because of the volume of data collected, the number of treatments compared, the opportunity to compare results at two similar sites and the existence of control plots at each site each year.

RESULTS

Four years of sampling at CRP and 5 years of sampling at PVPP (for purposes of comparison these will be referred to collectively as 9 sampling years) resulted in a species pool of 68 species. Thirty-six species were present at both preserves, 16 species occurred only at CRP, 16 species occurred only at PVPP (Appendix D). A total of 22,961 data points (8,210 from CRP and 14,751 from PVPP) were analyzed from 231 transects averaging 100 hits each in 43 different treatments.

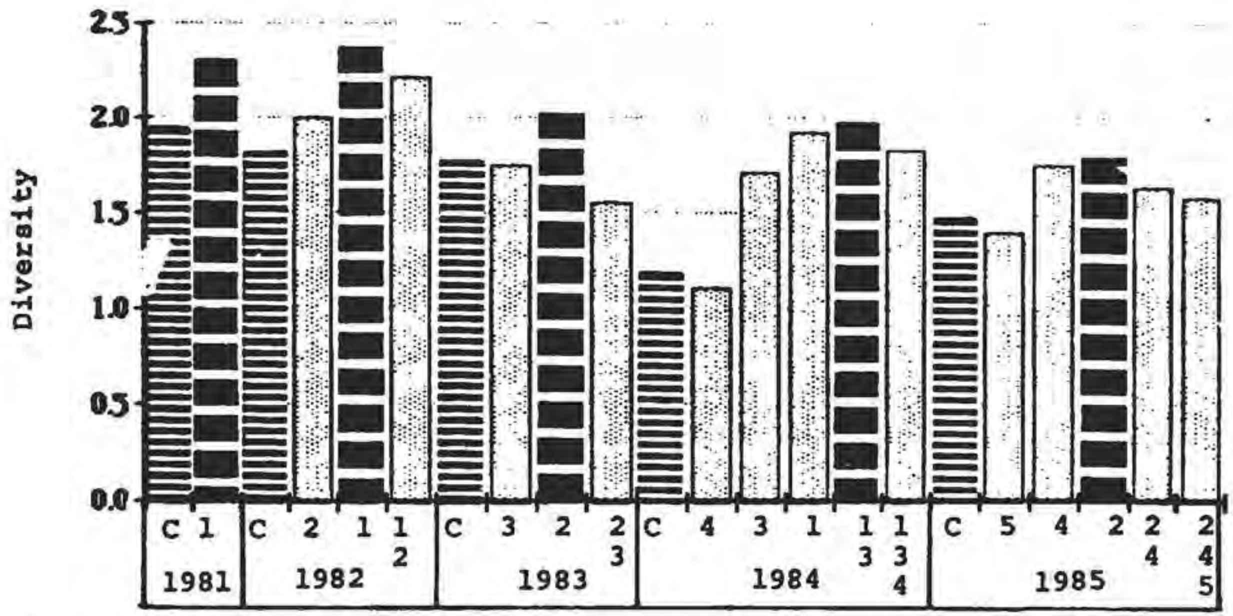
Diversity

In 8 of 9 sampling years, diversity was higher in a burn treatment than in the control plot (Figures 11 and 12) and comparison of once-burned treatments shows that in 6 of 7 sampling years where there are two or more once-burned treatments, the more recent once-burned treatment has higher diversity than older once-burned treatments. Of 15 treatments burned in multiple (2 or 3) years, two noteworthy trends exist. In both sampling years where there are two twice-burned treatments (and the burns were in consecutive years), the more recent twice-burned combination has higher diversity than older twice-burned treatments.



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $^2_3$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in diversity imposed by a burn treatment ▩ other treatments

Figure 11. $\bar{x}H'$ (Diversity: Mean Value of All Transects Within a Treatment): CRP



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in diversity imposed by a burn treatment ▩ other treatments

Figure 12. $\overline{x}$H' (Diversity: Mean Value Of All Transects Within a Treatment): PVPP

In all 4 years where twice-burned and thrice-burned treatments were sampled, twice-burned treatments had higher diversity than thrice-burned treatments.

Of 34 burn treatments, 18 had higher diversity than the nine unburned controls. Except for CRP in 1983, the treatments with the highest diversity each year were recent once or twice-burned treatments.

Richness and evenness both influence diversity. In 6 of 9 sampling years, the treatment with the highest species richness also was the most diverse (Figures 13 and 14). In 6 of 9 sampling years, the treatment with the highest evenness also was the most diverse.

In 4 of 9 sampling years, the same treatment that exhibited the greatest diversity was also the richest and most even. These same four treatments (three at PVPP) were all the most recent once-burned treatments during those sampling years.

Percent Composition By Vegetation Category

Grasses, followed in descending order of percent composition by forbs (other than legumes) and legumes, are the three categories of herbaceous vegetation at the two sites. Percent composition of the three categories show similar annual fluctuations in control plots at both sites (Figure 15). The effect of the 43 different treatments on relative composition is variable (Figures 16 and 17) but several patterns emerge.

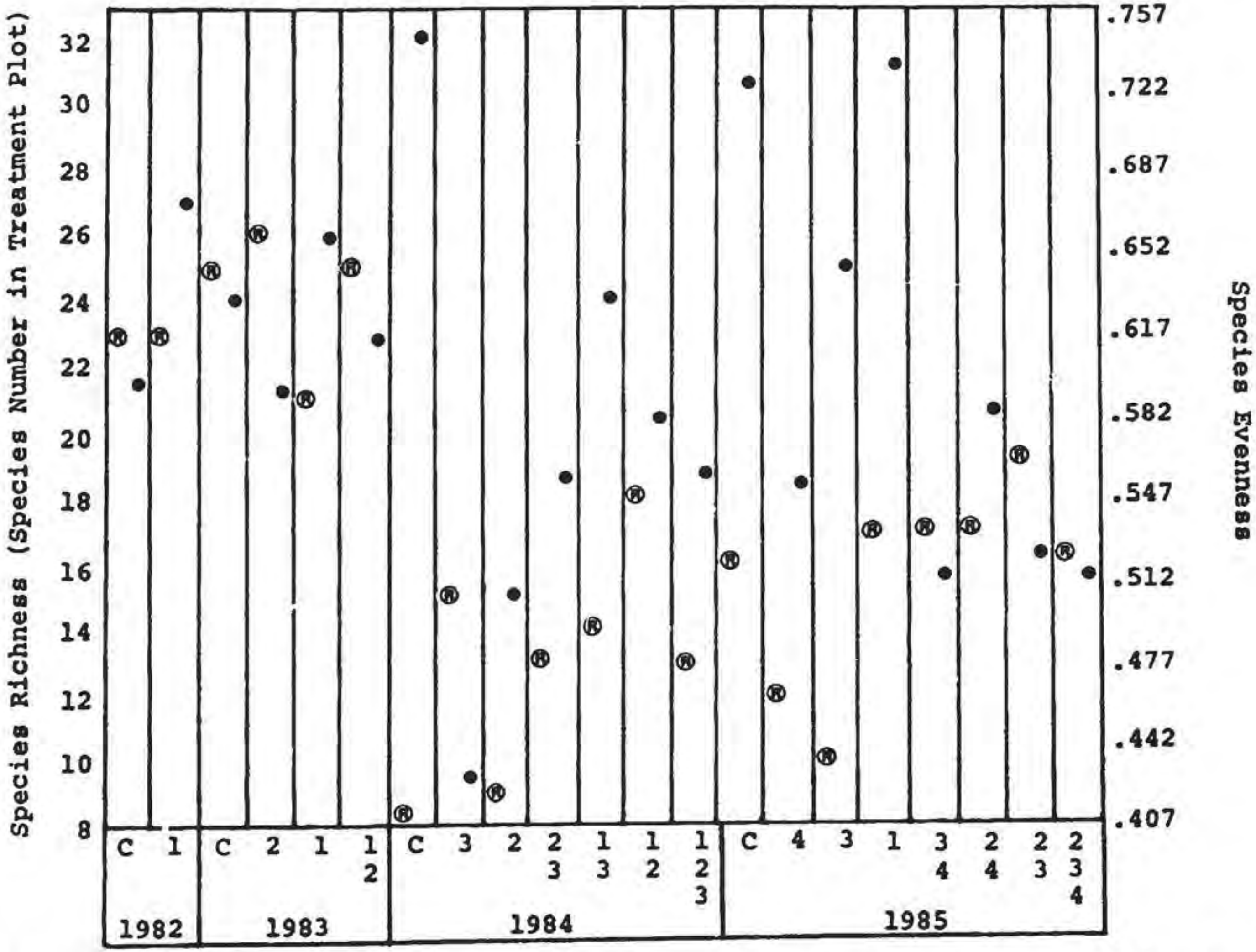


Figure 13. Species Richness (®) and Evenness (•) at CRP (see Fig. 12 for Treatment Code)

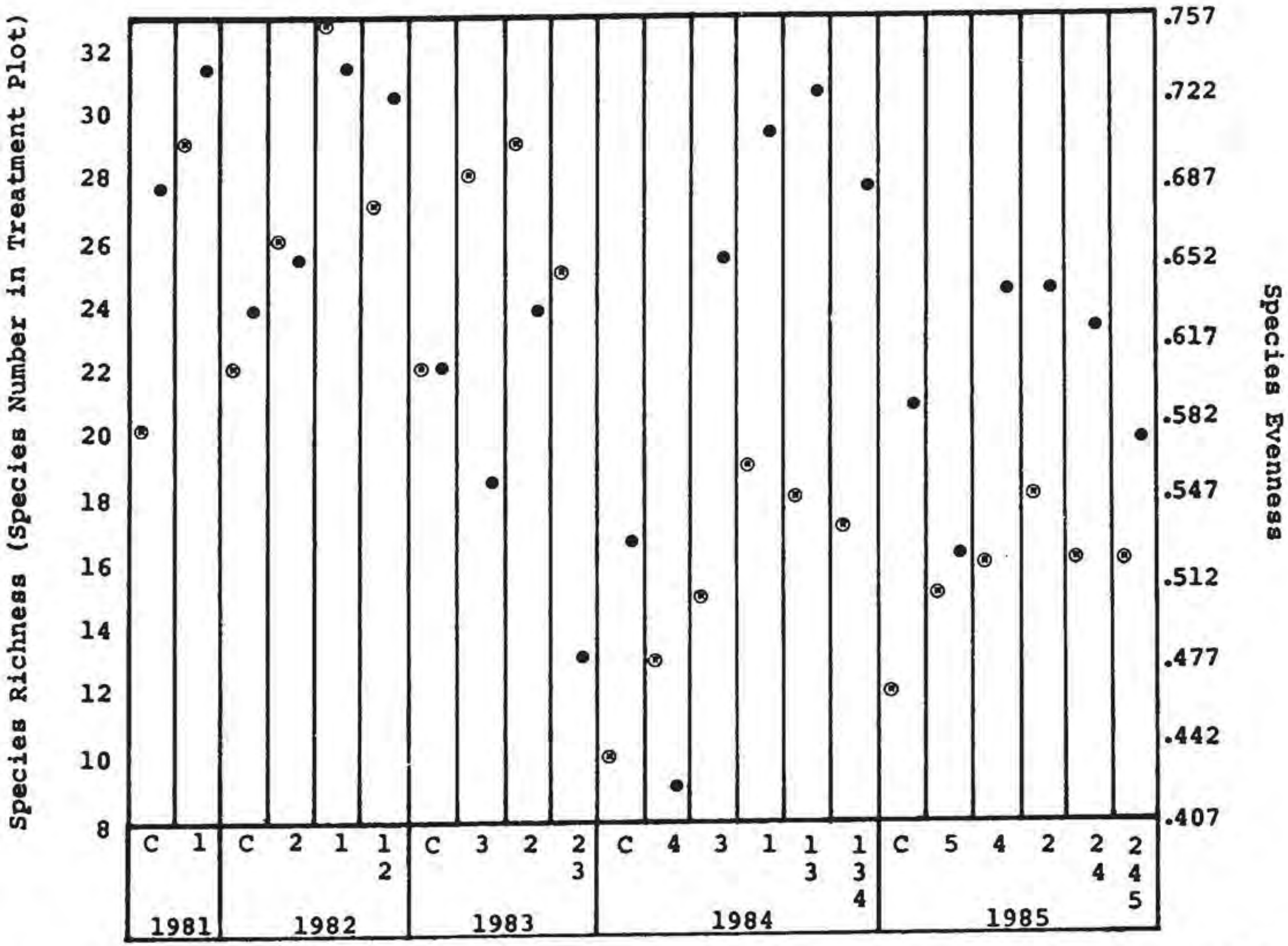


Figure 14. Species Richness (⊛) and Evenness (•) at PVPP (see Fig. 13 for Treatment Code)

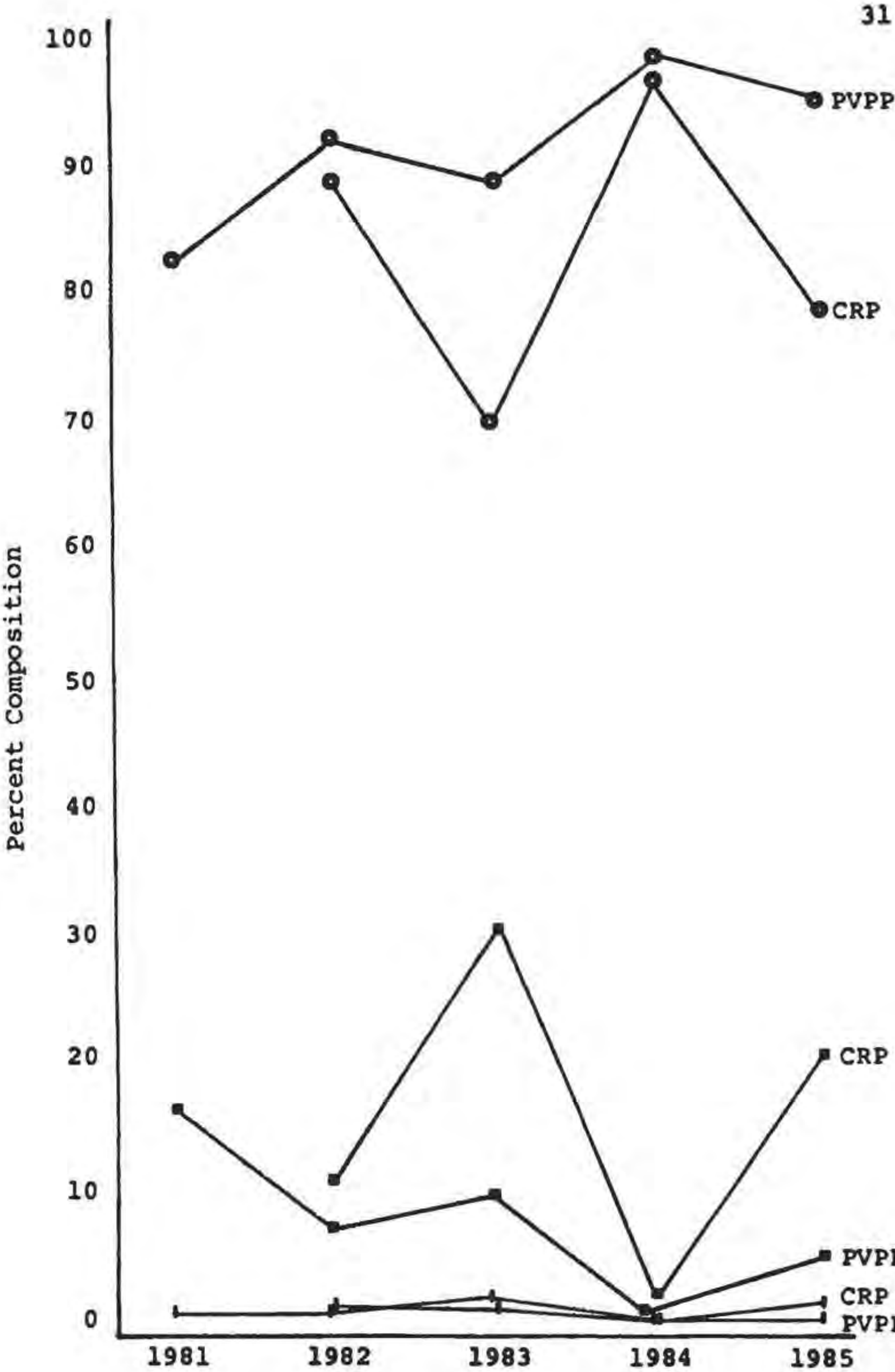
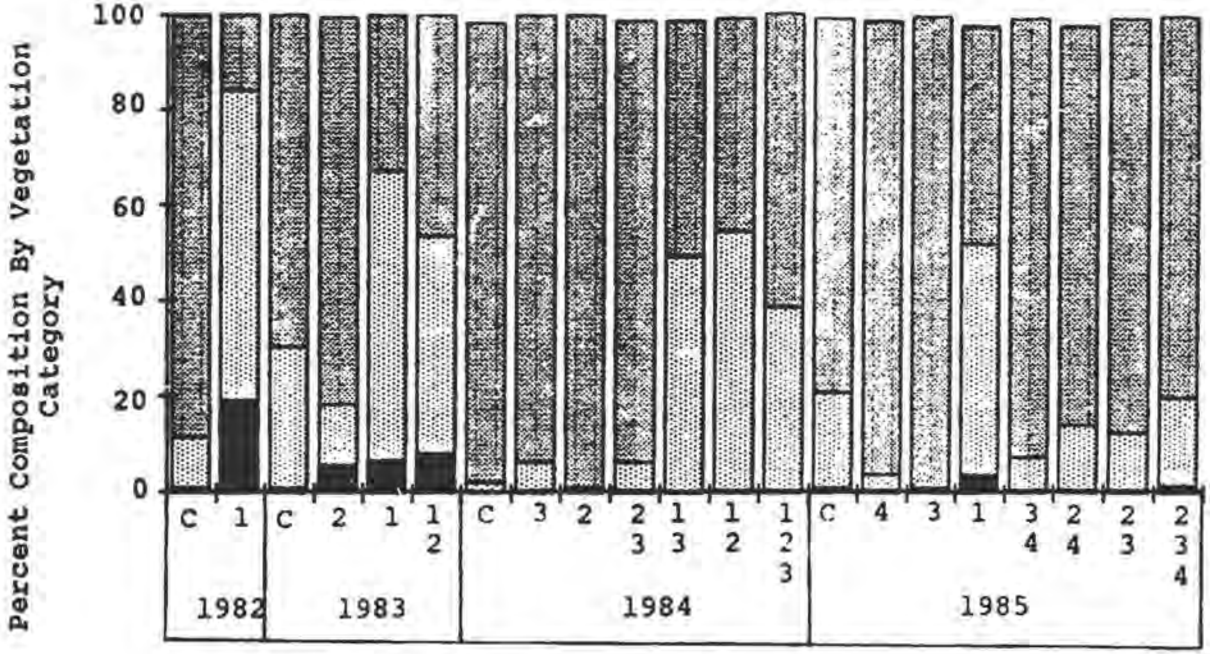
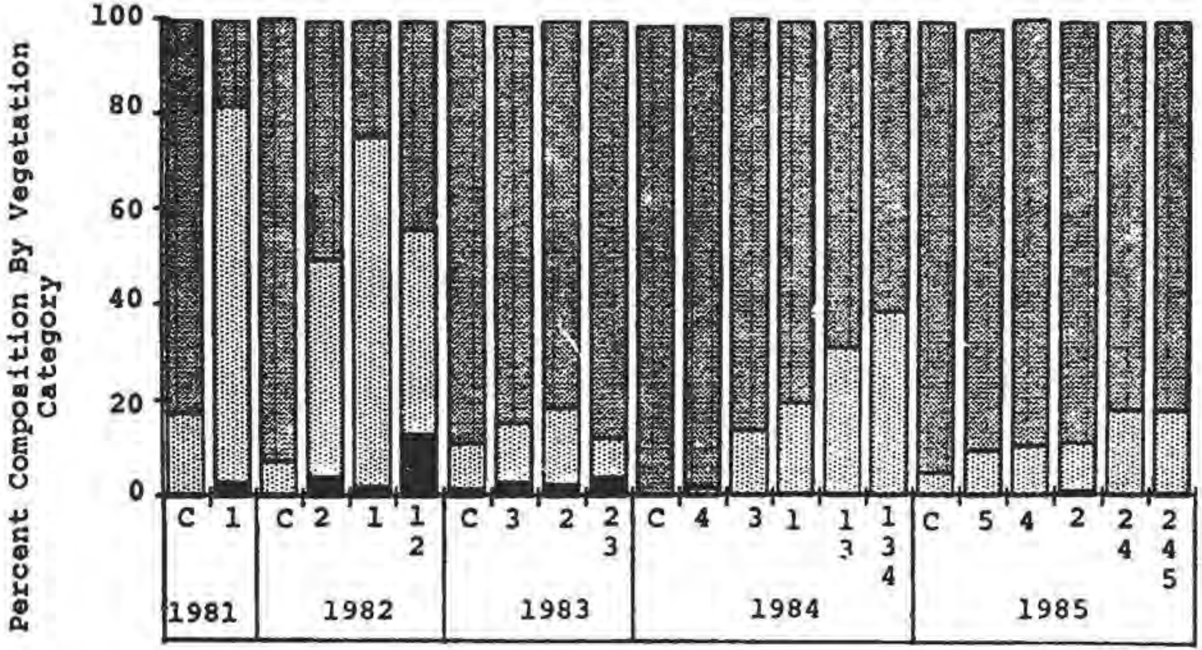


Figure 15. Annual Fluctuations in Percent Composition of Legumes (ı), Forbs (Other Than Legumes) (■), and Grasses (⊙) in Control Plots. Years represent year of spring sampling.



