Assumptions Used to Justify Prescribed Fire as a Restoration Tool in California Annual Grasslands

RICHARD J. REINER

The Nature Conservancy, 500 Main Street, Chico, CA 95928
rreiner@tnc.org

PETER M. HUJIK

The Nature Conservancy, 500 Main Street, Chico, CA 95928

JACOB F. POLLOCK

Department of Ecology and Evolutionary Biology, University of California, Santa Cruz, CA 95064
pollock@ucsc.edu

ABSTRACT. Prescribed fire can aid in the restoration of annual grasslands by altering vegetation composition. Information about how certain plants, or guilds of plants, respond to fire is useful for land managers trying to improve native plant diversity. Published studies support some of the plant/fire relationships that land managers use to justify prescribed burning. Other commonly used "rules of thumb" are not supported by experimental data. We considered four common reasons that land managers in Northern California use for conducting prescribed fires in annual grasslands. These are 1) native forbs will increase, 2) annual weeds will be reduced, 3) native grasses will be promoted and 4) native species richness will increase. We review the literature regarding these hypotheses and also present preliminary findings from 13 prescribed fires in Tehama County annual grasslands. Our literature review and burn data from Tehama County supports the notion that both native and non-native annual forbs increase after fire. Most studies show that spring fires reduce non-native annual grasses including weeds such as *Taeniatherum caput-medusae*; however, the outcome is species-specific and may depend on the phenology of the grass at the time of the burn. A majority of studies suggest that native bunchgrasses such as *Nassella* spp. are promoted by low intensity fire. Native annual grasses also increased after fires in our Tehama County plots. We conclude that fire can, but does not always, cause an increase in overall native species richness or cover. While all four assumptions considered are supported by the literature, the specific outcome is clearly dependent on the species present, the season of burn, fire intensity, and post-fire conditions.

CITATION. Reiner, R. J., P. M. Hujik and J. F. Pollock. 2007. Assumptions used to justify prescribed fire as a restoration tool in California annual grasslands. Pages 167-173 in R. A. Schlising and D. G. Alexander (Editors), Vernal Pool Landscapes. Studies from the Herbarium, Number 14. California State University, Chico, CA.

INTRODUCTION

Prescribed fire can aid in the restoration of annual grasslands by altering vegetation composition (Menke, 1992; Reiner, 2007). Fire can directly kill or harm individual plants as well as reduce their reproductive potential (Whelan, 1995). It can also affect the competitive balance between species by altering the post-fire growing environment. Fires can be applied over large areas at modest costs, making it a practical management tool in many types of grassland (Biswell, 1989).

Conceptual models that attempt to predict the response of grassland vegetation to fire are useful for managers trying to promote native plant diversity. Models are generally based on specific assumptions about how certain plants (or guilds of plants) respond to fire. Research supports some vegetation/fire relationships land managers embrace; however, other commonly used "rules of thumb" are not well supported by experimental data and it appears that in many cases the outcomes are site-specific.

We consider four assumptions that land managers

concerned with promoting biodiversity use to justify conducting fires in Northern California annual grasslands.

1) Native forbs will respond positively to fire.
2) Annual weeds will be reduced the year following fire.
3) Native grasses will be promoted by fire.
4) Fire will increase overall native species richness.

This paper examines past research literature as well as draws on monitoring data from 13 prescribed fires in eastern Tehama County to explore these assumptions.

METHODS

Tehama County Prescribed Burns

The Nature Conservancy conducted 13 prescribed spring burns in low-elevation (100-200 feet) eastern Tehama County annual grasslands between 1996 and 2003. Individual prescribed burns were approximately 500 acres in size and in some cases included multiple fenced pastures. Pastures were generally, but not always, monitored for individual species cover the spring before and the spring following each burn. In some cases, a second spring following the burn was monitored. Sampling was based on permanent 1-meter square plots located along transects of varying length within a pasture. The number of plots also varied between 30 and 42 per pasture. Cover was estimated within each plot by major plant guilds (native annual forbs, non-native annual forbs, native annual grass, non-native annual grass, etc.). Due to missing data, either pre- or post-burn, the full set of data was reduced to a smaller subset for analysis. This analysis included 33 pasture-year combinations. The means presented below are from paired t-tests comparing pre- and post-burn guild cover. Pollock (2006) presented detailed methods and a statistical analysis of these data.