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▩ grasses ■ legumes ▩ forbs (other than legumes)

Figure 16. Percent Composition By Vegetation Category: CRP



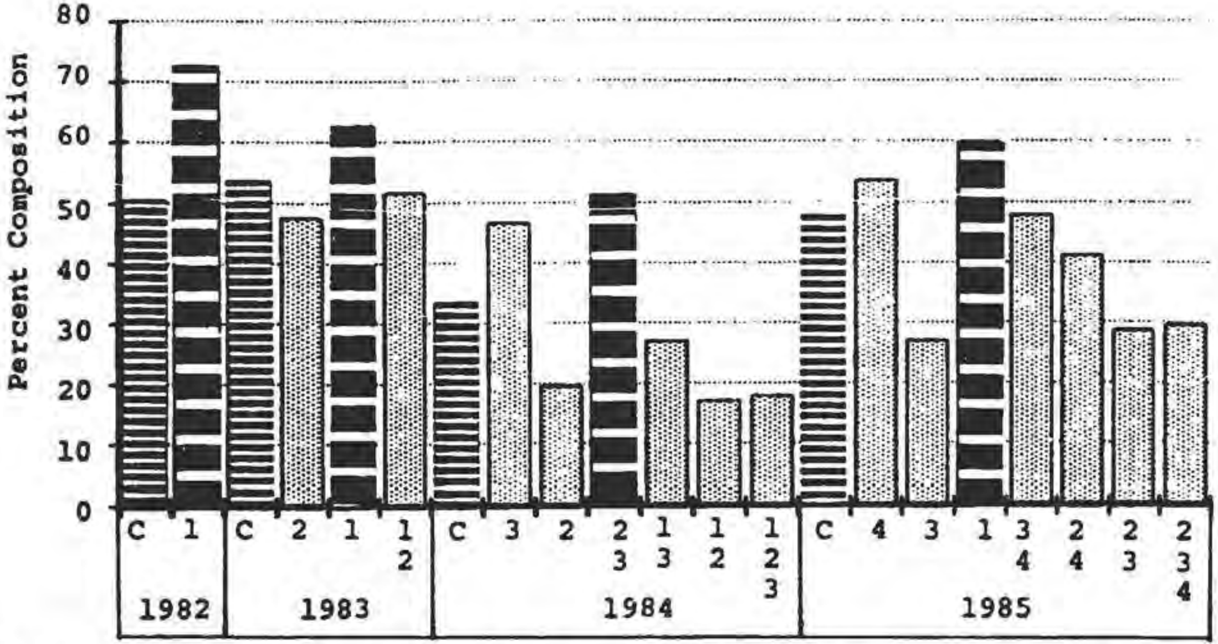
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $^{2}_{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▩ grasses ■ legumes ▩ forbs (other than legumes)

Figure 17. Percent Composition By Vegetation Category: PVPP

Natives and Aliens

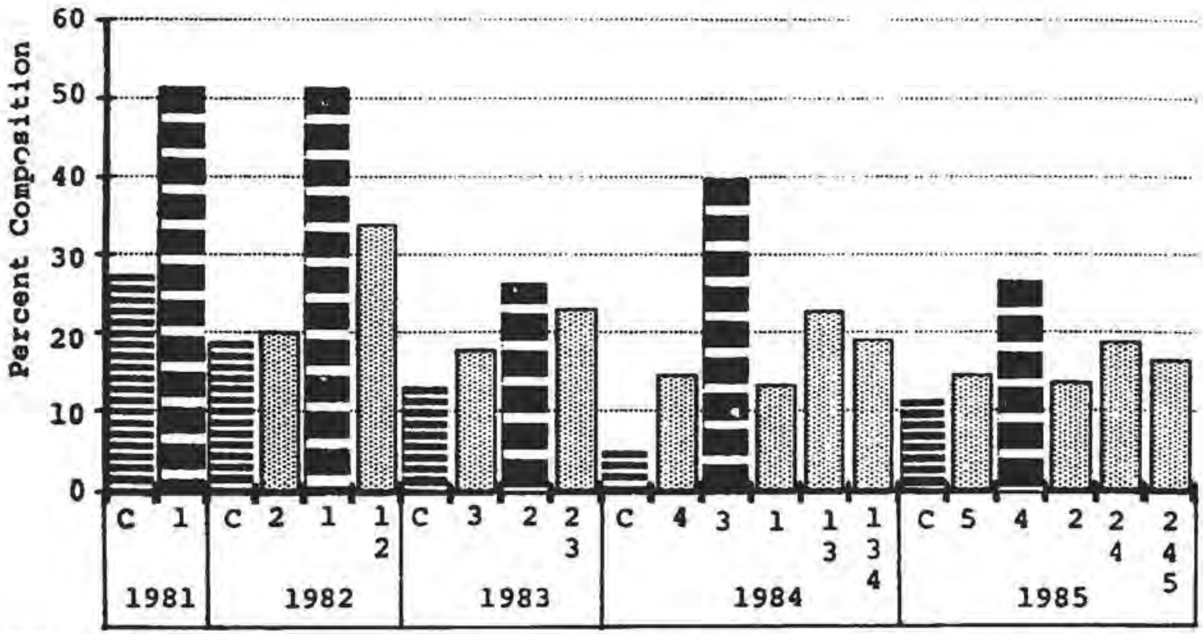
To further analyze the effect of fire on grassland species composition, the entire data matrix was divided into nine categories (Appendix D) so that percent composition of native and alien species could be compared relative to the various burn treatments.

Percent composition of natives (Figures 18 and 19) was lowest in control plots in 6 of 9 sampling years (1 year at CRP and all 5 years at PVPP). Composition of natives in control plots at PVPP ranged from 27% in 1981 to a low of 4.67% in 1984. Composition of natives in control plots at CRP ranged from 53.71% in 1983 to a low of 33.33% in 1984. Burning increased composition of natives from 18.56% to 59.45% at PVPP in 1982. Native composition reached its highest level, 72.44%, in the once-burned treatment at CRP in 1982. Of 34 burn treatments, 24 had higher native percent composition than control plots (including all 17 burn treatments at PVPP). Compared to control plots, the highest percent composition of natives resulted from the most recent once-burned treatment in 6 of the 9 sampling years and from older once-burned or twice-burned treatments in 3 of the 9 sampling years. The control plot at PVPP always had the lowest native percent composition of all treatments (Figure 19). The plot burned at PVPP in 1980 that was sampled in 1981 had the highest percent composition of natives of all treatments from 1981 through 1985.



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. [controls symbol] controls [greatest symbol] greatest increase in % composition imposed by a burn treatment [other symbol] other treatments

Figure 18. Native Species at CRP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 19. Native Species at PVPP: Percent Composition by Treatment

Circumstances of that burn were such that there was a residual effect; percent composition of natives remained high from year to year. Such trends were more easily interpreted when the nine categories of native and alien vegetation were independently analyzed relative to the various burn treatments.

Individual Species

The five most abundant species at both preserves (a total of six species; four species were common to both preserves) account for 78% (CRP) and 89% (PVPP) of the total percent composition in control plots (Table 1, see p. 11). Percent composition of these six species along with Vulpia Myuros (a common alien annual grass), Hemizonia pungens (the most abundant native annual forb), Erodium (the most common genus of alien annual forbs), Brodiaea pulchella (the most common native perennial forb), and Lasthenia and Lepidium (two less common native genera which are important food sources for insects, birds, and mammals) was independently analyzed to better assess the response of individual species to various burn treatments.

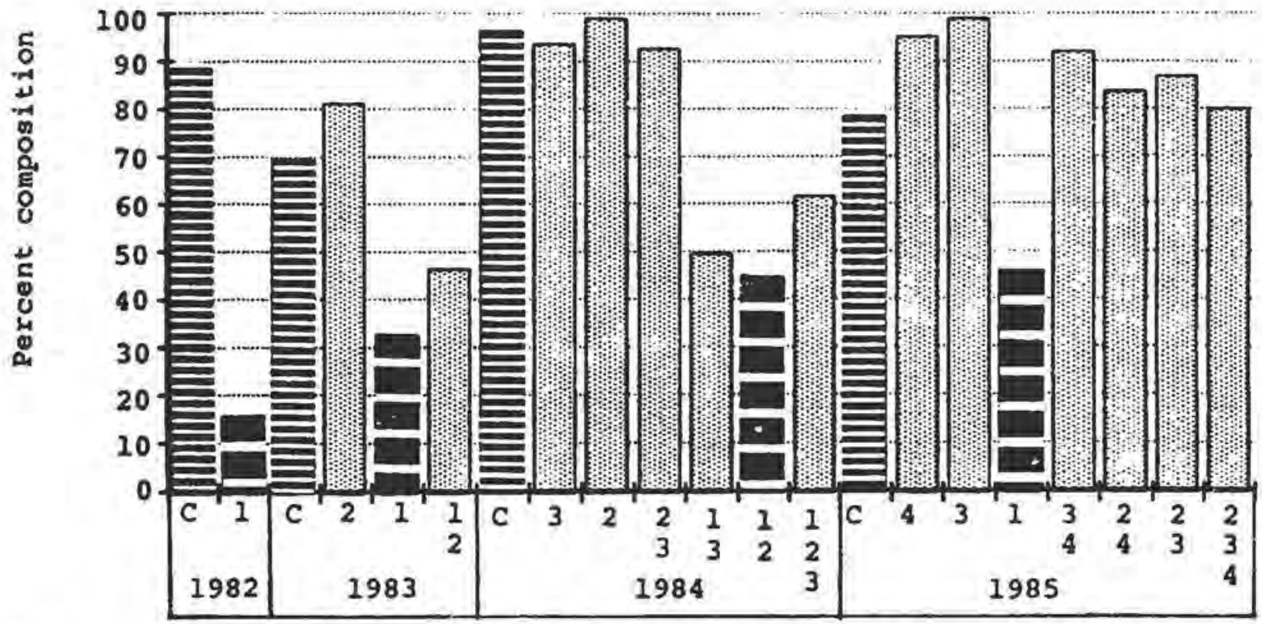
Annual Grasses

This category of herbaceous vegetation is the most abundant at both sites (always greater than 65% in controls). The changing pattern of percent composition of annual grass in the control plots at CRP and PVPP is the same from 1982 to 1985, but percent composition was always higher at PVPP. The years 1982 and 1984 can be considered as "grass years" (Pitt and Heady 1978).

Fire significantly reduced percent composition of annual grasses (Figures 20 and 21). Compared to control plots, the lowest percent composition of annual grasses resulted from the most recent once-burned treatment in 6 of 9 sampling years, thrice-burned treatments in 2 of 9 sampling years, and the most recent twice-burned treatment in 1 of 9 sampling years. Recent once-burned treatments show lower percent composition compared to older burns in 9 of 13 situations. In both years where there are two twice-burned (consecutive years) treatments, the more recent of the two combinations has lower percent composition. In 3 of 4 years when twice-burned and thrice-burned treatments were sampled, the thrice-burned treatment had lower percent composition. Of 34 burn treatments, only 8 had higher percent composition of annual grasses than was found in control plots. Percent composition in control plots was always higher than in burn treatments at PVPP.

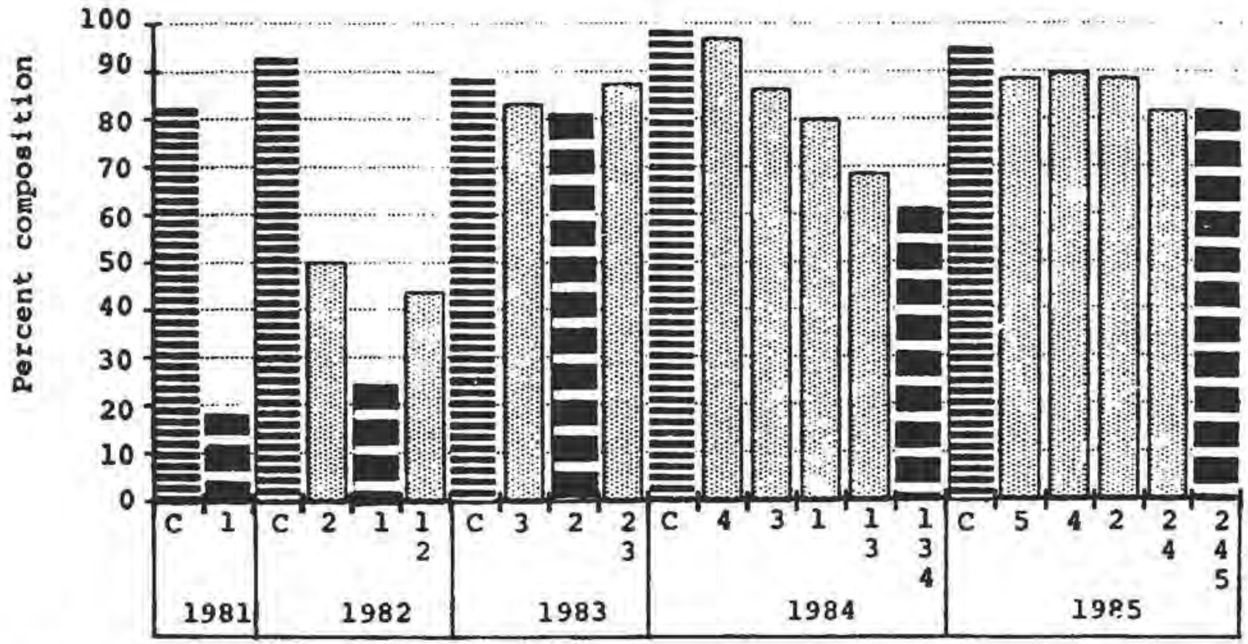
Native Annual Grasses

The response of native annual grasses (Figures 22 and 23) to fire was similar to that for grasses overall (aliens plus natives). Fire reduced percent composition of native annual grasses in 19 of 34 burn treatments but percent composition was higher than in control plots in 15 of 34



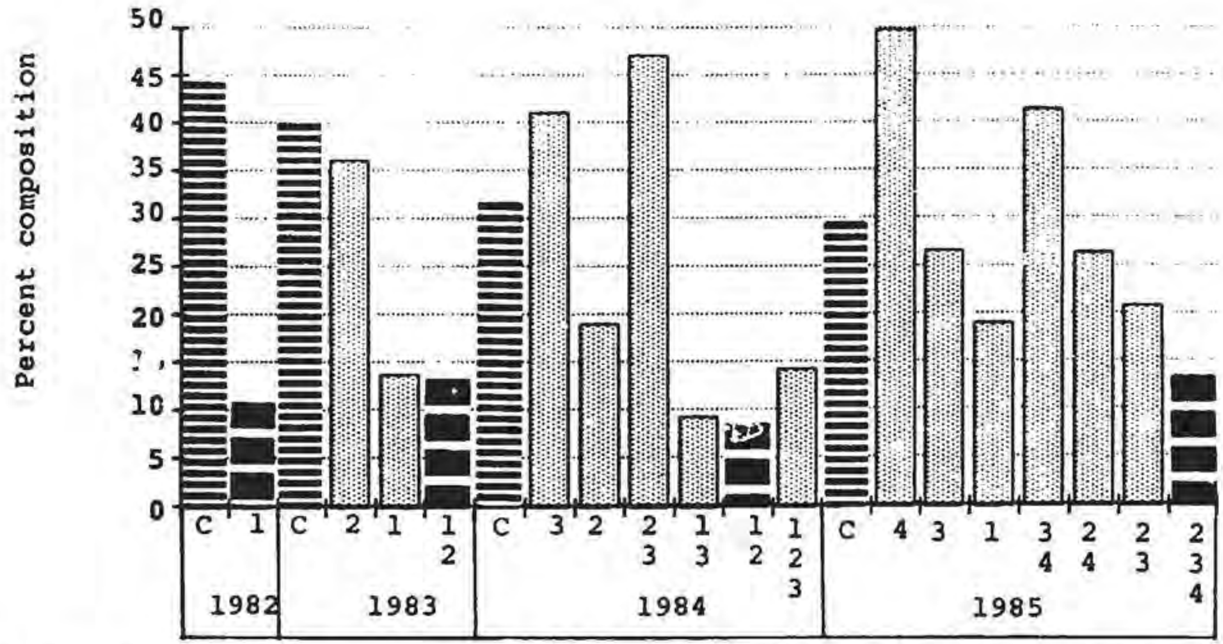
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$ = plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest decrease in % composition imposed by a burn treatment ▩ other treatments

Figure 20. Annual Grasses at CRP: Percent Composition by Treatment



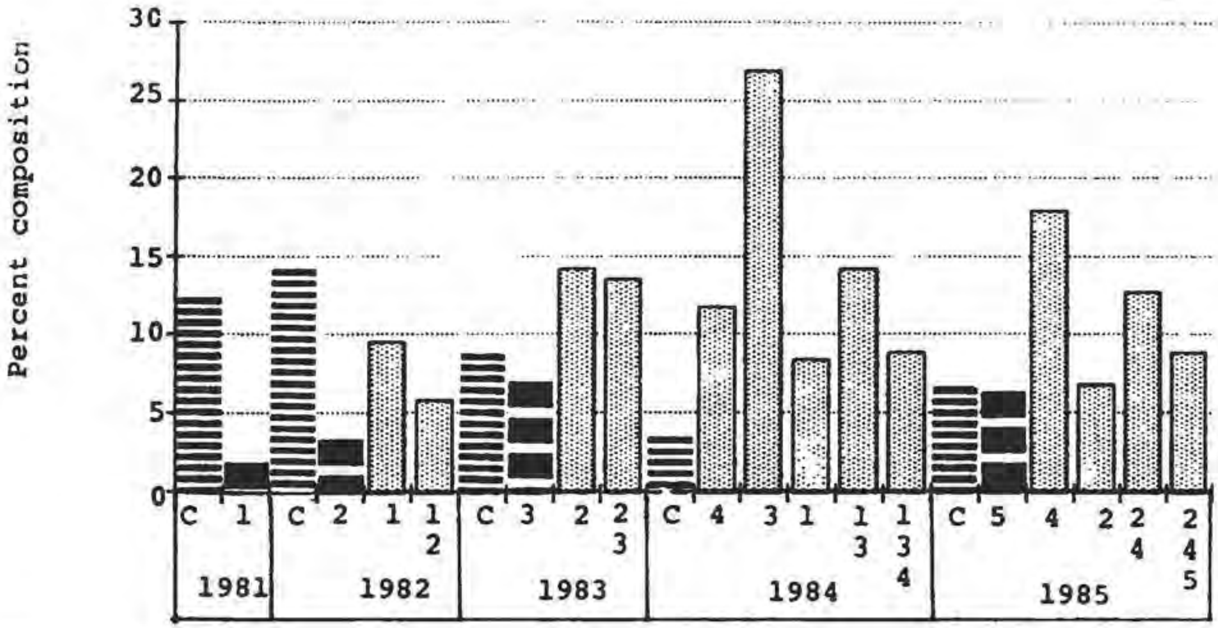
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest decrease in % composition imposed by a burn treatment ▩ other treatments

Figure 21. Annual Grasses at PVPP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. controls greatest decrease in % composition imposed by a burn treatment other treatments

Figure 22. Native Annual Grasses at CRP: Percent Composition by Treatment



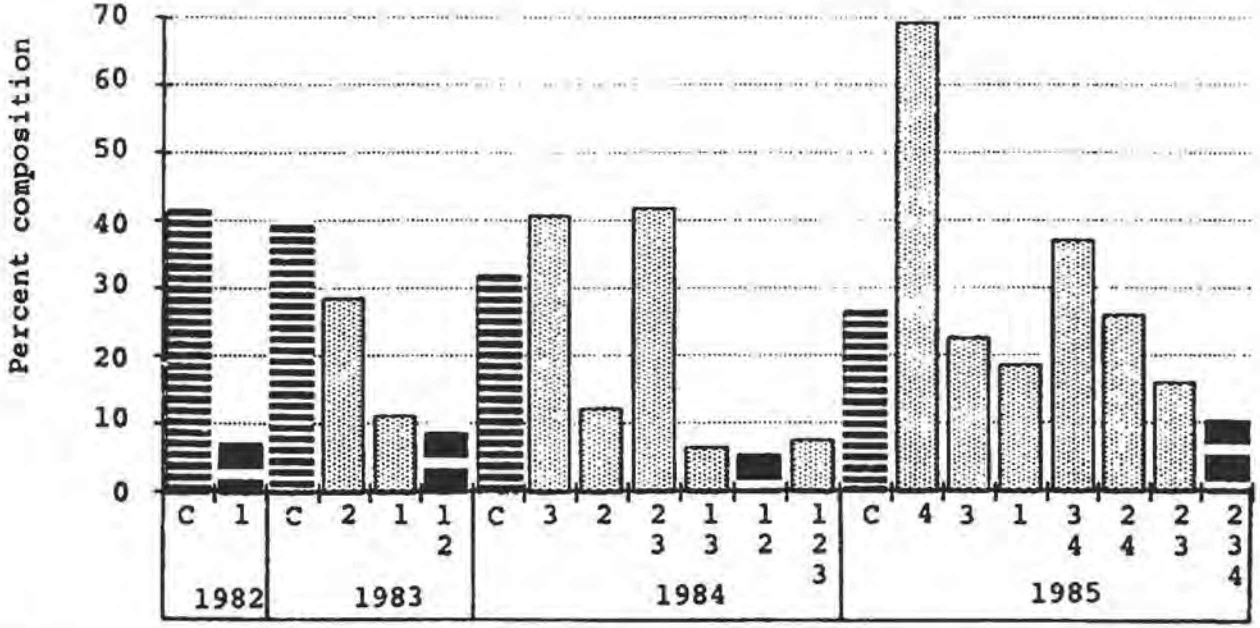
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest decrease in % composition imposed by a burn treatment ▩ other treatments

Figure 23. Native Annual Grasses at PVPP: Percent Composition by Treatment

burn treatments (compared to grasses overall, where only 8 of 34 burn treatments had higher percent composition than control plots). Native annual grass cover consists almost entirely of one dominant species, Hordeum depressum, whereas alien annual grasses consist of five dominant species (Table 1, see p. 11). In some years when conditions benefit percent composition of grasses overall, it is likely that the dominant alien grasses interact competitively to suppress the percent composition of the native grass component.

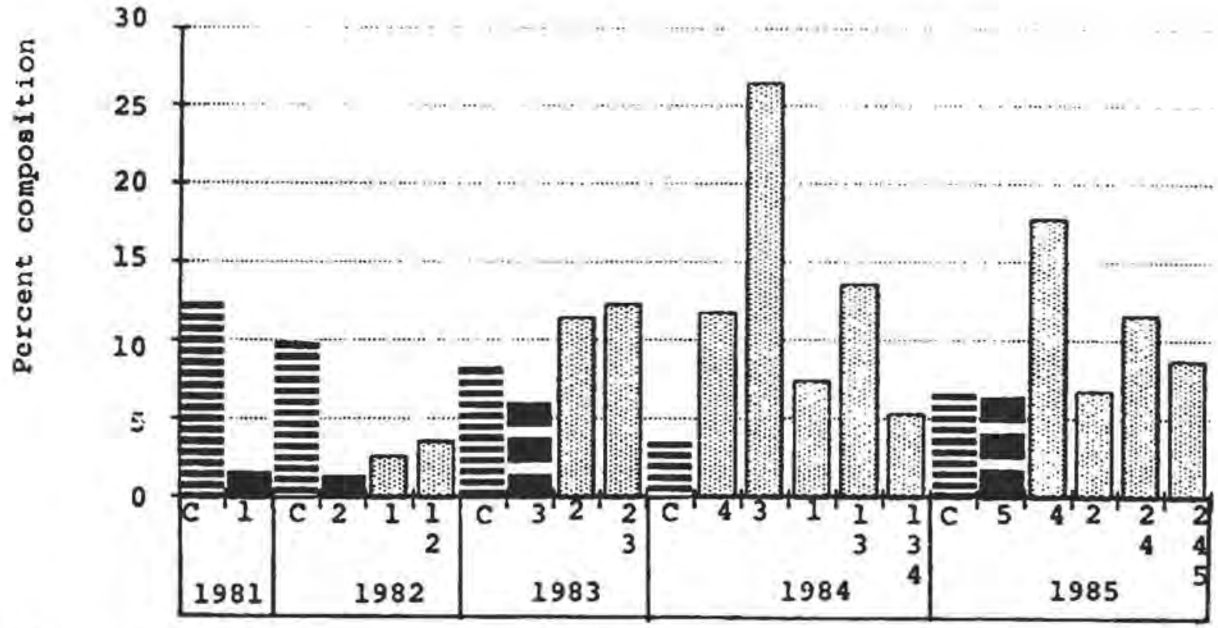
Hordeum depressum

This is the only native annual grass to make it to the "top five" in this study. H. depressum, alkali barley, is the most abundant species in total percent composition in control plots at CRP (38%) and the fourth most abundant species at PVPP (8%). This difference in abundance is probably due to its affinity for more alkaline soils such as those found at CRP (Crampton 1974). Fire reduced percent composition of this cover type (Figures 24 and 25) in 7 of 9 sample years. Compared to the control plots, the lowest percent composition of this species resulted from once-burned treatments in 5 of 8 sampling years and multiple-burned treatments in 3 of 8 sampling years. In 4 of 4 years when twice-burned and thrice-burned treatments were sampled, the thrice-burned treatment had lower percent composition. This is the opposite of the situation with annual grasses as a whole but shows some similarity between the response of



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $^{2}_{3}$= plot burned 2 years and 3 years prior to sampling, etc. controls greatest decrease in % composition imposed by a burn treatment other treatments

Figure 24. Hordeum depressum at CRP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $^{2}_{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest decrease in % composition imposed by a burn treatment ▩ other treatments

Figure 25. Hordeum depressum at PVPP: Percent Composition by Treatment

Vulpia Myuros and H. depressum. Of 34 burn treatments, 19 had lower percent composition of H. depressum than was found in control plots. This species falls somewhere between Vulpia Myuros and Bromus mollis in its response to fire.

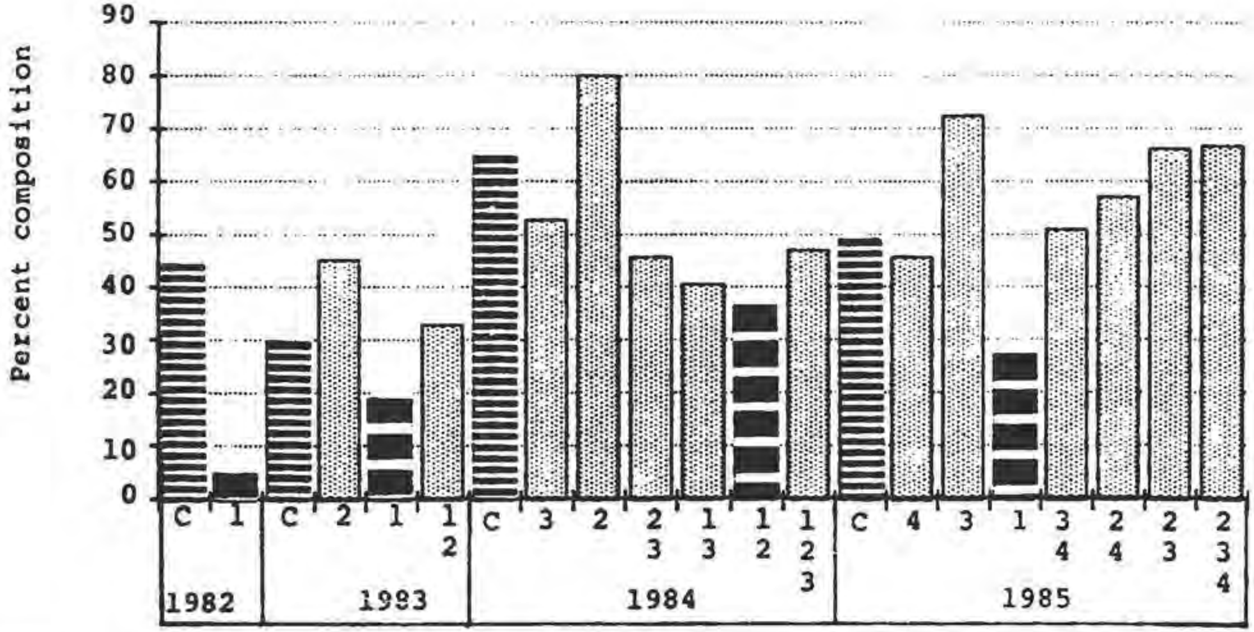
Alien Annual Grasses

The response of alien annual grasses (Figures 26 and 27) to fire was almost exactly like that for grasses overall (aliens plus natives). Fire reduced percent composition of this cover type in 26 of 34 burn treatments; the same number as with grasses overall.

Even though fire suppresses grasses, it appears that native annual grasses are out-competed by alien annual grasses in burned plots after dry rainfall years or after wet years with early rains. This phenomenon can be attributed to the tendency of Bromus mollis, the most abundant species in total percent composition in control plots (34% at PVPP and 12% at CRP), to germinate with early fall moisture (Heady 1956).

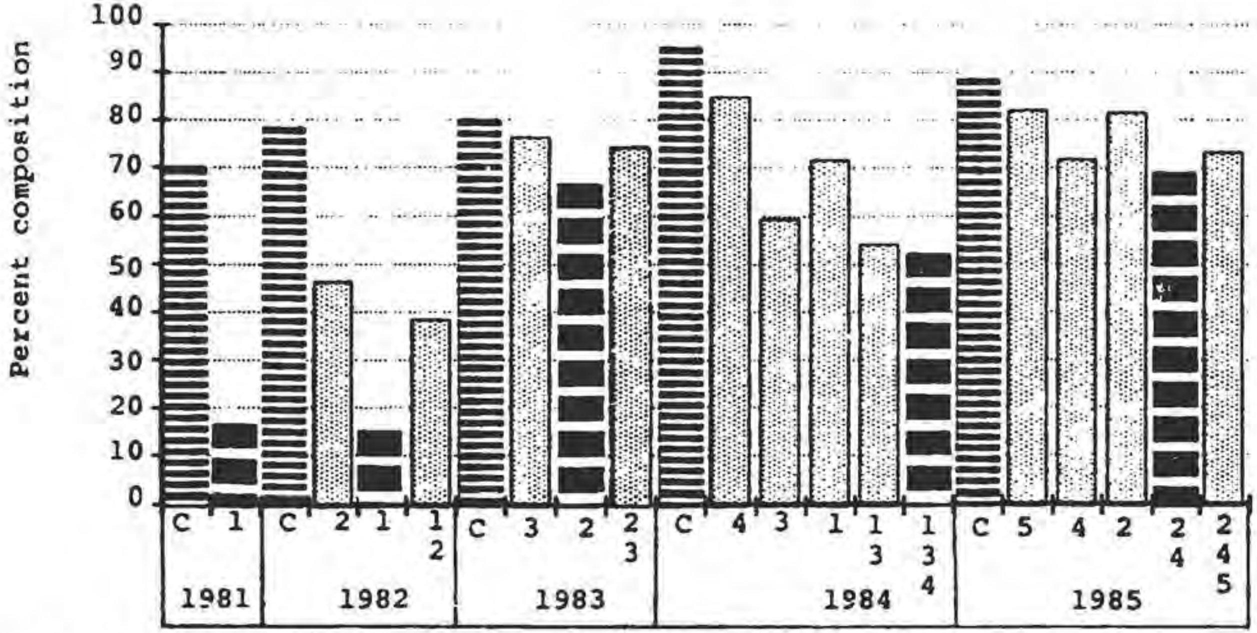
Hordem leporinum

This alien grass is the second most abundant species in total percent composition in control plots at PVPP (21%) and the fourth most abundant species at CRP (9%). Fire decreased percent composition of this species (Figures 28 and 29) in all 9 sampling years. Compared to the control plots, the lowest percent composition of this species



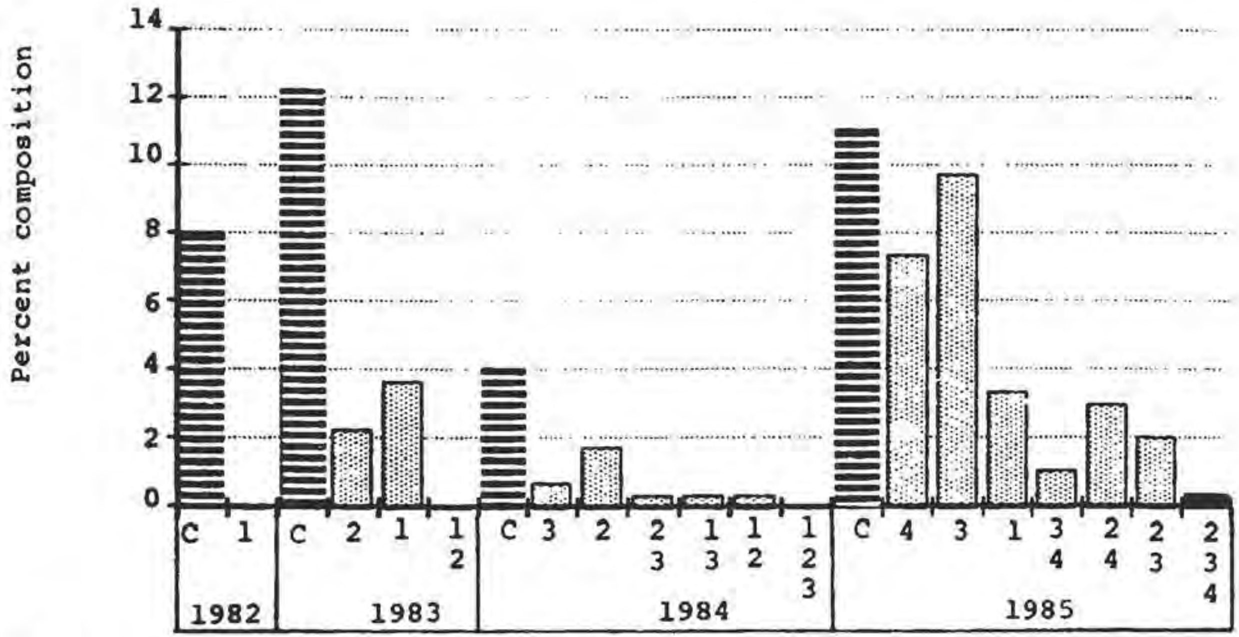
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest decrease in % composition imposed by a burn treatment ▩ other treatments

Figure 26. Alien Annual Grasses at CRP: Percent Composition by Treatment



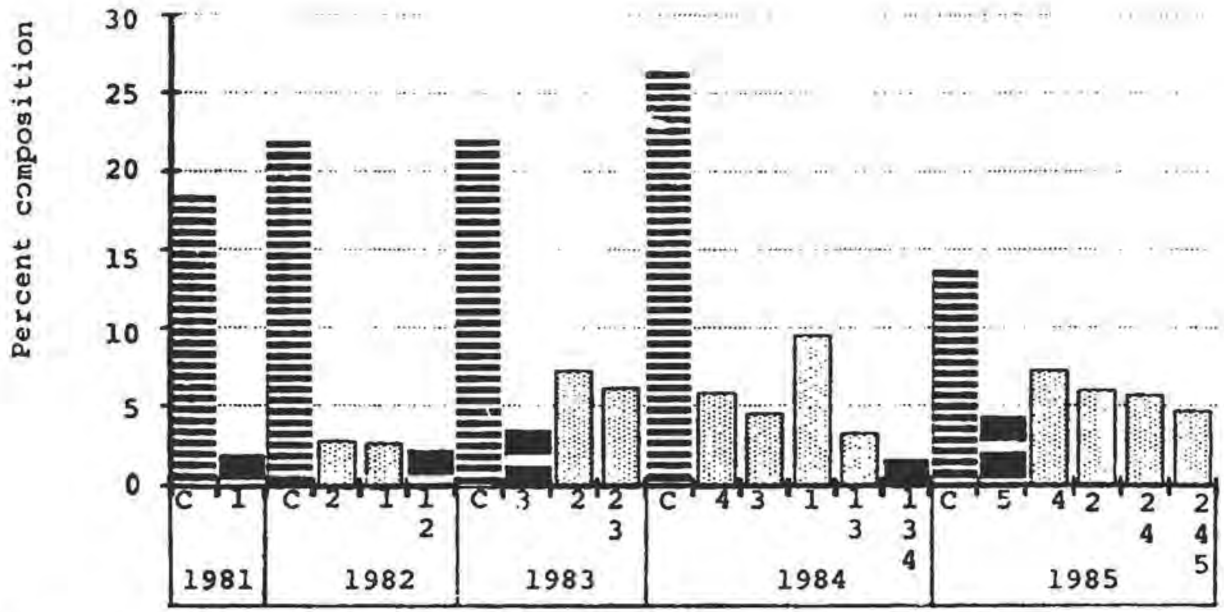
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest decrease in % composition imposed by a burn treatment ▩ other treatments

Figure 27. Alien Annual Grasses at PVPP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $^2_3$= plot burned 2 years and 3 years prior to sampling, etc. controls greatest decrease in % composition imposed by a burn treatment other treatments

Figure 28. Hordeum leporinum at CRP: Percent Composition by Treatment



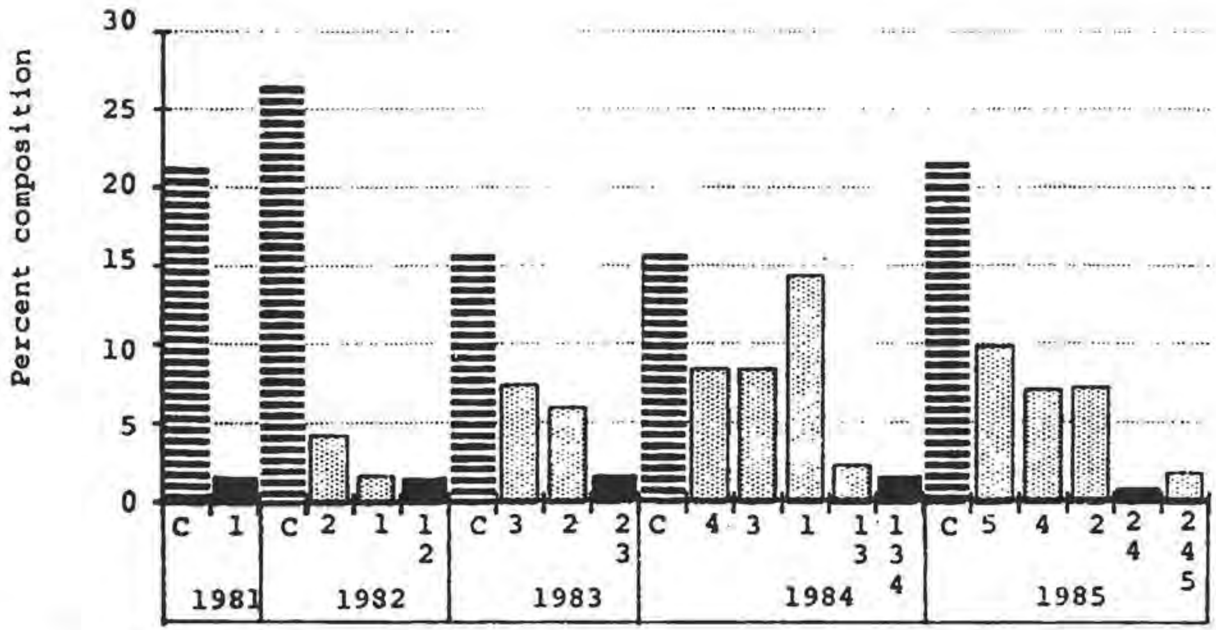
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest decrease in % composition imposed by a burn treatment ▩ other treatments

Figure 29. *Hordeum leporinum* at PVPP: Percent Composition by Treatment

resulted from twice-burned treatments in 4 of 9 sampling years, once-burned treatments in 3 of 9 sampling years, and thrice-burned treatments in 2 of 9 sampling years. In 4 of 4 years when twice-burned and thrice-burned treatments were sampled, the thrice-burned treatment had lower percent composition. H. leporinum shares this trait with H. depressum. Of 31 burn treatments where this species was present, all 31 had lower percent composition for this species than was found in control plots. Of all the alien annual grasses, it appears that fire had the greatest detrimental impact on this species. Percent composition was lower in twice-burned treatments than in once-burned treatments and likewise it was lower in thrice-burned treatments than it was in twice-burned treatments.

Bromus rubens

This alien grass is the third most abundant species in total percent composition in control plots at PVPP (20%) and the fifth most abundant species at CRP (4%). Fire decreased percent composition of this species (Figures 30 and 31) in all 9 sampling years. Compared to the control plots, the lowest percent composition of this species resulted from the most recent twice-burned treatment in 4 of 9 sampling years, thrice-burned treatments in 3 of 9 sampling years, and the most recent once-burned treatment in 2 of 9 sampling years. In 3 of 4 years when twice-burned and thrice-burned treatments were sampled, the thrice-burned treatment had



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $^{2}_{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest decrease in % composition imposed by a burn treatment ▩ other treatments

Figure 31. Bromus rubens at PVPP: Percent Composition by Treatment

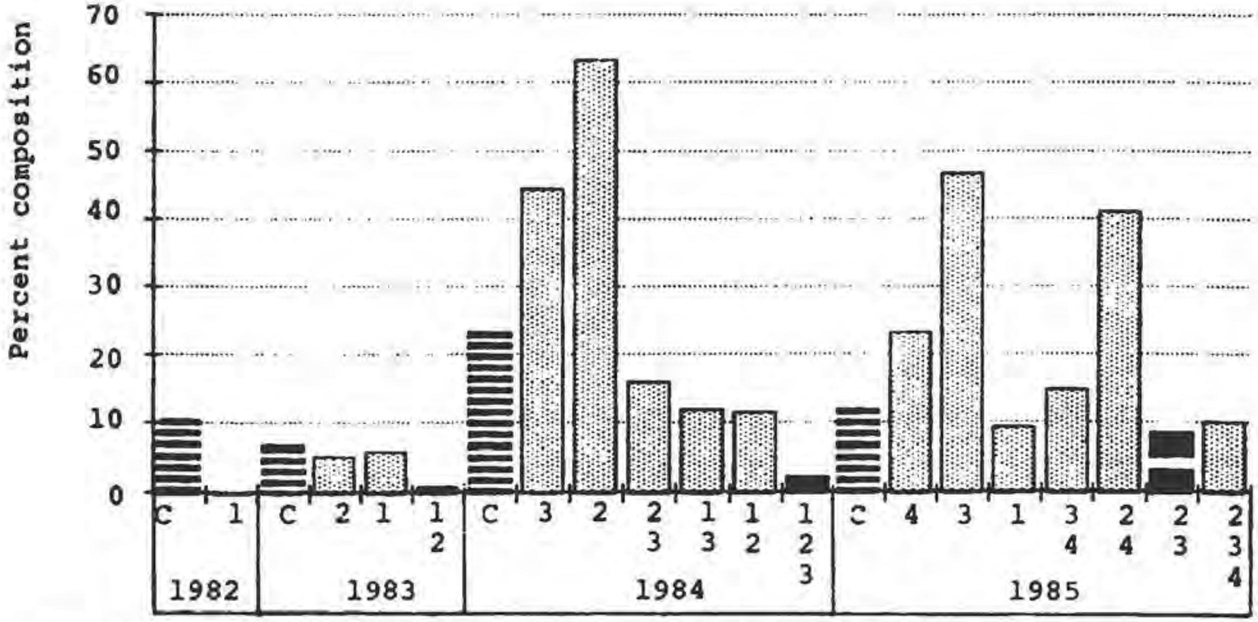
lower percent composition. Of 31 burn treatments where this species was present, 29 had lower percent composition for this species than was found in control plots. Percent composition was highest in control plots at PVPP in all 5 years and in 3 of 4 years at CRP. Except for Hordeum leporinum, B. rubens appears to be the most fire-intolerant grass.

Bromus mollis

This was the most abundant species in total percent composition in control plots at PVPP (34%) and the third most abundant at CRP (12%). It thrives in the mulch of unburned plots and will increase in percent composition under heavy mulch (Heady 1956). Fire reduced percent composition of this species (Figures 32 and 33). Compared to the control plots, the lowest percent composition of B. mollis resulted from the most recent once-burned treatment in 3 of 9 sampling years, the most recent twice-burned (consecutive) treatment in 3 of 9 sampling years, and thrice-burned treatments in 3 of 9 sampling years.