RESULTS AND DISCUSSION

Assumption: Native Forbs will Respond Positively to Fire

Although a plant's response to fire is species-specific, burning in California annual grasslands tends to promote the growth of forbs and geophytes over annual grasses (Heady, 1972; D'Antonio et al., 2002). Fire damages annual grass seed crops, immediately removes thatch, exposes mineral soil, and provides good post-fire germinating conditions for forbs.

Thatch, the dead and decaying material accumulated from previous year's growth, influences grasslands in numerous ways. On the positive side, thatch helps recycle nutrients, retard erosion, improve water infiltration, and shades the soil (McNaughton, 1968). However, in the absence of grazing and fire, thatch accumulates and eventually shades out forbs (Heady, 1956; Bentley and Fenner, 1958). Grasslands with years of accumulated thatch tend to be dominated by tall, introduced, annual grasses such as *Avena* spp. with few forbs (Heady, 1958). When fires remove thatch, forbs are offered open and sunny sites for germination and growth.

In most studies conducted in California annual grasslands, both native and introduced forb species appear to respond positively to burning (D'Antonio et al., 2002). The actual species favored is influenced by a plant's ability to protect itself from fire, the seed bank, season of fire, fire intensity, and its response to post-fire conditions (Whelan, 1995).

Forb species that respond positively to fire in annual grasslands are most often those that protect their growing parts. For example, geophytes such as *Brodiaea* spp. protect their growing points underground and generally respond positively to fire (Stone, 1951; Gill, 1977). Plants that produce hard seeds that fall to the ground and find their way into cracks in the soil are favored. *Erodium* spp., which have long coiled awns capable of moving seed into the soil, are the most common "fire followers" in California annual grasslands. Many *Erodium* spp. are non-native and they compete with native species for space.

The season in which a burn is conducted also effects which forbs are favored. Meyer and Schiffman (1999) found that conducting burns in the spring increased the post-fire abundance of native forbs more than fall or winter burns. However, non-native *Erodium* spp. cover also increased following spring burns in this study. Parsons and Stohlgren (1989) demonstrated an increase in the native clover, *Trifolium microcephalum*, after three consecutive spring burns while *Orthocarpus attenuatus* responded best to fall burns.

One reason that the forb community may respond favorably to springtime burning (as compared to fall burning) is due to the fact that fire removes the

ground layer of thatch. Forb seeds are thus exposed to months of direct summer heat and light. Rice (1985) found that *Erodium* spp. seeds in more exposed summer locations experience more heat stratification and had greater germination than those with less summer heat exposure. Similarly, Peterson (2005) working with native clovers found that summer scarification was necessary for germination at Vina Plains, Tehama County, California.

Fires generally result in temporary increases of available nitrogen (Menke and Rice, 1981) and may have negative effects on native species richness by favoring only a few fast-growing species such as *Erodium* spp. (Foster and Gross, 1998). On the other hand, multiple years of back-to-back fires tend to deplete nitrogen at a site, favoring native species over exotics. In a meta-analysis of 19 studies of fire in California annual grasslands, D'Antonio et al. (2002) found that although both native and exotic forbs increased after a single fire, there was a small increase in natives after multiple years of fires.

Tehama County Prescribed Burns. In our prescribed burn study in eastern Tehama County, native annual forbs (NAF) showed an increase in mean post-burn cover of 7% ($t = 3.703$, $df = 12$, $P = 0.003$). The trend was positive for 11 out of 13 pastures with a downward trend for two pastures (Figure 1a). These two departures from the general upward trend were both during years in which several other pastures followed the same downward trend. In some pastures the increase was as much as 15% and in others it was almost imperceptible.

Exotic annual forbs (EAF) also showed an increase in mean post-burn cover of 10% ($t = 4.266$, $df = 12$, $P = 0.0001$). The trend was positive for 10 out of 13 pastures and no change for the three remaining (Figure 1b). The magnitude of change varied from no change to 25% increase.

Assumption: Annual Weeds will be Reduced by Fire

Non-native plants, particularly exotic annual grasses, constitute the majority of cover in most California annual grasslands; thus, their control is key to most restoration efforts. The working hypothesis in most restoration burning is that properly timed fire can be used to directly kill the seeds of non-native annual grasses, and in turn, reduce competition for native species (Menke, 1982; Fossum, 1990; George et al., 1992).

A meta-analysis of fire studies by D'Antonio et al. (2002) found that fire does reduce the cover of annual grasses the year following an initial fire. However, the effects may be short-lived, with annual grass densities returning to the same or more the year following the fire.

Unlike the response of forbs to burn timing, annual grasses appear to be less sensitive to burn season. However, this is not universal, as Meyer and Schiffman (1999) found a greater reduction in annual grasses with a spring burn compared to fall burning.

The frequency at which a grassland is burned has been shown to reduce the abundance of annual grasses at some sites (Parsons and Stohlgren, 1989; Delmas, 1999). However, other studies have found that only certain species, such as *Hordeum marinum*, are reduced while *Avena* spp. and *Vulpia* spp. tend to increase (Hansen, 1986; DiTomaso et al., 1999; D'Antonio et al., 2002). The lack of consistency between studies is likely due to species-specific fire tolerance and variables such as the grasses phenology at the time of the burn. A strategy for reducing a variety of annual grasses might be to vary spring ignition dates for burns in successive years.

It has been demonstrated that fire can be successfully used to suppress specific exotic species such as *Taeniatherum caput-medusae* (Pollak and Kan, 1998) and *Centaurea solstitialis* (DiTomaso et al., 1999). These authors report that *Taeniatherum caput-medusae* can often be controlled with a single spring burn, whereas *Centaurea solstitialis* control may require two or more burns in successive years.

Tehama County Prescribed Burns. In our Tehama County burns, exotic annul grasses showed an average decrease of 8% in cover ($t = 2.169$, $df = 12$, $P = .051$) with some pastures showing a decease as high as 40% (Figure 1c). The trend was downward for nine out of 13 pastures, with an upward trend for four pastures. However, these four upwards trends were slight when compared to the strong downwards trend for almost all other years.

Assumption: Native Grasses will be Promoted by Fire

There is a significant body of work examining the effects of fire on *Nassella* spp., California's most widespread native perennial grasses (Ahmed, 1983; Garcia-Crespo, 1983; Fossum, 1990; Langstroth,