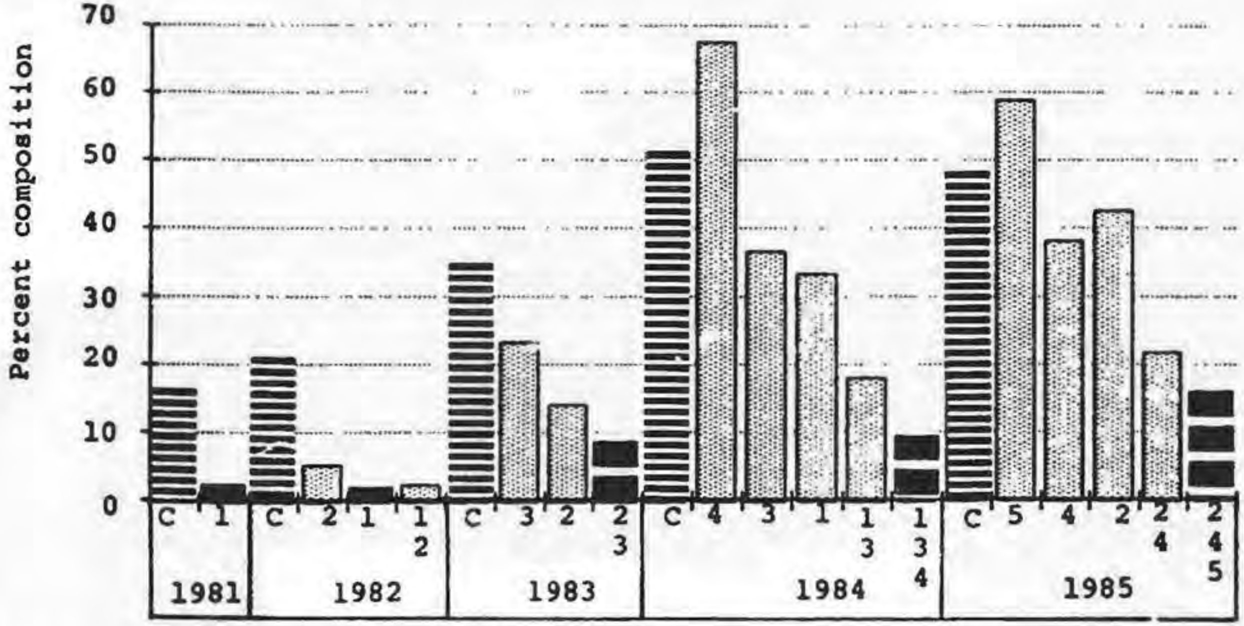
Vulpia Myuros

This annual grass, listed by Munz and Keck (1959) as the native, Festuca megalura, is now recognized as the European alien Vulpia Myuros (Lonard and Gould 1974). This was the fifth most abundant species in total percent composition in control plots at PVPP (6%). Fire increased percent



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $^{2}_{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest decrease in % composition imposed by a burn treatment ▨ other treatments

Figure 32. <u>Bromus</u> <u>mollis</u> at CRP: Percent Composition by Treatment

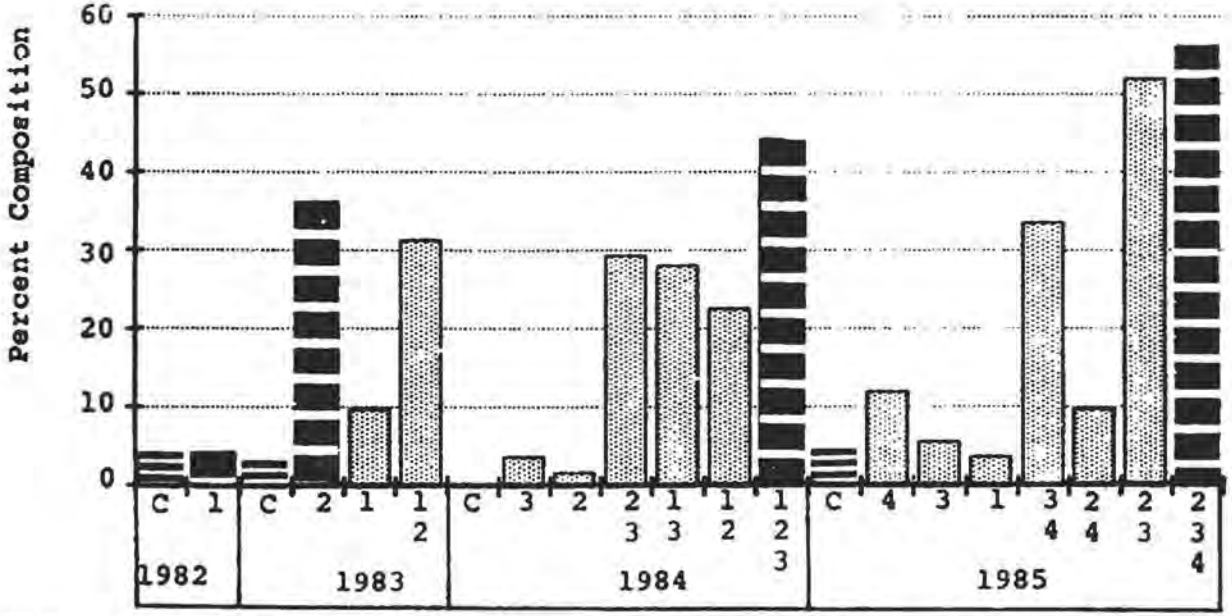


KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest decrease in % composition imposed by a burn treatment ▩ other treatments

Figure 33. <u>Bromus mollis</u> at PVPP: Percent Composition by Treatment

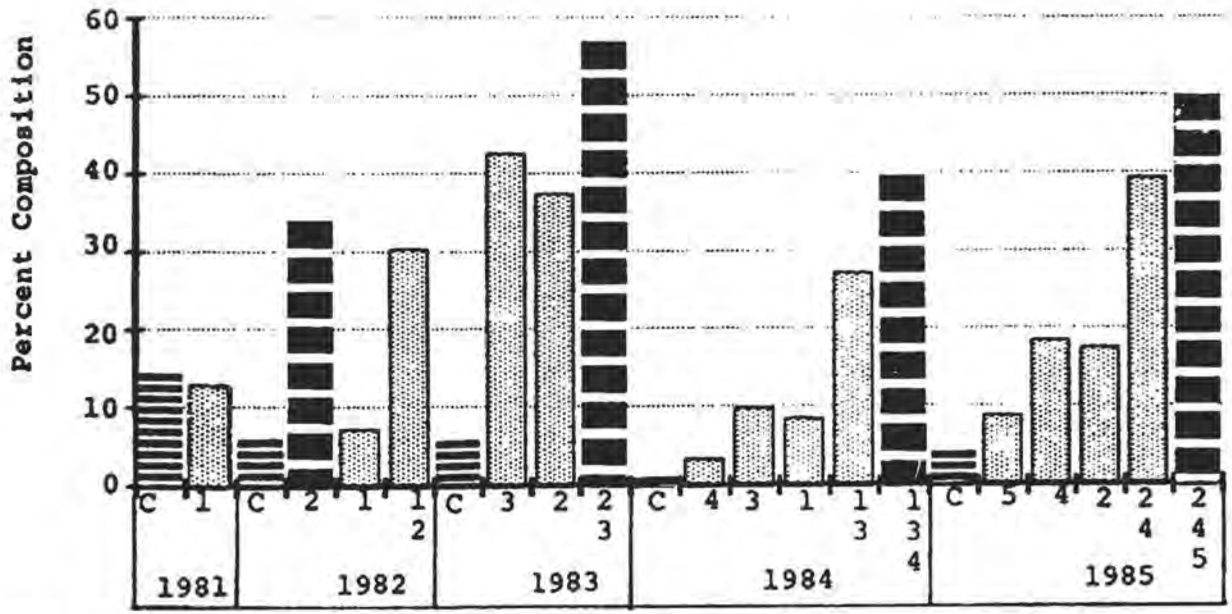
composition of this cover type (Figures 34 and 35) in 8 of 9 sampling years. No other annual grass responded so favorably to fire. Compared to the control plots, the highest percent composition of V. Myuros resulted from thrice-burned treatments in 4 of 8 sampling years, once-burned treatments in 3 of 9 sampling years, and a twice-burned treatment in 1983 at CRP. The control plot had the higher percent composition of the two treatments at CRP in 1982. Recent once-burned treatments showed lower percent composition compared to older burns in 9 of 13 situations. This is true of B. mollis and annual grasses as a whole; more recent once-burned treatments reduce percent composition as compared to older once-burned treatments.

In 4 of 4 years when twice-burned and thrice-burned treatments were sampled, the thrice-burned treatment had higher percent composition. This is opposite of the situation with annual grasses as a whole where thrice-burned treatments reduced percent composition in 3 of 4 sampling years. Of 34 burn treatments, 32 had higher percent composition of V. Myuros than was found in control plots. This is remarkably different from the results for grasses as a whole where only 8 of 34 treatments had higher percent composition than the control.



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$ = plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 34. Vulpia Myuros at CRP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest increase in % composition imposed by a burn treatment ▩ other treatments

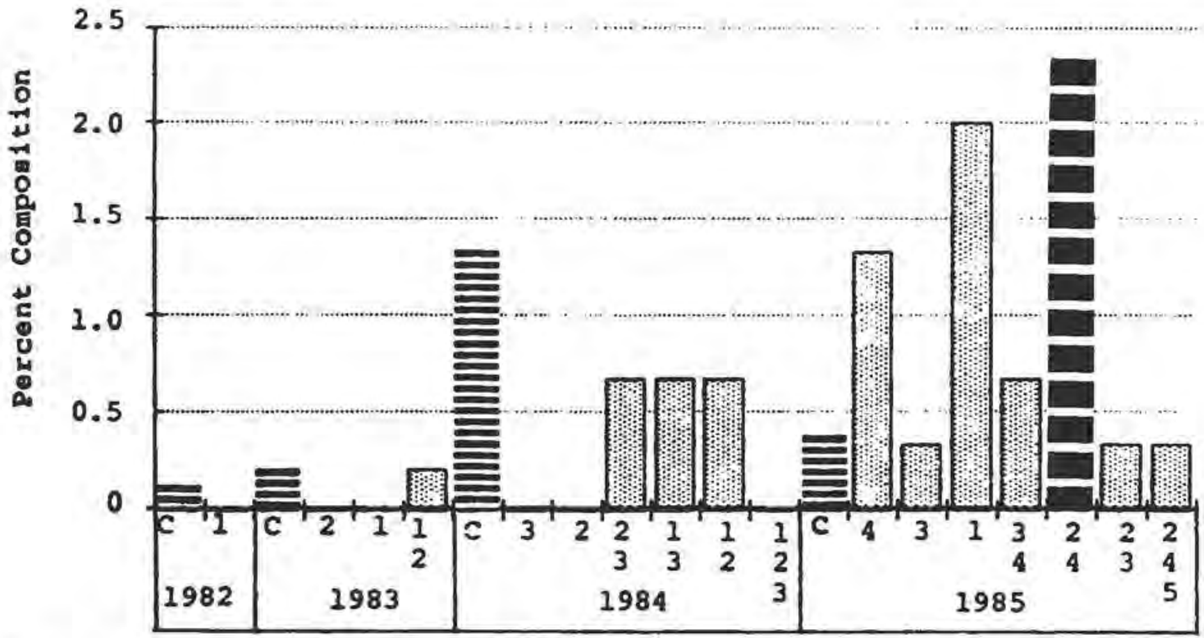
Figure 35. Vulpia Myuros at PVPP: Percent Composition by Treatment

Native Perennial Grasses

Four species of perennial grasses, all natives, occur at the two study sites. Distichlis spicata and the three rarer species account for such a small part of the sample pool that there is scarcely enough data to draw conclusions about this group of grasses. Bartolome and Gemmill (1981) and Rogers (1981) describe how difficult it is for native perennial grasses to compete reproductively with the highly successful, competitive alien annuals. The few data available (Figures 36 and 37) suggest that burns, especially with 1-year intervals, may favor these perennials.

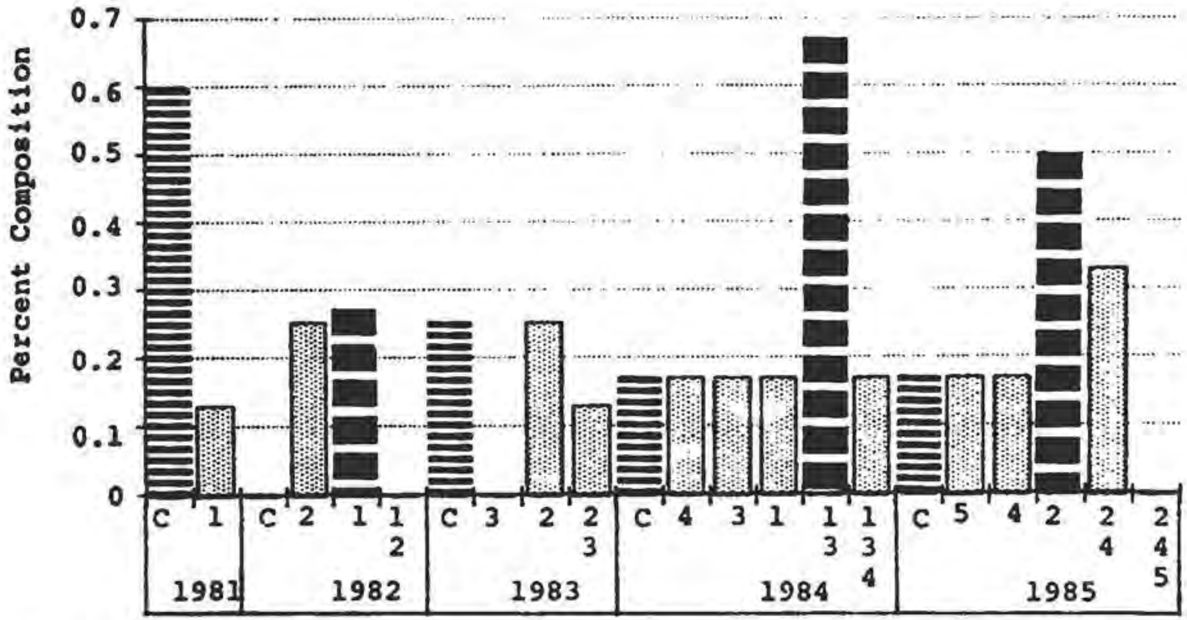
Legumes

This category of herbaceous vegetation was the least abundant in the control plots (it never comprised over 3%) at both sites. The changing annual pattern of percent composition of legumes in control plots at CRP differed slightly from the pattern at PVPP. Fire increased percent composition of legumes in all 9 sampling years (Figures 38 and 39). Compared to control plots, the greatest increase in percent composition of legumes resulted from the most recent once-burned treatment in 5 of 9 sampling years and from a twice-burned treatment in the other 4 sampling years (three of these twice-burned treatments had the most recent burn as one of the two burns). Of 29 burn treatments where legumes were sampled, 24 had higher percent composition than control plots. Legumes benefit from mild fall conditions



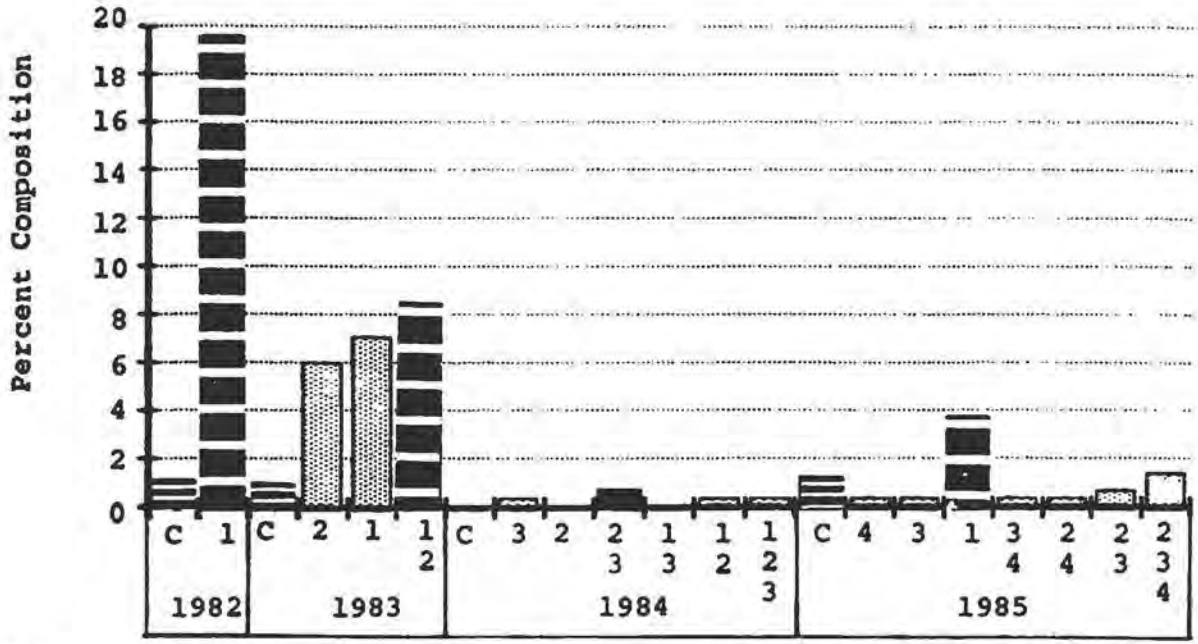
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$ = plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 36. Native Perennial Grasses at CRP: Percent Composition by Treatment



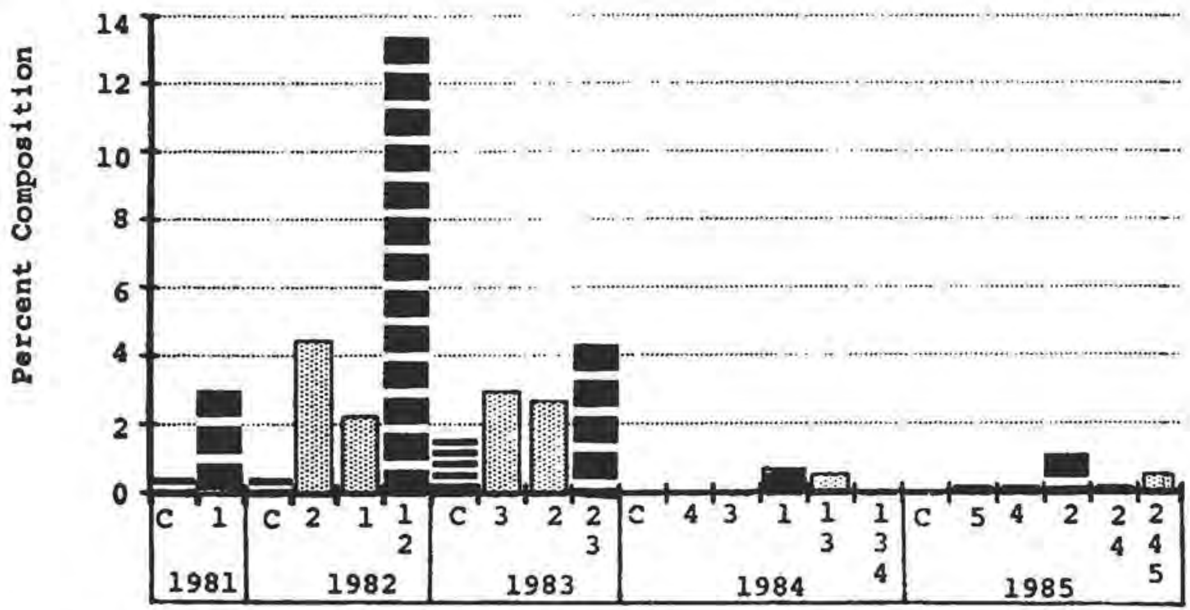
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$ = plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 37. Native Perennial Grasses at PVPP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 38. Legumes at CRP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 39. Legumes at PVPP: Percent Composition by Treatment

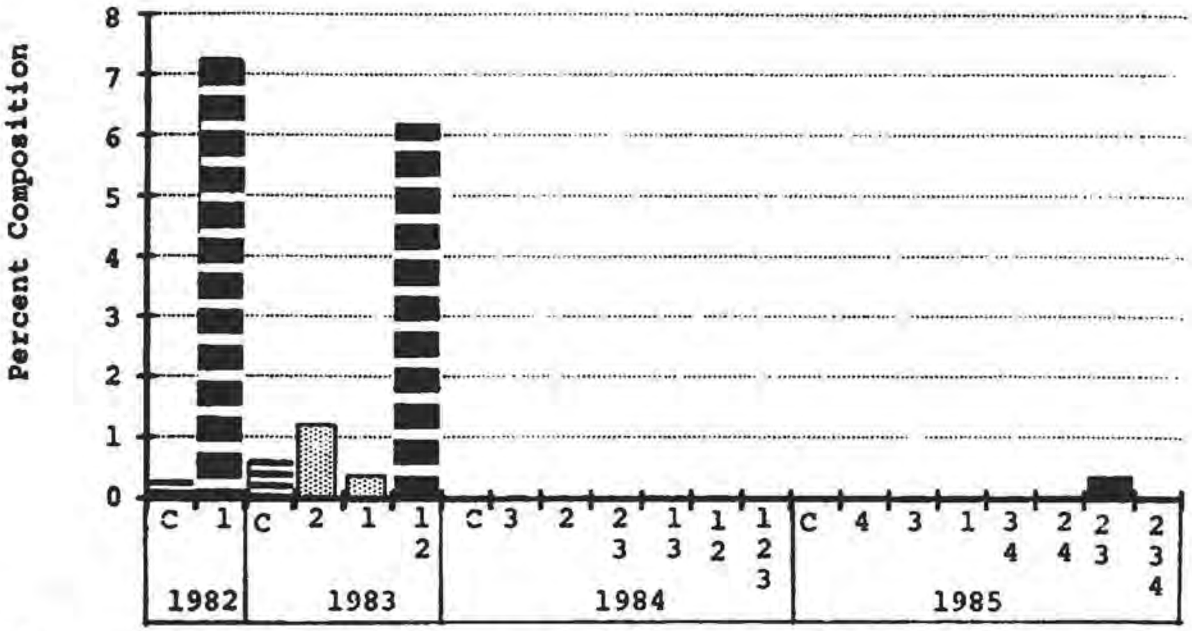
and late spring rains (Duncan and Woodmansee 1975, Pitt and Heady 1978). Compared to control plots, all burn treatments at both sites in 1982, and to a lesser extent in 1983, helped legumes live up to their potential in these "clover years."

Native Annual Legumes

The response of native annual legumes (Figures 40 and 41) to fire was similar to that for legumes overall (aliens plus natives). Fire increased percent composition of these four species in 17 of 18 burn treatments. Compared to control plots, the greatest increase in percent composition of native annual legumes resulted from the most recent once-burned treatment in 4 of 8 sampling years and the most recent twice-burned (consecutive) treatment in the other 4 sampling years.

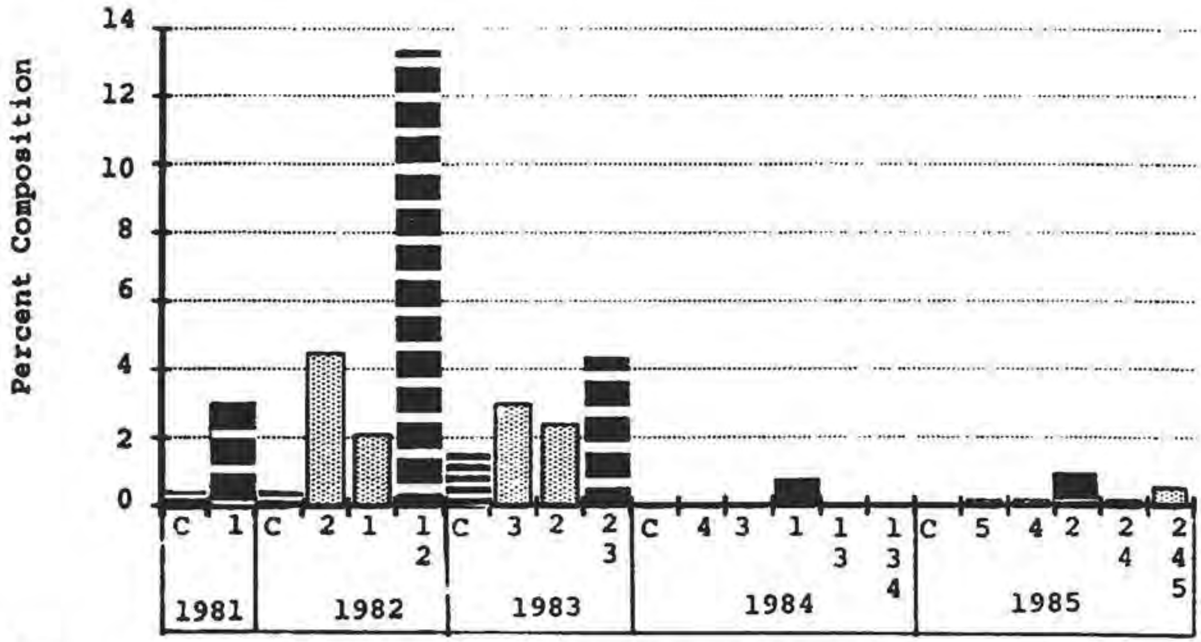
Alien Annual Legumes

The response of alien annual legumes (Figures 42 and 43) to fire was similar to that for legumes overall. Fire increased percent composition of these two species, *Medicago polymorpha* and *Melilotus indicus*, in 14 of 19 burn treatments. Compared to control plots, the greatest increase in percent composition of alien annual legumes resulted from the most recent once-burned treatment in 6 of 8 sampling years and a twice-burned treatment in the other 2 sampling years.



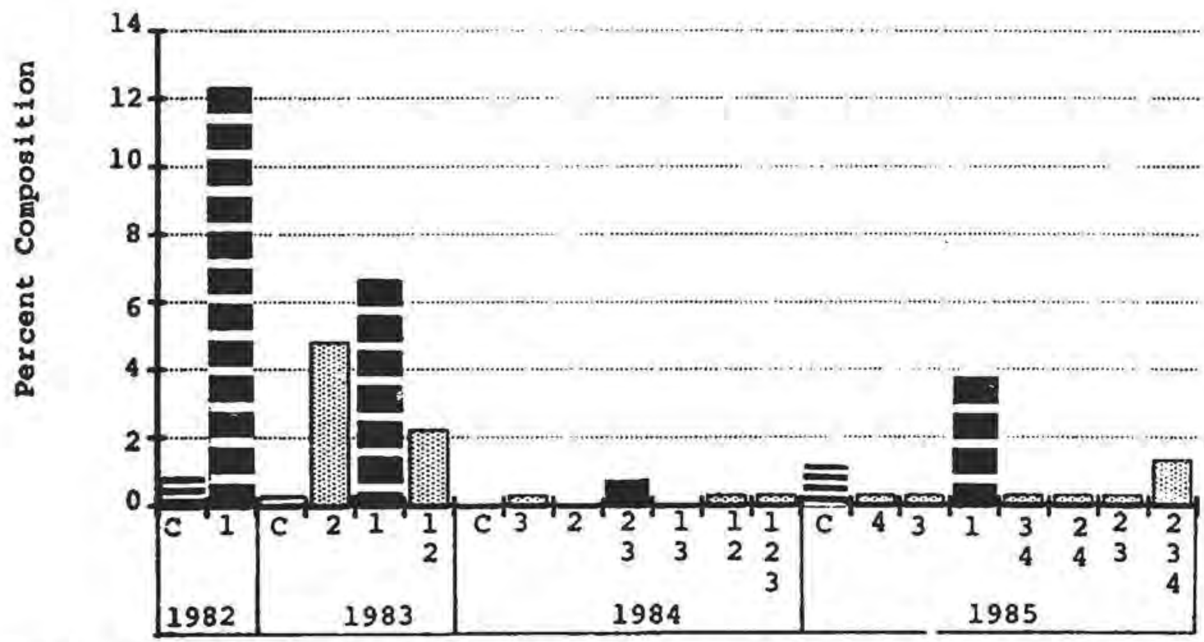
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 40. Native Annual Legumes at CRP: Percent Composition by Treatment



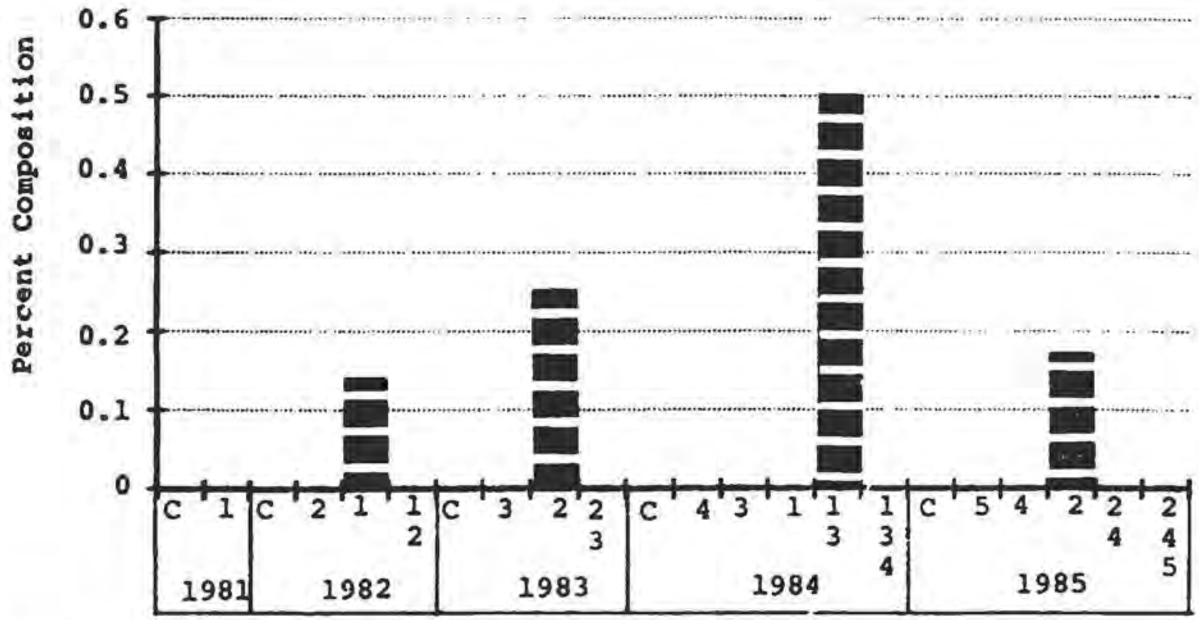
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\begin{smallmatrix}2\\3\end{smallmatrix}$ = plot burned 2 years and 3 years prior to sampling, etc. controls greatest increase in % composition imposed by a burn treatment other treatments

Figure 41. Native Annual Legumes at PVPP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$ = plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest increase in % composition imposed by a burn treatment ▨ other treatments

Figure 42. Alien Annual Legumes at CRP: Percent Composition by Treatment



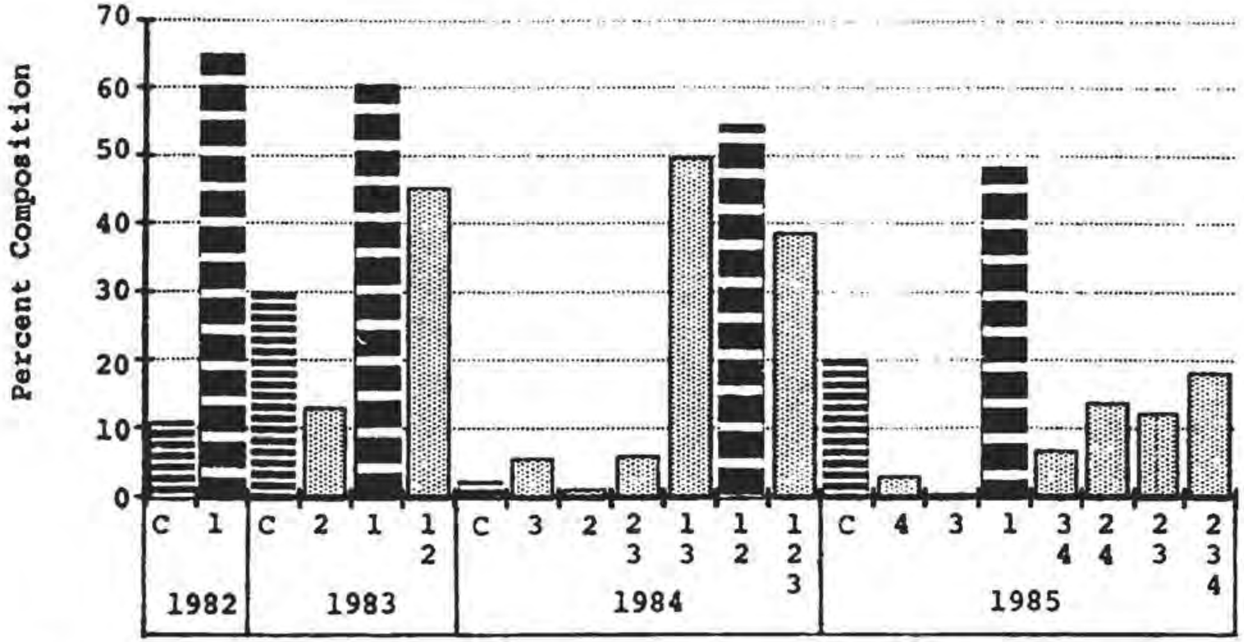
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$ = plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 43. Alien Annual Legumes at PVPP: Percent Composition by Treatment

Forbs (Other Than Legumes)

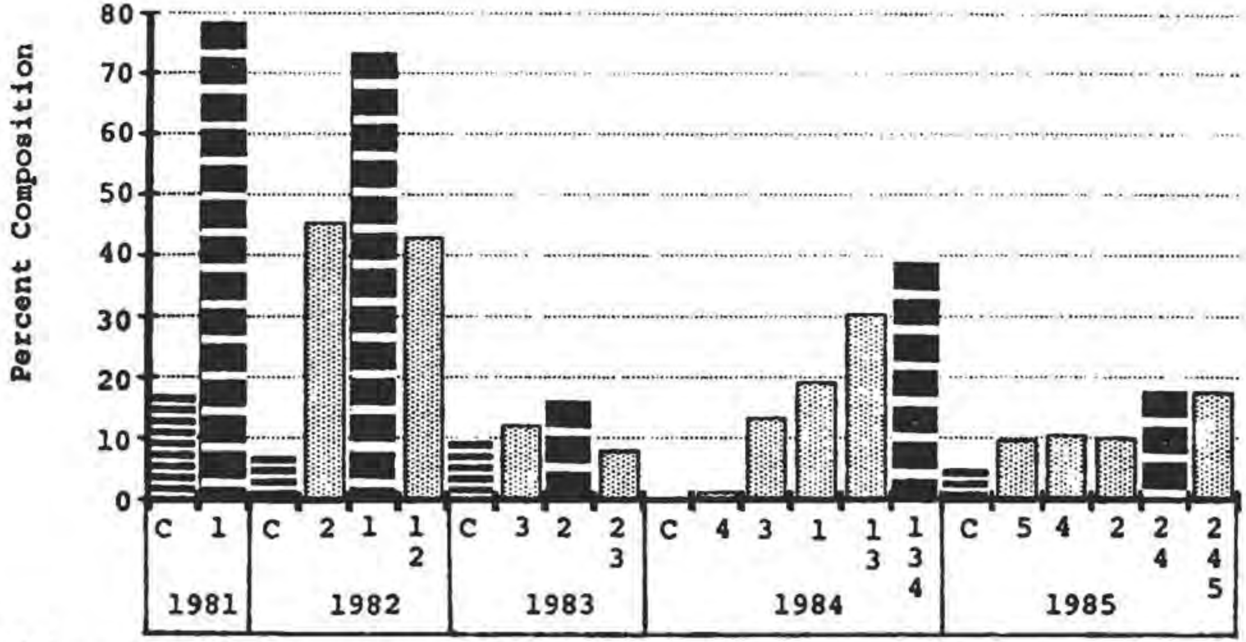
Forbs, in this discussion, refers to forbs other than legumes. Forbs were more abundant than legumes but less abundant than grasses in the control plots at both sites in every sampling year. The changing pattern of percent composition of forbs in the control plots at CRP and PV"P is the same from 1982 to 1985 but percent composition of forbs was always higher at CRP. In control plots at both sites in 1983, and to a lesser extent in 1985, percent composition of forbs increased as grass composition decreased.

Fire significantly increased percent composition of this cover type (Figures 44 and 45). Compared to control plots, the greatest increase in percent composition of forbs resulted from the most recent once-burned treatment in 6 of 9 sampling years, the most recent multiple burn treatment (burned 2 or 3 times) in 2 of 9 sampling years, and the most frequently burned treatment in 1 of 9 sampling years. Recent once-burned treatments show higher percent composition compared to older burns in 8 of 10 situations. In both years where there are two twice-burned (consecutive years) treatments, the more recent of the two combinations has higher percent composition. Twice-burned treatments (with a 1-year interval between burns) showed higher percent composition than twice-burned (consecutive) treatments in three of four situations. Of 34 burn treatments, 26 had higher percent composition than control plots. The highest



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 44. Forbs (Other Than Legumes) at CRP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$ = plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 45. Forbs (Other Than Legumes) at PVPP: Percent Composition by Treatment

percent composition of forbs always resulted from burning (compare Table 3 and Table 1, see p. 11); this is opposite of the grass response to fire.

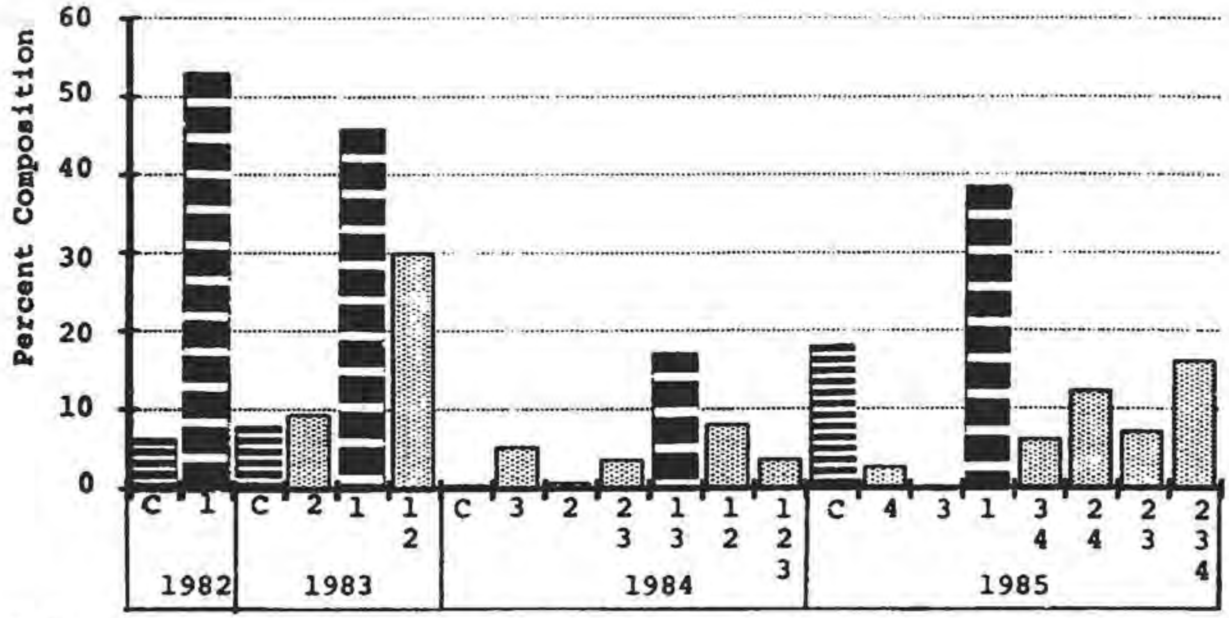
Table 3. Dominant Plant Species in Burned Plots Showing Highest Percent Composition of Native Species

CRP		PVPP	
*Hemizonia pungens	31%	*Vulpia Myuros	18%
*Hordeum depressum	15%	*Bromus mollis	17%
*Vulpia Myuros	9%	*Hordeum depressum	11%
Medicago polymorpha	8%	*Hemizonia pungens	11%
*Bromus mollis	5%	*Erodium cicutarium	5%
*Erodium cicutarium	5%	Erodium botrys/ obtusiplicatum	5%
*Erodium moschatum	4%	*Erodium moschatum	5%
Lepidium dictyotum	4%	Bromus rubens	5%
Amsinckia intermedia	3%	Hordeum leporinum	5%
Lasthenia Fremontii	2%	Brodiaea pulchella	4%
	86%		86%

The ten most abundant species from each preserve are listed in decreasing order of abundance. Abundance is calculated as percent composition of total data points from the burn treatments which imposed the highest percent composition of native species each year at a given preserve. Species favored by fire that occur at both preserves are indicated with an asterisk (*).

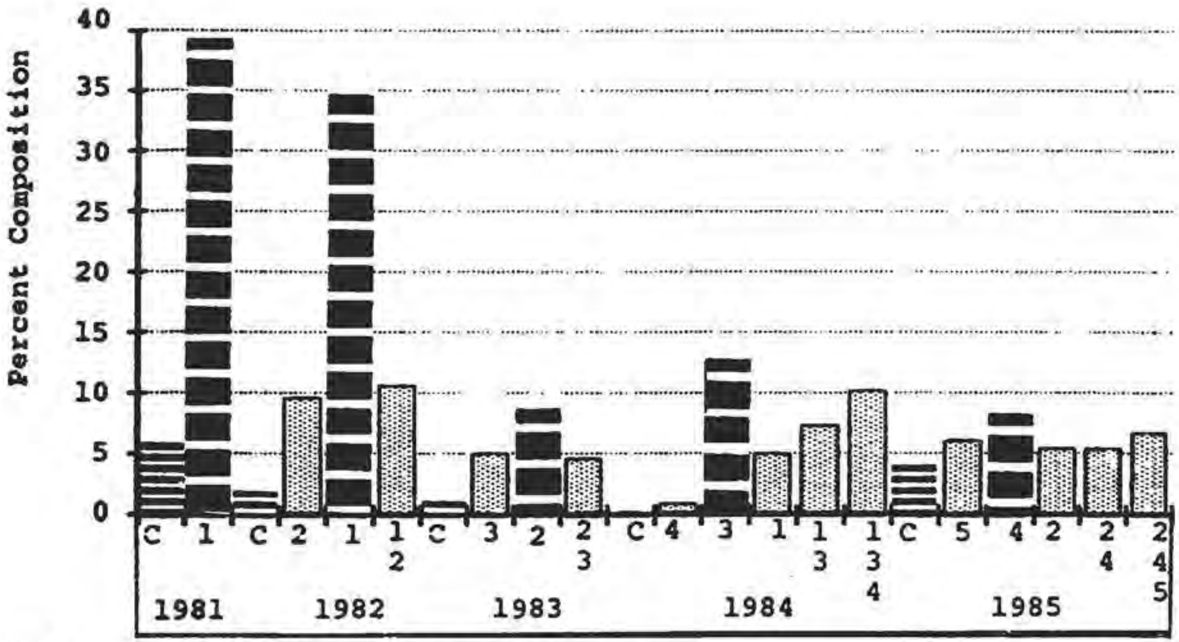
Native Annual Forbs (Other Than Legumes)

The response of native annual forbs to fire was similar to that for annual forbs overall. Fire increased percent composition of this large group (27 species) in 28 of 34 burn treatments (Figures 46 and 47). Control plots had the lowest percent composition of any treatment in 8 of 9 years. Fire encourages forbs by reducing percent composition of



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 46. Native Annual Forbs (Other Than Legumes) at CRP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 47. Native Annual Forbs (Other Than Legumes) at PVPP: Percent Composition by Treatment

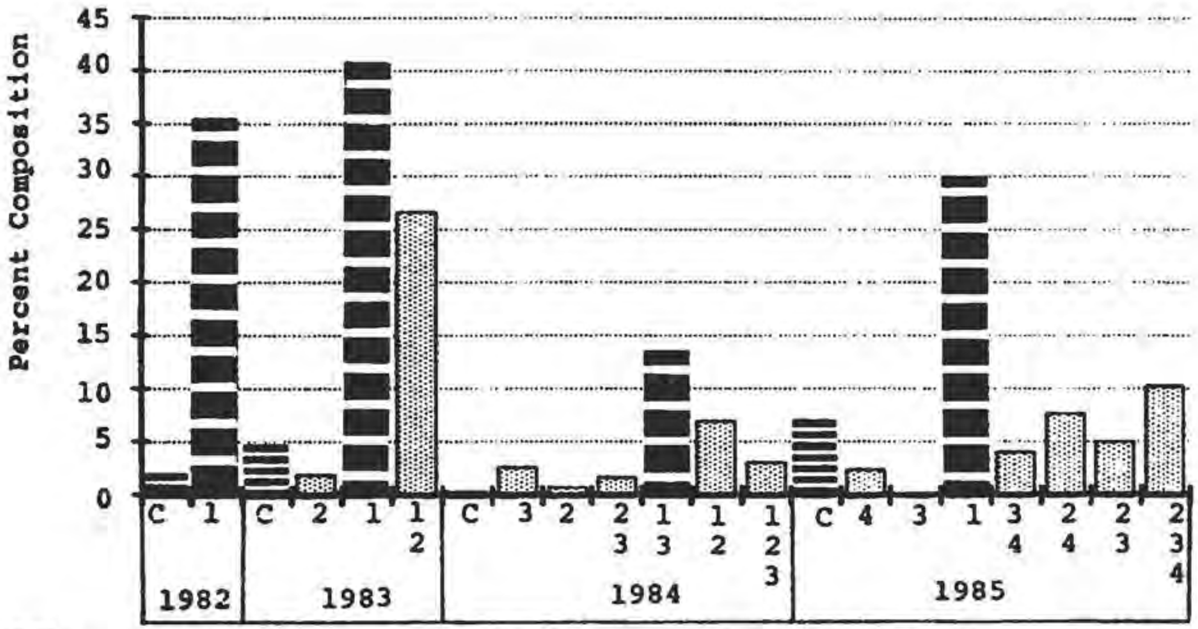
grasses. It is on such burned plots that "winter greenery explodes briefly into a spectacular quilt of many-hued wildflowers" (Preston 1981).

Hemizonia pungens

Fire increased percent composition of this species (Figures 48 and 49) in all 9 sampling years. The highest percent composition of this species resulted from the most recent once-burned treatment in 6 of 9 sampling years and an old once-burned treatment in 1 of 9 sampling years. In both years where two twice-burned (consecutive) treatments were sampled, the more recent combination had higher percent composition. In both years where twice-burned (consecutive) and twice-burned (with a 1-year interval) were sampled, the twice-burned (interval) treatment showed higher percent composition. Of 33 burn treatments where this species was present, 26 had higher percent composition for this species than was found in control plots. H. pungens is least often encountered in control plots or old burn treatments.