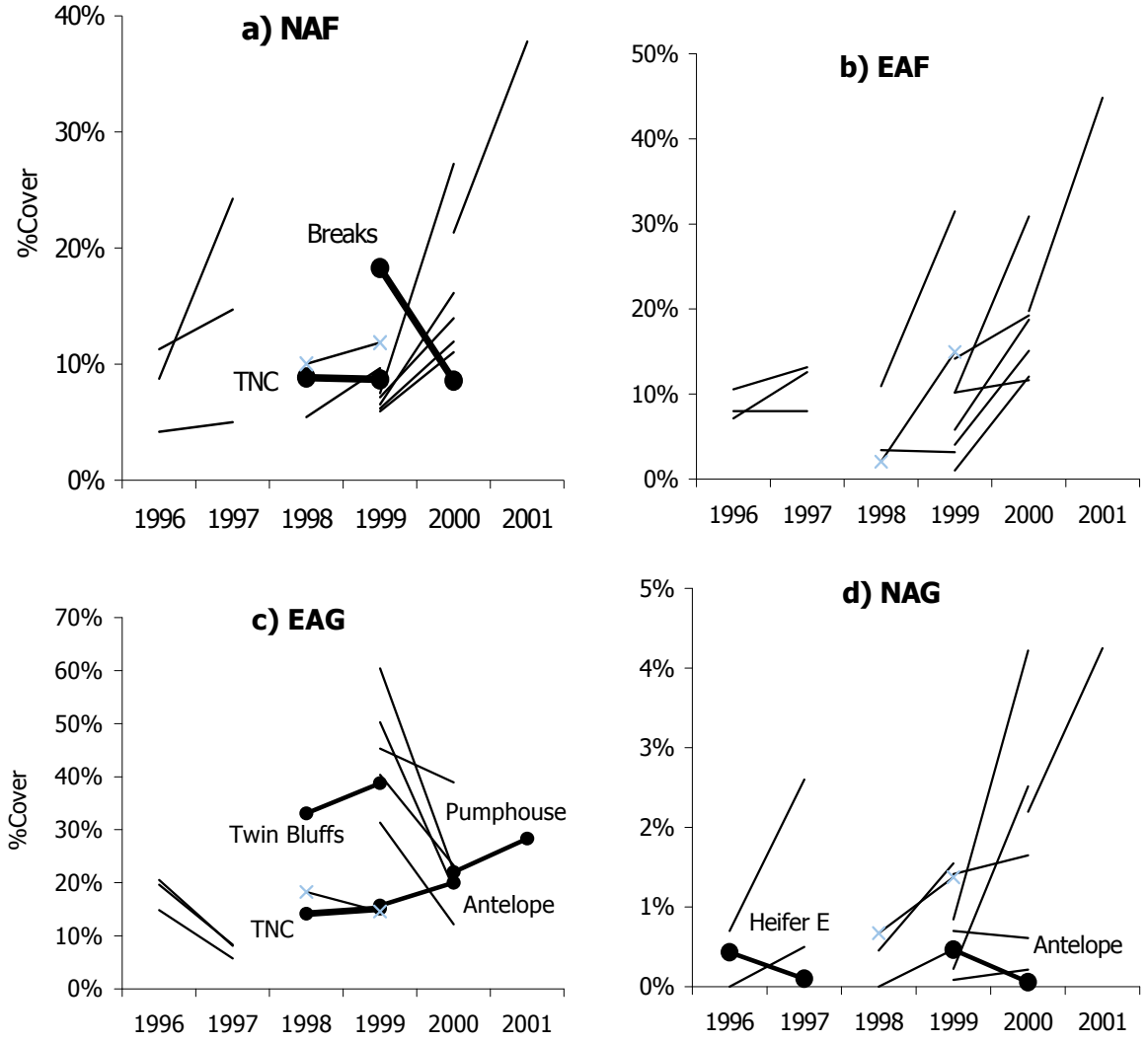

FIGURE 1. Change in % cover of major guilds one year after spring fires, a) Native Annual Forbs (NAF), b) Exotic Annual Forbs (EAF), c) Exotic Annual Grasses (EAG), d) Native Annual Grasses (NAG). Each of 13 fires is indicated by a line showing the pre-burn % cover at one end and the post-burn % cover at the other. Departures from the general trend are shown in bold and labeled with the pasture name. Note the change of scale on the y axes (from Pollock, 2006).

1991; Dyer, 1993; Hatch et al., 1999; Fehmi and Bartolome, 2003). Most research supports the hypothesis that *Nassella* spp. responds positively to fires of low to moderate severity. Seedling establishment is also assisted by fire (Dyer, 1993). *Nassella* spp. is often seen along roads and rail right-of-ways that frequently burn and can be observed greening up and flowering just days after spring fires. Research by Arguello (1994) also reports small increases of *Danthonia californica* following fire.