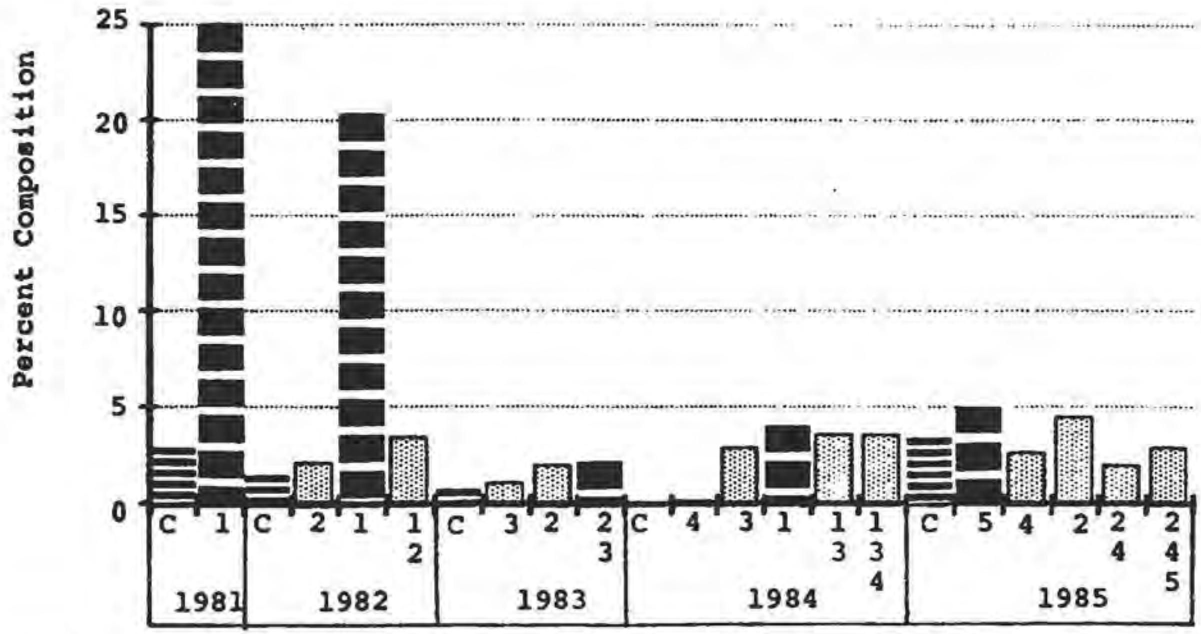
Lepidium (2 Species)

Data from Lepidium dictyotum and Lepidium nitidum were pooled. These forbs are important food sources, especially for mammals. Fire increased percent composition of these species (Figures 50 and 51) in all 9 sample years. Compared to the control plots, the highest percent composition of these species resulted from once-burned treatments in 7 of 9



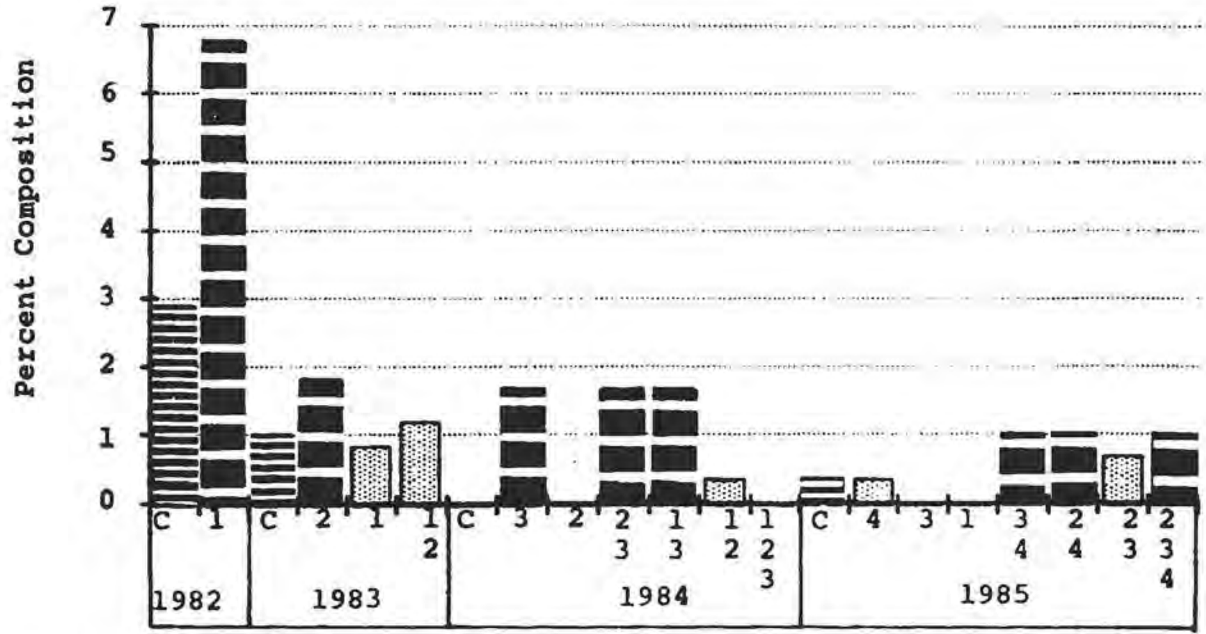
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 48. Hemizonia pungens at CRP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$ = plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 49. Hemizonia pungens at PVPP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$ = plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 50. <u>Lepidium</u> (2 Species) at CRP: Percent Composition by Treatment

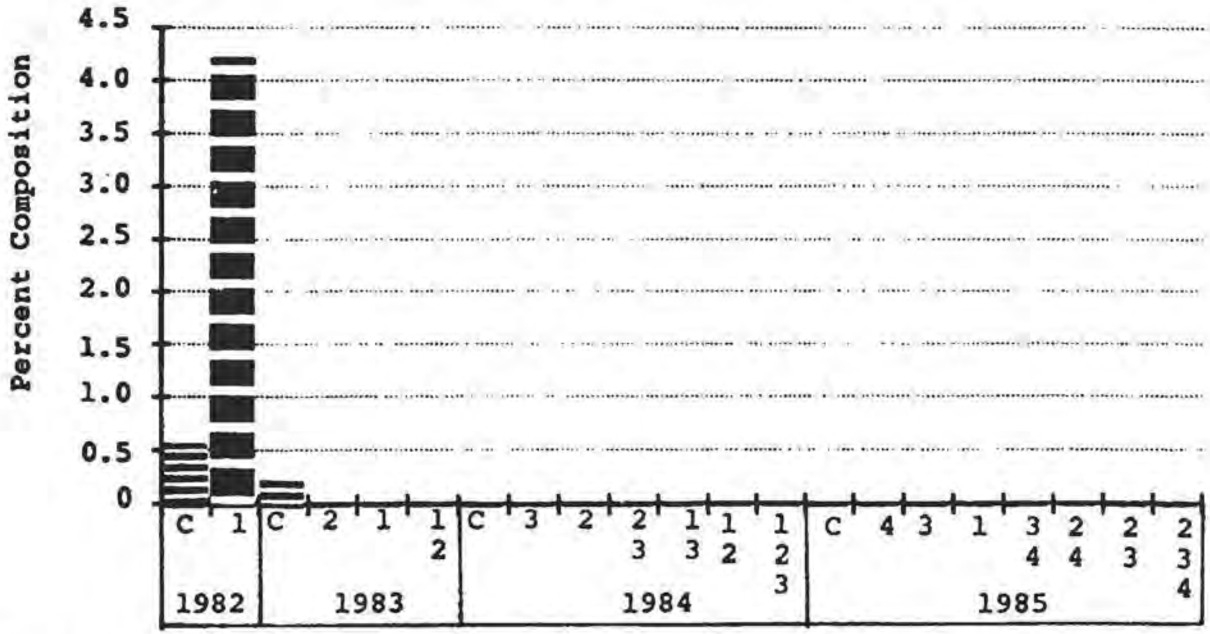
sampling years and multiple-burn treatments in 2 of 9 sampling years. Of 29 burn treatments where these species were present, 26 had higher percent composition for these species than was found in control plots.

Lasthenia (2 Species)

Data from *Lasthenia chrysostoma* and *Lasthenia Fremontii* were pooled. Neither species is very abundant in percent composition but these forbs provide food for insects, birds, and rodents. *L. chrysostoma* was the only species present in samples at CRP. Fire increased percent composition of these species (Figures 52 and 53) in 6 of 7 sampling years where *Lasthenia* was encountered. Compared to the control plots, the highest percent composition of these species resulted from the most recent once-burned treatment in 2 of 6 sampling years. Of 16 burn treatments where these species were present, 15 had higher percent composition for these species than was found in control plots.

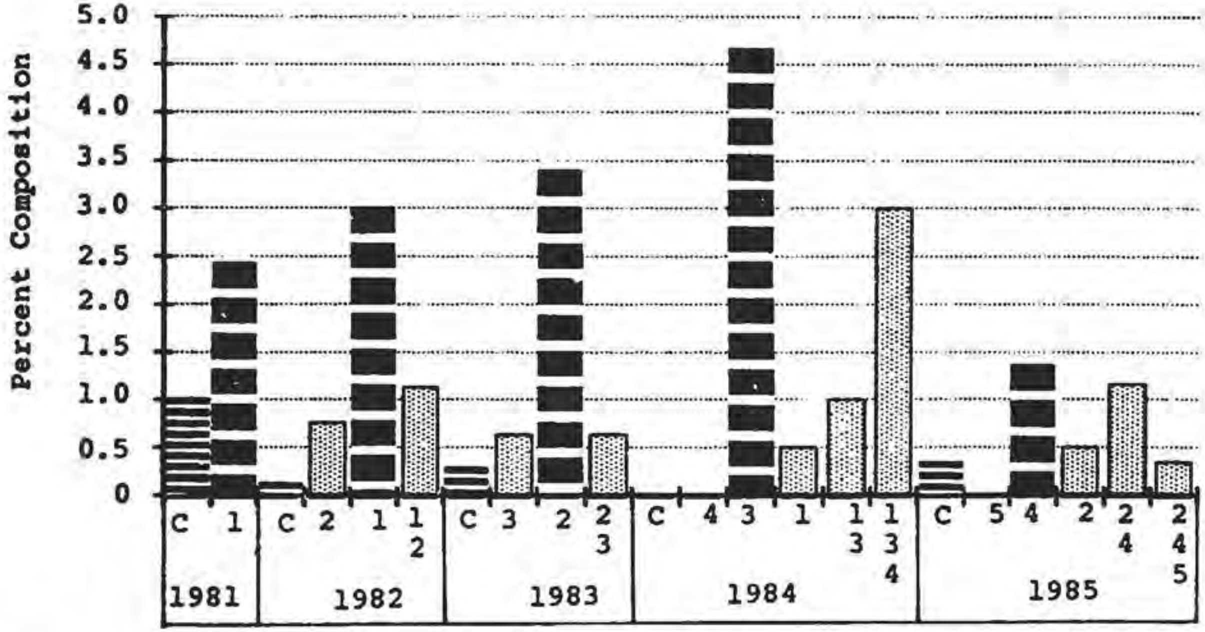
Alien Annual Forbs (Other Than Legumes)

The response of alien annual forbs to fire was similar to that for forbs overall. Fire increased percent composition of this group in 22 of 34 burn treatments (Figures 54 and 55). Unlike native forbs, some burn treatments reduced alien forb percent composition. This category of herbaceous vegetation includes three species of



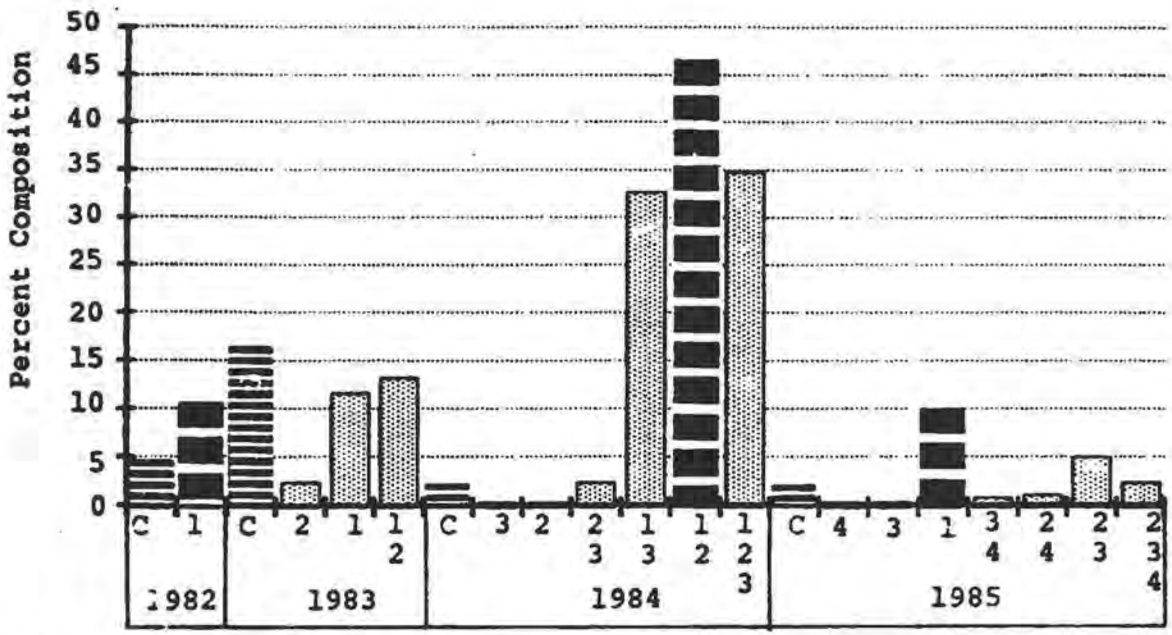
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 52. Lasthenia (2 Species) at CRP: Percent Composition by Treatment



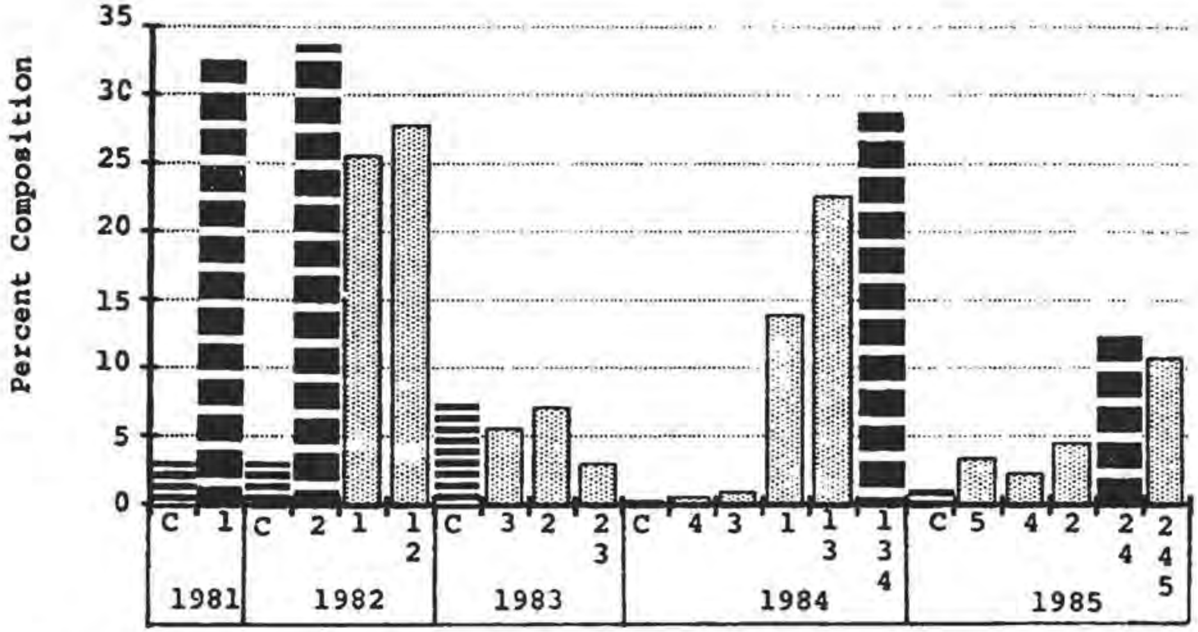
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 53. Lasthenia (2 Species) at PVPP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$ = plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 54. Alien Annual Forbs (Other Than Legumes) at CRP: Percent Composition by Treatment



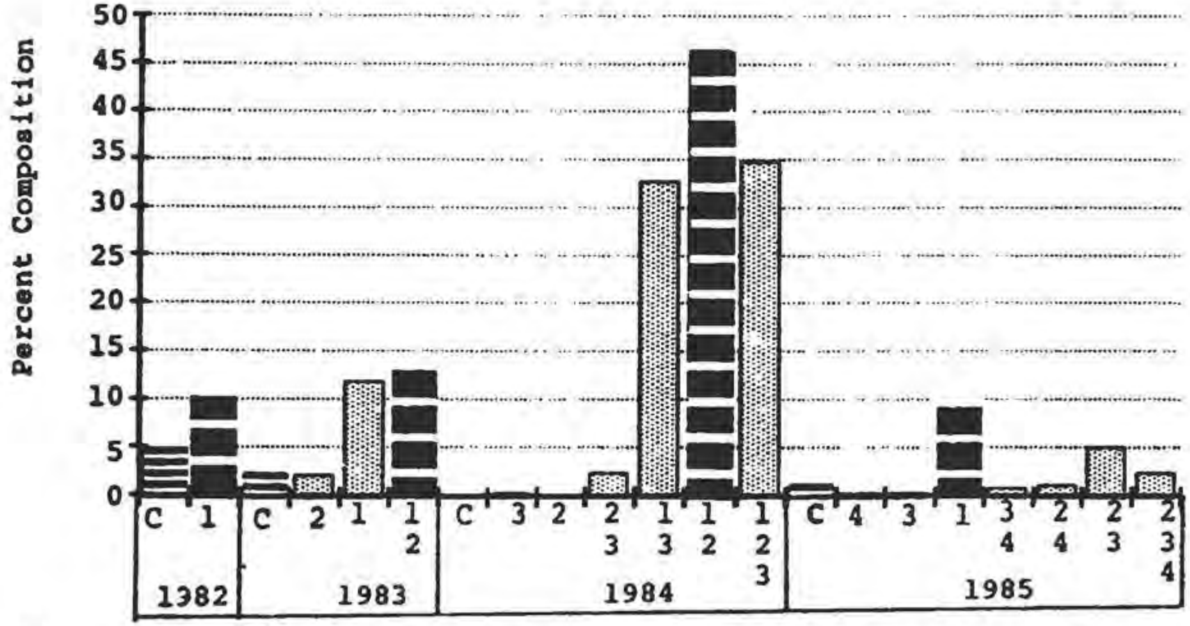
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 55. Alien Annual Forbs (Other Than Legumes) at PVPP: Percent Composition by Treatment

Erodium, a genus which is favored by recent fire (Table 3). Like many forbs, Erodium does well when drought follows early rains. Since it germinates and quickly sends a tap root down to deeper water, it is not as drought affected as are shallow-rooted grasses (Bartolome 1976). Very wet years, like 1983, favor grasses. This might explain why this was the only year when percent composition of alien annual forbs in the control plot was higher than in any burn treatment at either CRP or PVPP. This category of herbaceous vegetation is favored by fire. In a CRP plot which was burned in 1982 and 1983 then sampled in 1984, alien annual forbs comprised 46.33% of total composition; the maximum showing by this category.

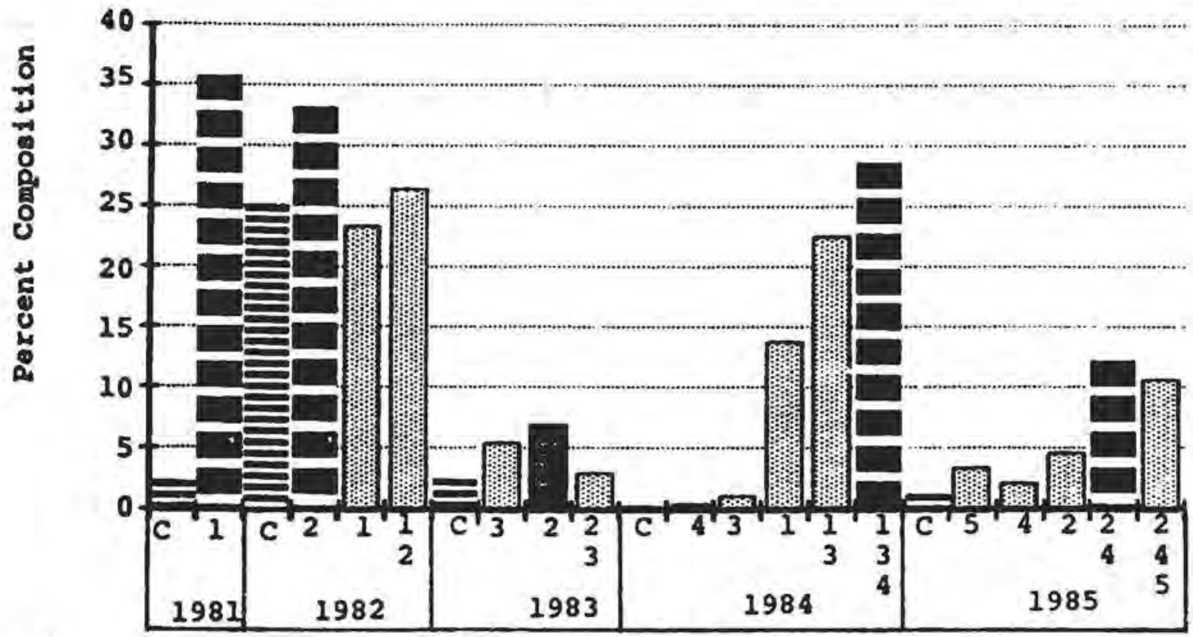
Erodium (3 Species)

Data from Erodium botrys/obtusiplicatum, E. cicutarium, and E. moschatum were pooled. Fire increased percent composition of this group of species (Figures 56 and 57) in all 9 sampling years. Compared to the control plots, the highest percent composition of this group resulted in 5 of 9 sampling years, the most recent twice-burned treatment in 3 of 9 sampling years, and a thrice-burned treatment in 1 of 9 sampling years. Of 33 burn treatments where this group was present, 27 had higher percent composition for this species than was found in control plots. Fire always increased percent composition of Erodium, but each subsequent year in



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 56. Erodium (3 Species) at CRP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $^{2}_{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 57. <u>Erodium</u> (3 Species) at PVPP: Percent Composition by Treatment

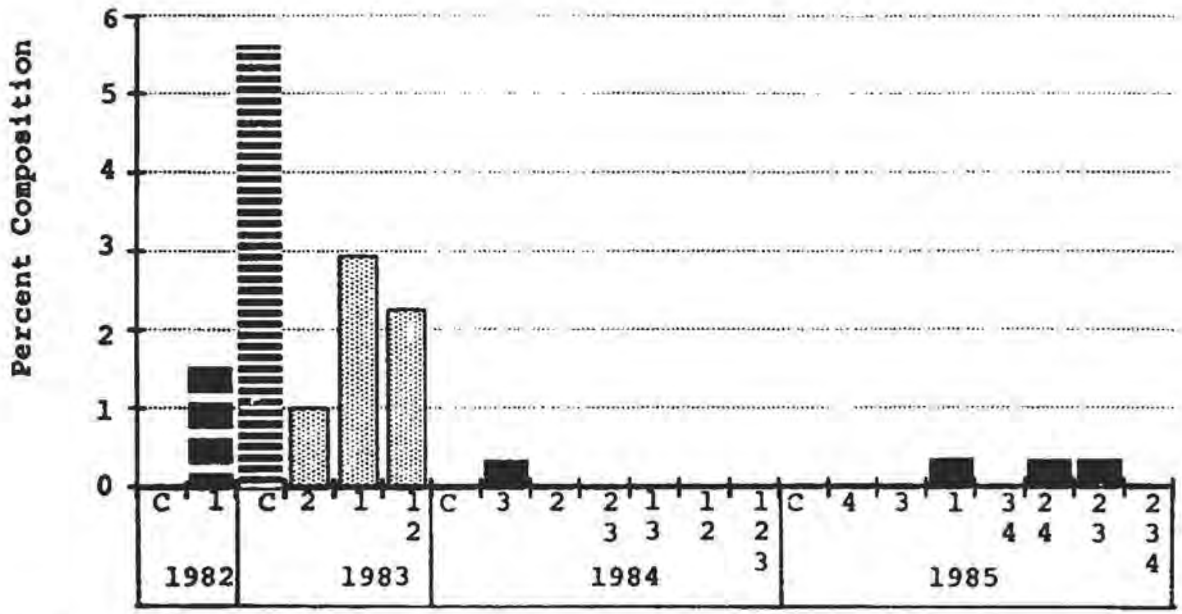
plots with no additional burns, percent composition steadily decreased. The only year where there was an exception to this trend was in 1985, after a warm, dry rainfall season coupled with late germination (November).

Native Perennial Forbs (Other Than Legumes)

Fire increased percent composition of this group in 12 of 19 burn treatments (Figures 58 and 59). *Brodiaea pulchella* and *Delphinium recurvatum* seem especially sensitive to climate, making poor showings in dry years (1984 and 1985). Compared to control plots, recent once burned treatments resulted in the greatest increase in percent composition for this species group.

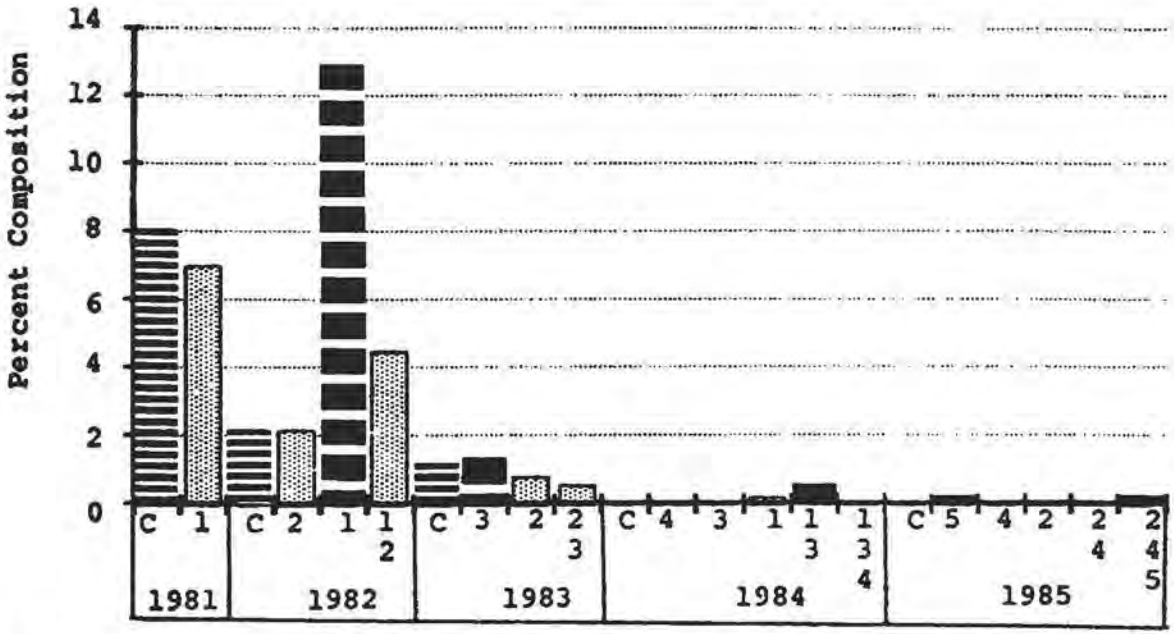
Brodiaea pulchella

This bulb is the only perennial that was abundant enough to be examined in detail (Table 3, see p. 73). Fire increased percent composition of this species (Figures 60 and 61) in 5 of 8 sampling years. In one of the other 3 years, percent composition was the same in the control as it was in the treatment. Of 14 burn treatments where this species was present, six had higher percent composition than was found in control plots. This species may benefit from mulch and surrounding vegetation that protects the bulb from digging by California ground squirrels, *Citellus beecheyi*. Evidence seen at PVPP suggests that when this mulch is burned away, the bulbs are more readily accessible to squirrels as they root around for this desirable food source.



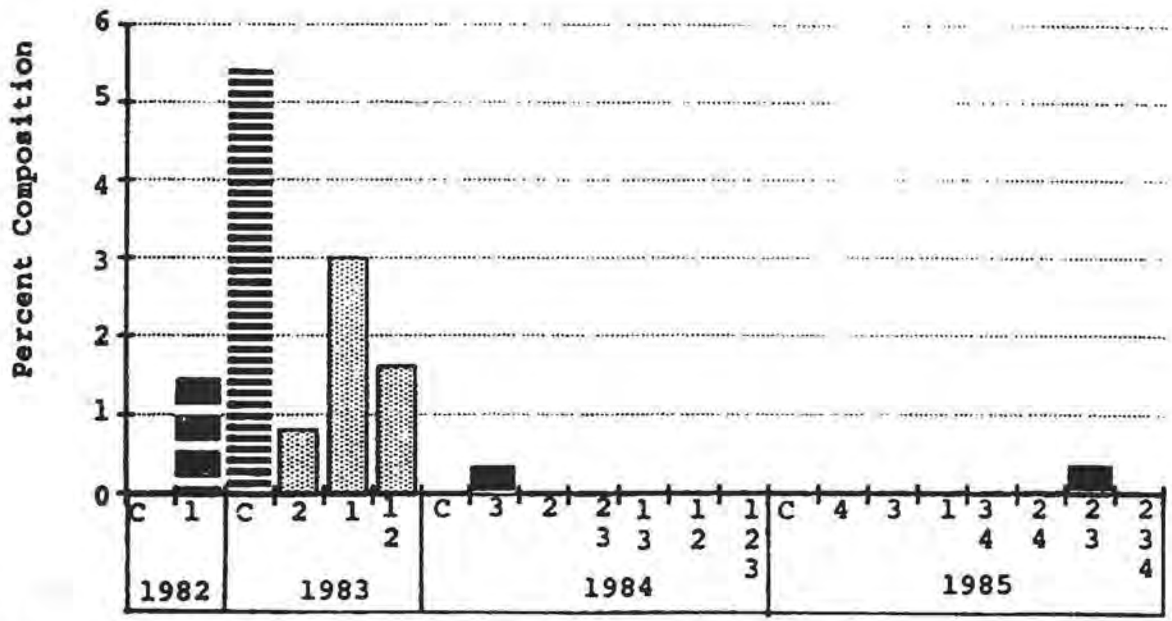
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ▬ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 58. Native Perennial Forbs (Other Than Legumes) at CRP: Percent Composition by Treatment



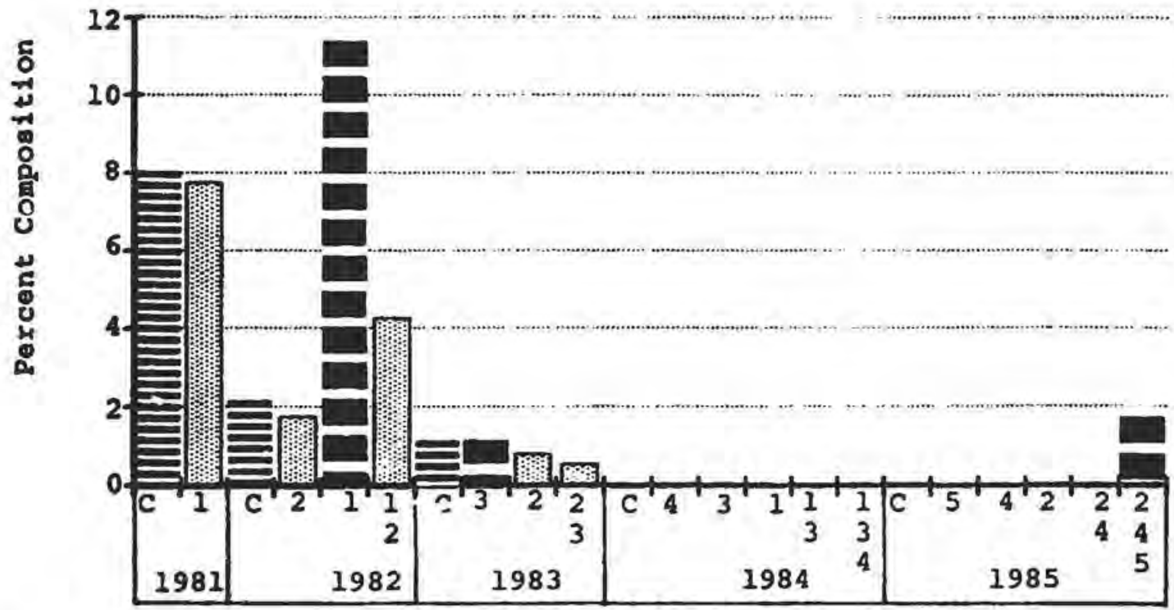
KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$ = plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest increase in % composition imposed by a burn treatment ▨ other treatments

Figure 59. Native Perennial Forbs (Other Than Legumes) at PVPP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$ = plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest increase in % composition imposed by a burn treatment ▩ other treatments

Figure 60. Brodiaea pulchella at CRP: Percent Composition by Treatment



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. controls greatest increase in % composition imposed by a burn treatment other treatments

Figure 61. Brodiaea pulchella at PVPP: Percent Composition by Treatment

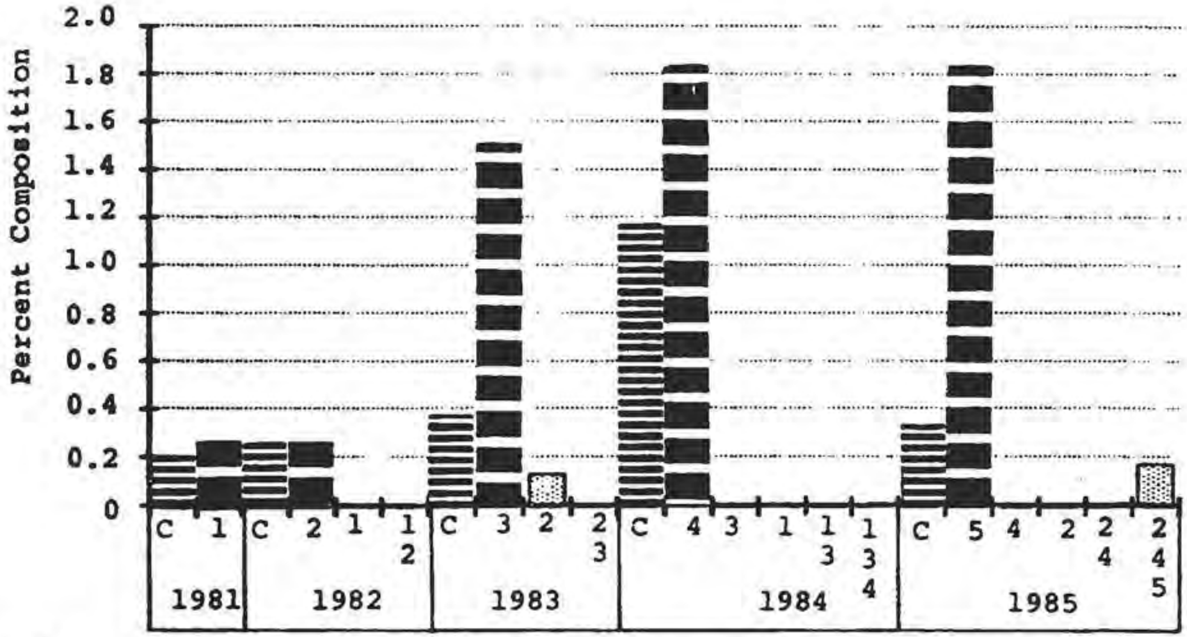
Native Perennial Shrub

Haplopappus acradenius, the only woody perennial in the species pool, was not encountered at CRP. It was recorded on only 12 treatments at PVPP (Figure 62). Compared to control plots, percent composition was higher in four of seven burn treatments.

Certain vegetation categories (native perennial grasses, legumes, native legumes, alien legumes, native perennial forbs, and native perennial shrub) and individual species (*Lepidium*, *Lasthenia*, and *Brodiaea pulchella*) comprise such a small part of the sample pool (in all or most years) that the information shown on the corresponding figures may not be meaningful. Even though these species and species groups had low percent composition in most years, the figures reflect changes that were measurable by this study's sampling method. Most of these changes, though proportionately small, tended to resemble the overall changes in composition of related species and species groups.

Indices Of Similarity

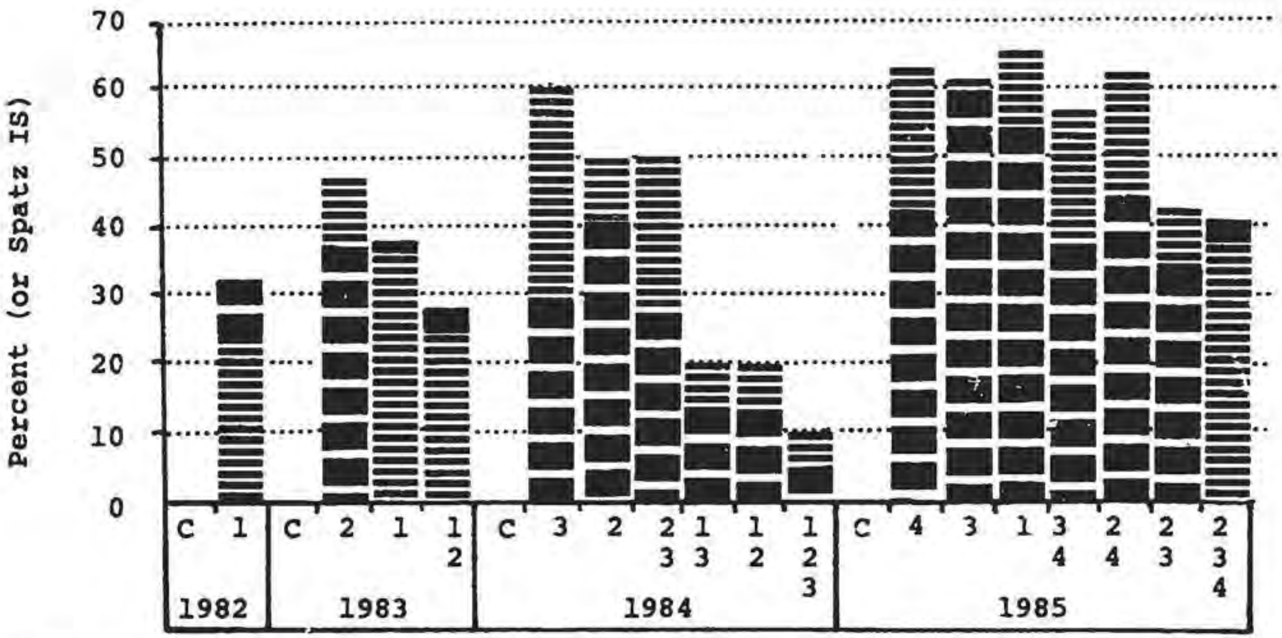
The effect of time on species composition was examined by calculating indices of similarity (IS) between a given control and all treatments at that study site that year. Plots burned most recently, especially those burned two or three times, have the lowest IS in all cases (using either



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▤ controls ■ greatest increase in % composition imposed by a burn treatment ▩ other treatments

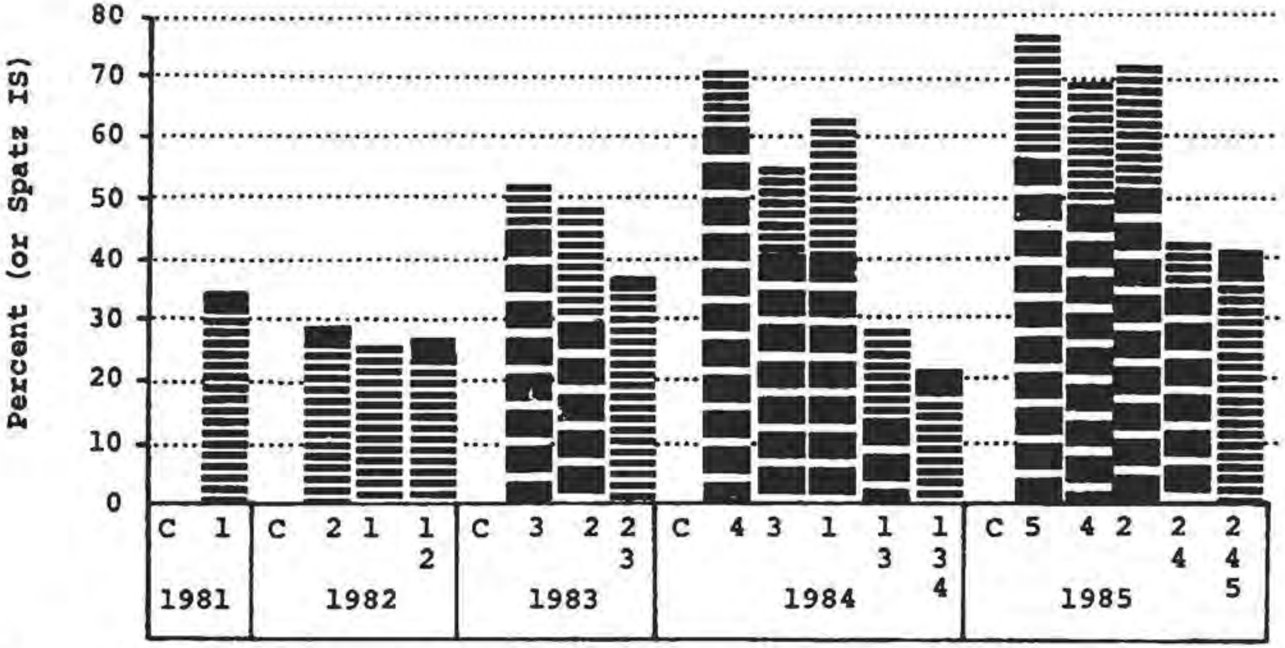
Figure 62. Native Perennial Shrub at PVPP: Percent Composition by Treatment

IS formula). This means that these plots differed most from controls in terms of species composition. Each year that passed without fire caused the species composition of a previously burned plot to bear a greater resemblance to the unburned control (Figures 63 and 64). Species composition in plots that were burned most recently or most often may be most dissimilar to a control, but this does not infer anything about the diversity or the proportion of native species in the plot. For example, a plot with low diversity may have a higher proportion of native species than a more diverse plot. Also, a burned plot and its corresponding control plot may have a high IS value but neither plot may be very diverse.



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $\frac{2}{3}$= plot burned 2 years and 3 years prior to sampling, etc. ▬ Spatz Similarity Index ▤ Percent Similarity. Index values reflect similarity between a given control and all treatments at CRP that year. The higher of the two IS values appears behind the lower value in this graph.

Figure 63. Indices of Similarity at CRP



KEY: Year figures represent the year of spring sampling. Treatment codes: C = control plots; 1 = plot burned in fall of year prior to sampling; 2 = plot burned 2 years previously; $^{2}_{3}$= plot burned 2 years and 3 years prior to sampling, etc. Spatz Similarity Index Percent Similarity. Index values reflect similarity between a given control and all treatments at PVPP that year. The higher of the two IS values appears behind the lower value in this graph.

Figure 64. Indices of Similarity at PVPP

DISCUSSION

Fire increases species diversity. Because fire has an adverse effect on the dominant grasses, a decline in their percent composition provides competitive release for other groups; legumes and especially forbs.

Native species benefit from fire at the expense of alien species for the same reason that fire increases diversity. When the dominant species group, alien grasses, is reduced by fire, forbs--most of which are fire adapted natives--move into the gap left by the alien grasses.

Pitt and Heady (1978) claimed that fire, like other disturbance factors, influences only the magnitude and not the direction of change in species composition. The major botanical trends appear to answer most strongly to changing weather patterns. This study did not produce any evidence to the contrary. For example, *Hemizonia pungens*, like all the other forbs, does well in years when grasses do poorly; it does especially well with the help of previous fire. In years when *H. pungens* increased markedly in the control plot, there was a corresponding rise is percent composition in burn treatments. In no year, when *H. pungens* showed only modest increases in a control plot, did it increase markedly in a burn treatment.

Repeated burning does not reduce species diversity (Vogl 1979). Species diversity changes annually even without fire, but in this study, fire was a source of added diversity in most cases. There is no such thing as optimum diversity because management conditions which increase the diversity of one group are often disadvantageous to another (Moore 1985).

If a resource manager wishes to increase diversity, and if native species are deemed more desirable, then fire is one available means to that end.

Local climate, soil and species composition impose their own subtle interactions on the outcome of a fire and it would be unwarranted to generalize to other areas.

Generalizing within species groups can be misleading. When "grasses" are reduced by fire, perennials are affected differently than annuals. Among the annuals, alien grasses may respond differently than natives. A careful examination of the fire response in the five dominant annual grasses (Vulpia Myuros, Hordeum depressum, Bromus mollis, Bromus rubens, and Hordeum leporinum), indicates that these species are arrayed along a fire tolerance gradient. At the bottom end is H. leporinum. Since it thrives best in its own abundant mulch, it prefers no fire at all. B. rubens tolerates fire only slightly better. B. mollis, midway up the scale, can benefit from fire when the less tolerant species, reduced by a burn, do not germinate until this early starter is well on its way to being a seedling. The native, H. depressum, seems even better adapted to occasional fire and V. Myuros thrives under a regime of fire (Figure 28). Such findings advise against unwarranted generalizations . . . a "grass year" may not be a "grass year" for all grass species.

Fire is a major agent of change in species composition and diversity, but various key factors are interrelated by a complex of interactions. Malin (1984) states it eloquently: "Generalization is always dangerous and nowhere more so than on the matter of fire and vegetation. The variables are too numerous . . . ."

Mulch is a key factor in maintaining a so-called climax of alien annuals in the California grasslands. Litter coverage of soil (Evans and Young 1972) benefits seedling establishment of alien annuals. Germination is further aided by mulch's tendency to moderate temperature and moisture (Evans and Young 1970). The reduction of evaporation (Hopkins 1954) benefits annuals and perennial seedlings as well (Glendening 1942). The soil moisture required by annual and perennial alike, usually goes to the annuals in our modified grassland today. Occasional fires (Weaver and Rowland 1952) and cattle grazing (Vogl 1974) both modify the mulch layer but in different qualitative ways. Continued heavy grazing reduced mulch (Hedrick 1948) to the benefit of filaree (Erodium) at the expense of Bromus *diandrus* (Jones and Evans 1960). This two-sided impact is very much like the result of a burn. Grazing intensity does not exert as much influence on botanical composition as do variable weather patterns (Pitt and Heady 1979), but the mulch has an impact on subdominant species during the period of rapid plant growth in spring (Heady 1961). Competition for light is often important as a limiting factor to subdominants when there are taller or broad-leaved plants in the grass canopy (Hufstader 1976). As long as they get their first half inch of rain at the proper time in the fall (by November), grasses will germinate and put on early spring growth (Table 4) (Murphy 1970). However, they will produce little seed if they do not also get ample rainfall after mid-March (Ewing and Menke 1983). Progeny that mature in the next growing season will be smaller, on average, and usually produce small seeds themselves. Even though this vegetation is annual, the effect of a drought can last into the next year. Loss of mulch by fire or grazing can produce drought-like effects by decreasing the water storage capacity of the soil. Each annual grass species has an optimum tolerance range with respect to moisture and soil nutrients (Hull and Muller 1976). If nitrogen levels are low enough to restrict grass growth, then legumes may gain a competitive advantage over the grasses that usually shade them out (Jones and Woodmansee, 1979). *Erodium*, with its rapid root extension, can thrive under a low sulfer regime

Table 4. Growing Season Weather Summary

YEAR	FALL (Sept., Oct. & Nov.)			WINTER (Dec. & Jan.)		SPRING (Feb., March & April)		ANNUAL SUMMARY		CATEGORY OF VEG. FAVORED
	Germin.	Temp.	Rain	Temp.	Rain	Temp.	Rain	Temp.	Rain	
1980-1981	Jan.23	H(102%)	D(6%)	H(117%)	D(77%)	H(108%)	D(97%)	H(106%)	D(71%)	Forbs
1981-1982	Oct. 28&29	C(98%)	W(151%)	H(107%)	D(56%)	H(103%)	W(166%)	N(101%)	W(119%)	Forbs & Legumes
1982-1983	Sept. 24-26	C(96%)	W(238%)	H(103%)	W(163%)	H(103%)	W(200%)	N(99%)	W(193%)	Forbs
1983-1984	Sept. 29&30	(H106%)	W(265%)	H(124%)	D(46%)	H(107%)	D(30%)	H(109%)	D(78%)	Grass
1984-1985	Nov. 16&17	N(101%)	W(230%)	C(86%)	D(68%)	H(106%)	D(46%)	N(101%)	D(83%)	Grass

Each season and each year is characterized as hot (H) or cold (C), wet (W) or dry (D); relative to percent deviations from mean values. N=normal. Germination dates correspond to first storm of a rainfall season that dropped 12.5 mm or more or rain. A growing season's temperature-rainfall pattern and its germination date interact to favor a particular category of vegetation; "grass" year, "clover" year, etc.

which discourages its competitor, Bromus mollis; but sufficient nutrient levels favor B. mollis over Erodium as the superior competitor for light (McCown and Williams 1968).

Germination, seed production, and seed behavior are another set of factors that interact with fire in grassland. In years when perennial grasses have produced ample seed, for example, they have an advantage over annuals because they start growth with less fall rain than annuals need (Biswell 1956). A properly timed fall burn (during growth of annuals but prior to annual seed production) coupled with selective mowing (to protect growing perennials) could further aid perennials by reducing annual grasses which compete for soil moisture.

Bartolome (1979) recommends further study of the micro-environment during the critical 1st days of the growth season to determine what selective pressures affect the early seedling stage. Even seed dormancy varies among annuals, with dormancy in grasses breaking down more rapidly than in legumes (Jain 1982). A seedbed bared by fire will favor forb species, like Erodium, having seeds with self-burial mechanisms over grass species that require litter coverage for germination (Young et al. 1981). This is an example of the interaction between seed behavior, fire, and mulch. Seed production in annual vegetation is high, but fire can significantly reduce the numbers of germinating seedlings during the first post-fire growing season (Biswell and Graham 1956, Smith 1970).

Rodent activities contribute to the dynamics of grassland species composition. The establishment of *Erodium* in California's grasslands, coupled with cattle grazing, has increased the population of rodents, ground squirrels in particular (Fitch 1948). These rodents have very likely had an important role in affecting grassland species composition (Biswell 1956). *Microtus californicus* and *Mus musculus* consumed 37% of *Bromus diandrus* seed, 44% of *Hordeum leporinum* seed, and 75% of *Avena fatua* seed in two California studies (Batzli and Pitelka 1970, Borchert and Jain 1978). *Microtus* are especially fond of foliage. Ground squirrels also feed exclusively on leaves, stems and roots of annuals in winter and spring, especially *Erodium*. Flowers of many forbs, especially conspicuous species like *Gilia tricolor*, are among the preferred spring foods of ground squirrels (Fitch 1948). The amount of vegetation eaten by rodents accounts for less than 10% of what they destroy annually by trampling and other activities. In their study of rodent impact on grazing land, Fitch and Bentley (1949) showed that three rodent species eliminated a total of 76% of the foliage by the end of the growing season: ground squirrels destroyed 35%; gophers, 25%; and kangaroo rats, 16%. All three species occur at CRP and PVPP. Such impacts by rodents, gramnivorous birds, and more numerous invertebrate herbivores, certainly rival the effect of fire and other major disturbance factors. Besides their direct impact on the vegetation, the burrowing activity of fossorial mammals modifies soil structure and provides sites for colonization by alien species. The fleshy bulbs of Brodiaea are a favored food item of ground squirrels. The increase in the squirrel population has probably had a detrimental effect on the Brodiaea population (Biswell 1956), partly because Brodiaea beds, once "roto-tilled" by squirrels, usually revert to stands of alien annual grasses.

Fire management of grassland should only be undertaken with thorough knowledge of these interrelated factors and with a clear statement of the management objectives. Beetle (1947) lists six factors that determine the character of a given grassland type in California: (a) the diversity of the vegetation; (b) rainfall; (c) climate; (d) slope; (e) altitude; and (f) soils. He adds, "Within the counties of California all of the factors are present in a degree of variability not met in whole states in the Great Plains region." Since the dry alluvial fans of the San Joaquin Valley were dominated by annual species (Wester 1981), it would be ill-advised to try to manage for perennial grasses on such soils in this region.

Before making a burn plan, a manager must determine local species composition. Heady (1956) recommends sampling near the end of the growing season when full forage crop is present. The major disadvantage of late sampling is that subdominants, like Lepidium and other forbs decrease as the season progresses (Hervey 1949).

Awareness of phenological information, germination requirements, and maturity rates will provide managers with the knowledge necessary to use fire to achieve desired results. A fall burn, for example, can be followed by late (spring) grazing to reduce seeds of undesirable annuals as they reach maturity (Laude 1957). More satisfactory composition may result from a fine-tuned combination of techniques, fire and grazing, for example, than from using either technique alone.

As Transeau (1935) wrote, "Fire . . . does not result in prairie . . . it helps to maintain . . . the prairie." In the modern Tulare Basin, the native component of annual grassland diminshes in the absence of fire. Fire, per se, is not good or bad; its effect varies according to species, time of burning, location, condition of the grassland, etc. (Kay 1960, Vogl 1979).

There is no way to divine the pristine grassland composition or fire frequency of the Tulare Basin, so fire management in this area should be conducted not in an attempt to "recreate nature" but in an effort to encourage and discourage target species and species groups.

Restoration of native vegetation is the goal on many grasslands, including nature preserves managed by state, federal, and private agencies (Bartolome and Gemmill 1981). Successful "cookbook" burn prescriptions, based on particular management objectives, can only result from several years of experimentation and sampling.

If fire has been absent from a fire-adapted grassland for many years, its initial impact may be more severe than after subsequent burns. Perennials are especially susceptible to the adverse effects of litter accumulation. For example, many bunches of the perennial grass, _Sporobolus airoides_, were killed by the 1981 PVPP fire because self-lodging had occurred in most bunches (Vogl 1979). Eight years' growth without a burn had produced an abundance of standing, dead tissue. This accumulation of fuel acted as kindling that helped incinerate these bunches. Those bunches that survived are more vigorous and appear to be well-adapted to more frequent fire that removes only 1 or 2 years' growth at a time (Cooper 1961).

Native forbs and bunchgrasses respond unfavorably to unnatural fire conditions (Vogl 1974). Such conditions include an absence of fire, too much fuel, or no wind during a burn. Even though natural fire frequency is unknown for this area, a burn prescription (wind, temperature and humidity conditions) designed to encourage native species should recreate, as much as possible, the conditions that would have been associated with naturally occurring fire. Except for fires set by native peoples of the Tulare Basin, lightning was probably the most important source of natural ignition. In pre-settlement Tulare Basin, a fall thunderstorm (most local thunderstorms occur in fall), accompanied by high winds, would have made for a fast-moving, quick-burning fire that would burn until it encountered a wet streambed or was doused by rain. If a prescribed burn is conducted under low wind conditions because of concerns for fire safety, then little or no heat can dissipate from a bunchgrass that is involved in flames.

Perennial grasses, probably uncommon in the pristine grassland of the Tulare Basin, are almost certainly rarer today than in pre-settlement times. *Stipa pulchra*, a native of more northern regions in the Central Valley, needs less initial rainfall than alien annual grasses to begin germination. However, even with an initial head start, *Stipa* seedlings seldom survive the period of rapid spring growth in grassland dominated by alien annuals. The more abundant, rapidly growing *Vulpia Myuros* and especially *Bromus mollis* outcompete the *Stipa* seedlings by using much of the available soil moisture and by shading them (Bartolome and Gemmill 1981). The native perennial *Stipa cernua* (rare at PVPP) and *Poa scabrella* (rare at CRP) grow in grasslands where the only abundant native annual is *Hordeum depressum*. Because *H. depressum* is intolerant of fire, rare perennials may have been favored by fire in the Tulare Basin prior to the advent of the superbly competitive alien annuals. An understanding of fire's effect on annual grasses can also benefit those interested in propagating native perennial grasses (McClaran 1981, Rogers 1981). Because of the variety of biotic and abiotic factors that interact with fire in grassland, fire (like all management techniques) should be planned to produce mosaic vegetation patterns on nature preserves (Vogl 1979, Moore 1985). This approach produces species refugia and enhances diversity.

Summary

Grassland in pre-settlement Tulare Basin was probably annual grassland with a large component of forbs; all these species were natives. In the 1980s, succession (in the absence of grazing or fire) leads to a "climax" community which is annual but which is dominated by alien grass s_'ecies to the near exclusion of forbs. This climax community is characterized by low species diversity and low percent composition of native species. In 18 of 34 burn treatments, fire increased diversity by reducing percent composition of the dominant alien annual grasses coincident with an increase in percent composition of forbs. In 7 of the 16 burn treatments with reduced diversity, there was an increase in percent composition of natives because native annual forbs are favored by fire.

Some species are adversely affected by fire. Of those species favored by fire, some prefer recurrent burns (these may be in consecutive years, or separated by a 1- or 2-year interval). The use of fire and the choice of fire frequency should be based on objectives for target species. Examination of this study's findings will allow a manager to select a burn treatment that favors desirable species or discourages undesirable species.

Seasonal weather conditions determine the direction of vegetation change in this annual community (will it be a "grass year" or a "forb year"?) but fire influences the magnitude of the vegetation change. A complex of other factors interact with weather and fire to affect these changes in vegetation.

Even though fire usually increases diversity and percent composition of natives at the two study sites, these results probably are only applicable to grasslands with similar climate and soil type. It is inadvisable to make generalizations about fire response even within a group like annual grasses. The five dominant annual grasses, for example, show a wide range of response to fire. Even though this is classified as an annual grassland, the species composition during a given spring is not entirely dependent on the influence of the most recent fall burn; it may take 5 years or more for a burned area to return to a species composition comparable to that in an unburned control plot.

To encourage diversity of native species, with their varied responses to fire, burns should be planned to produce a mosaic pattern of fire treatments with each treatment plot exhibiting a species composition influenced by its burn history.

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APPENDICES

APPENDIX A

DATA PROCESSING CODE NUMBERS FOR PLANT SPECIES IN THE TWO STUDY SITES

Data Processing Code Numbers For Plant
Species In the Two Study Sites

1. Alopecurus Howellii Vasey.

2. Bromus arizonicus (Shear) Steb.

3. Deschampsia danthonioides (Trin.) Munro ex Benth. var. gracilis (Vasey) Munz.

4. Vulpia Myuros (L.) K.C. Gmel. var. hirsuta Hack.

5. Vulpia microstachys (Nutt.) Benth. var. pauciflora (Beal) Lonard & Gould.

6. Hordeum depressum (Scribn. & Sm.) Rydb.

7. Phalaris angusta Nees ex Trin.

8. Puccinellia simplex Scribn.

9. Avena barbata Brot.

10. Bromus diandrus Roth.

11. Bromus mollis L.

12. Bromus rubens L.

13. Hordeum geniculatum Allioni.

14. Hordeum leporinum Link.

15. Hordeum vulgare L.

16. Amsinckia intermedia F. & M.

17. Atriplex sp.

18. Calandrinia ciliata (R. & P.) DC. var. Meziesii (Hook.) Macbr.

19. Gilia capitata Sims. ssp. staminea (Greene) V. Grant.

20. Gilia tricolor Benth. ssp. diffusa (Congd.) Mason & A. Grant.

21. Hemizonia pungens (H. & A.) T. & G.

22. *Lasthenia chrysostoma* (F. & M.) Greene. ssp. *gracilis* (DC.) Ferris.

23. *Lasthenia Fremontii* (Torr. ex Gray) Greene.

24. *Lasthenia minor* (DC.) Ornduff.

25. *Lepidium dictyotum* Gray.

26. *Lepidium nitidum* Nutt.

27. *Linanthus bicolor* (Nutt.) Greene.

28. *Lotus subpinnatus* Lag.

29. *Microseris elegans* Greene ex Gray.

30. *Microseris* sp.

31. *Montia Hallii* (Gray) Greene.

32. *Myosurus minimus* L.

33. *Orthocarpus erianthus* Benth.

34. *Orthocarpus purpurascens* Benth.

35. *Plagiobothrys nothofulvus* (Gray) Gray.

36. *Plantago Bigelovii* Gray.

37. *Plantago Hookeriana* F. & M. var. *californica* (Greene) Poe.

38. *Psilocarphus tenellus* Nutt. var. *tenuis* (Eastw.) Cronq.

39. *Sida hederacea* (Dougl.) Torr.

40. *Spergularia atrosperma* R. P. Rossb.

41. *Spergularia marina* (L.) Griseb.

42. *Tillaea erecta* H. & A.

43. *Trifolium amplectens* T. & G.

44. *Trifolium depauperatum* Desv.

45. *Trifolium gracilentum* T. & G.

46. *Trifolium variegatum* Nutt.

47. *Trifolium* sp.

48. *Veronica peregrina* L. ssp. *xalapensis* (HBK) Penn.

49. *Cerastium viscosum* L.

50. *Erodium Botrys* (Cav.) Bertol./*Erodium obtusiplicatum* (Maire, Weiller & Wilcz.) J.T. Howell.

51. *Erodium cicutarium* (L.) L'Her.

52. *Erodium moschatum* (L.) L'Her.

53. *Phalaris Lemmonii* Vasey.

54. *Lactuca Serriola* L.

55. *Medicago polymorpha* L.

56. *Melilotus indicus* (L.)

57. *Senecio vulgaris* L.

58. *Sisymbrium orientale* L.

59. *Stellaria media* (L.) Vill.

60. *Distichlis spicata* (L.)

61. *Poa scabrella* (Thurb.) Benth. ex Vasey.

62. *Sporobolus airoides* (Torr.) Torr.

63. *Stipa cernua* Steb. & Love.

64. *Brodiaea elegans* Hoover.

65. *Brodiaea pulchella* (Salisb.) Greene.

66. *Delphinium recurvatum* Greene.

67. *Eryngium Vaseyi* Coult. & Rose.

68. *Frankenia grandifolia* Cham. & Schlecht. var. *campestris* Gray.

69. *Haplopappus acradenius* (Greene) Blake. ssp. *bracteosus* (Greene) Hall.

APPENDIX B

FIRE BEHAVIOR INFORMATION FROM PRESCRIBED BURNS

Fire Behavior Information From Prescribed* Burns

Preserve	Burn Year	Burn Date	Burn Area (hectares)	Fuel Weight (kg/ha)	Wind Speed (Km/hr)	Wind Direct.	Dry Bulb Air Temp. (°C)	Flame Length (m)	Rate of Spread (m/min.)	Time Begin	Time End	Time Elapsed (min.)	Notes (Type of fire, weather information, etc.)
CRP	1981	June 13	6.80	--	16.81	NW	37.4	--	--	--	--	--	*This wild fire was not a prescribed burn. It entered CRP from neighboring grassland to the West.
CRP	1982	Oct. 1	10.70	--	<8.0	N	--	--	--	--	--	ca.15	15.5mm of rain fell on Sept. 24-26; grass seedlings were apparent. Hemizonia, fostered by the 1981 burn, proved to be good fuel during this year's burn.
CRP	1983	Aug. 23	1.98	2464	4.8 to 8.0	NW	29.2-31.9	.25-1.83	1.37-6.10	1640	1707	27	
CRP	1983	Aug. 23	1.55	3226	4.8 to 6.0	NW	29.2-31.9	1.22-1.83	1.52-6.10 on flank, up to 3.05 on one end	1710	1740	30	
CRP	1983	Oct. 16	80.21	--	0 to 8.0	SE	11.3-16.5	--	--	0915 1030 ignit.	--	--	Rel.hum. declined from 52% to 34% during burn. First fall rain (2.5-5.1mm) fell 1 to 2 weeks ago. Tall sparse veg. didn't burn. At 0830, temp. was 74°, rel. hum. was 73%; fire wouldn't carry until 0915 when conditions were as shown.
PVPP	1980	--	3.01	--	--	--	--	--	--	--	--	--	
PVPP	1981	Oct. 27	7.81	--	--	--	--	--	--	--	--	--	Many old bunches of Sporobolus airoides were entirely consumed by flames, because self-lodging (in the absence of fire) had occurred in these bunches.
PVPP	1983	Aug. 23	5.02	6743	<4.8	W	23.1	.30-1.22	.91-1.52, 9.14 at end	1030	1115	45	As usual, backfires were used during ignition; headfires burned most of the area.
PVPP	1983	Aug. 23	1.40	2774	3.22 to 8.04	W	±29.2	.15-.61	.91-3.05	1200	1225	25	As usual, backfires were used during ignition; headfires burned most of the area.

APPENDIX C

TREATMENT-SAMPLING INFORMATION

Treatment-Sampling Information

Treatment Number	Preserve	Sampling Year	Year(s) Burned	Number of Growing Seasons Since Burns	Number of Transects per Treatment	Sampling Date	Size of Sample Plot (In Hectares)
1	CRP	1982	C	C	9	April 1,4 & 5	90.4
2	CRP	1982	1981	1	9	April 1,4 & 5	6.8
3	CRP	1983	C	C	5	March 27	84.84
4	CRP	1983	1981	2	5	March 27	4.23
5	CRP	1983	1982	1	5	March 27	8.13
6	CRP	1983	'81&'82	1 & 2	5	March 27	2.57
7	CRP	1984	C	C	3	March 27	84.84
8	CRP	1984	1981	3	3	March 21	3.04
9	CRP	1984	1982	2	3	March 21	4.96
10	CRP	1984	'81&'82	2 & 3	3	March 21	.83
11	CRP	1984	'81&'83	1 & 3	3	March 21	1.19
12	CRP	1984	'82&'83	1 & 2	3	March 21	.60
13	CRP	1984	'81,'82&'83	1,2 & 3	3	March 21	1.74
14	CRP	1985	C	C	3	April 24	5.65
15	CRP	1985	1981	4	3	April 25	2.53
16	CRP	1985	1982	3	3	April 25	4.96
17	CRP	1985	1984	1	3	April 24	80.21
18	CRP	1985	'81&'82	3 & 4	3	April 25	.83
19	CRP	1985	'81&'83	2 & 4	3	April 25	1.19
20	CRP	1985	'82&'83	2 & 3	3	April 25	.60
21	CRP	1985	'81,'82&'83	2,3 & 4	3	April 25 & 26	1.74

Treatment Number	Preserve	Sampling Year	Year(s) Burned	Number of Growing Seasons Since Burns	Number of Transects per Treatment	Sampling Date	Size of Sample Plot (In Hectares)
22	PVPP	1981	C	C	5	April	11.80
23	PVPP	1981	1980	1	7	April	2.78
24	PVPP	1982	C	C	8	March 31	6.38
25	PVPP	1982	1980	2	8	March 31	1.61
26	PVPP	1982	1981	1	8	March 30	5.42
27	PVPP	1982	'80&'81	1 & 2	8	March 31	1.17
28	PVPP	1983	C	C	8	March 26	6.38
29	PVPP	1983	1980	3	8	March 26	1.61
30	PVPP	1983	1981	2	8	March 26	5.42
31	PVPP	1983	'80&'81	2 & 3	8	March 26	1.17
32	PVPP	1984	C	C	6	March 20	3.93
33	PVPP	1984	1980	4	6	March 20	1.61
34	PVPP	1984	1981	3	6	March 20	3.23
35	PVPP	1984	1983	1	6	March 20	2.45
36	PVPP	1984	'81&'83	1 & 3	6	March 20	2.19
37	PVPP	1984	'81,'82&'83	1,3 & 4	6	March 20	1.17
38	PVPP	1985	C	C	6	May 7	3.93
39	PVPP	1985	1980	5	6	April 20	1.61
40	PVPP	1985	1981	4	6	April 20	3.23
41	PVPP	1985	1983	2	6	May 7	2.45
42	PVPP	1985	'81&'83	2 & 4	6	April 20	2.19
43	PVPP	1985	'80,'81&'83	2,4 & 5	5	April 20	1.17

APPENDIX D

CATEGORIES OF NATIVE AND ALIEN PLANT SPECIES

Categories Of Native And Alien Plant Species

Category I: Native Annual Grasses

Alopecurus Howellii	P
Bromus arizonicus	
Deschampsia danthonioides var. *gracilis*	
Hordeum depressum	
Phalaris angusta	C
Phalaris Lemmonii	P
Puccinellia simplex	C
Vulpia microstachys var. *pauciflora*	

Category II: Alien Annual Grasses

Avena barbata	P
Bromus diandrus	
Bromus mollis	
Bromus rubens	
Hordeum geniculatum	
Hordeum leporinum	
Hordeum vulgare	C
Vulpia Myuros var. *hirsuta*	

Category III: Native Annual Legumes

Lotus subpinnatus	
Trifolium amplectens	
Trifolium depauperatum	
Trifolium gracilentum	
Trifolium variegatum	
Trifolium sp.	P

Category IV: Alien Annual Legumes

Medicago polymorpha

Melilotus indicus

Category V: Native Annual Forbs (Other Than Legumes)

Amsinckia intermedia	C
Atriplex sp.	
Calandrinia ciliata var. *Menziesii*	
Gilia capitata ssp. *staminea*	P
Gilia tricolor ssp. *diffusa*	
Hemizonia pungens	
Lasthenia chrysostoma ssp. *gracilis*	P
Lasthenia Fremontii	C
Lasthenia minor	C
Lepidium dictyotum	
Lepidium nitidum	
Linanthus bicolor	C
Microseris elegans	C

Microseris sp.	P
Montia Hallii	C
Myosurus minimus	P
Orthocarpus erianthus	
Orthocarpus purpurascens	C
Plagiobothrys nothofulvus	P
Plantago Bigelovii	
Plantago Hookeriana var. _californica_	P
Psilocarphus tenellus var. _tenuis_	P
Sida hederacea	C
Spergularia atrosperma	
Spergularia marina	P
Tillaea erecta	
Veronica peregrina ssp. _xalapensis_	

Category VI: Alien Annual Forbs (Other Than Legumes)

Cerastium viscosum	
Erodium Botrys/Erodium obtusiplicatum	
Erodium cicutarium	
Erodium moschatum	
Lactuca Serriola	
Senecio vulgaris	C
Sisymbrium orientale	C
Stellaria media	C

Category VII: Native Perennial Grasses

Distichlis spicata	
Poa scabrella	C
Sporobolus airoides	
Stipa cernua	P

Category VIII: Native Perennial Forbs

Brodiaea elegans	P
Brodiaea pulchella	
Delphinium recurvatum	C
Eryngium Vaseyi	P
Frankenia grandifolia var. campestris	P

Category IX: Native Perennial Shrub

Haplopappus acradenius ssp. bracteosus	P

C = species recorded only at CRP during sampling.

P = species recorded only at PVPP during sampling.

(NOTE: Trifolium at PVPP is not counted as an additional species.)