The intensity of a fire may significantly affect *Nassella* spp. survival. Marty et al. (2005), studied the effects of fire and grazing at a site in the foothills of the Central Valley that had not been burned or grazed heavily for many years. They found that mortality was 10% higher in burned versus unburned plots and even though seedling density increased after fire, seedlings did not return to pre-burn levels two years after the burn. These results may have been influenced by thatch accumulation in burned plots and the fact that the experimental burns were conducted using "backing fires" which tend to increase the heat experienced by individual plants. Interpreting studies regarding native bunchgrasses and fire is made difficult by the fact that fire not only affects the mortality of established plants and the regeneration of new seedlings, but it can also cause mature plants to fragment into what may appear to be separate individuals. For this reason,

studies which examine only density data should be viewed with caution.

Tehama County Prescribed Burns. Our Tehama County burn units did not contain enough cover of native perennial grasses to draw significant conclusions. Native annual grasses, however, did show small increases. Native annual grasses (NAG) increased an average of 1% ($t = 2.725$, $df = 12$, $P = 0.02$). Increases were seen in 11 out of 13 pastures (Figure 1d). As with NAF, the downward trends occurred alongside numerous upward trends in the same year. The trends show an increase of 5-10 times the starting cover; however, these changes are from very low starting points (< 1% cover). The two downward trends are also from very low starting points.

Assumption: Fire will Increase Native Species Richness

D'Antonio et al. (2002) conducted a meta-analysis on 19 replicated studies that quantitatively measured the effects of fire in California annual grassland. Their overarching conclusion was that "fire does not result in a straightforward increase in native vegetation or a consistent decrease in exotic cover." However, when life groups (grass, forb, bulb, etc.) were compared, native species benefited in some treatments. Although fire increased both native and exotic forbs, native forbs were favored only if livestock grazing was present, or when there was a wet year preceding the fire.

Harrison et al. (2003) studied the effects of fire on both invaded annual grasslands and mostly native serpentine grasslands in the Northern Coast Range. They found that fire increased native and exotic species richness on both the invaded grassland and the native grassland. However, fire increased native species richness more than exotic species richness at sites dominated by natives (serpentine soils); but it increased the richness of exotic species more than that of native species in the invaded grasslands. In their words "the rich tended to get richer and the poor poorer in terms of native and exotic species." Therefore, the presence of exotics in a grassland should be considered before using fire as a tool in their restoration and management.

It is debated if repeated fires in consecutive years help restore overall native species diversity and cover (D'Antonio et al., 2002). However, some studies report that consecutive fires actually reduce species diversity. Delmas (1999), working at Vina Plains in Tehama County, found a decrease in native richness and an increase in cover of exotic forbs after burning in consecutive years.

Tehama County Prescribed Burns. Overall, there did not appear to be any consistent post-burn trends in species richness for any of the guilds (Figure 2). However, the data suggest that for certain years and for certain places, burning may be able to affect richness substantially. Post-burn NAF richness showed a slight upward trend during 1996-1997 with two relatively small increases and one moderate increase (Figure 2a). However, during 1998-2001 most of the pastures showed a low to moderate decrease in richness with burning, with one large decline in 1998-1999 of almost 20 species. The many slight differences, some positive and some negative, make it hard to generalize about the changes in NAF richness induced or potentially induced by fire. However, it is clear that it is possible to have dramatic changes in richness in some pastures after fire and that different years may show different trends in NAF post-fire richness.

CONCLUSIONS

Fire is an instant and powerful modifier of grassland conditions. Post-fire, both native and non-native forbs increase at the expense of non-native annual grasses. The conditions that tip the balance towards native forbs most likely depend on pre-fire site conditions, the fire behavior, the seed bank, and the post- fire climate. Altering fire season and intensity are refinements that could help select for specific forb composition. All of these factors deserve more study.

It is clear that prescribed fires can be used to control specific weeds by targeting them while their reproductive parts are most vulnerable to fire. Exotic annual grasses can be targeted by early spring burns. It is important, however, to consider which species will ultimately replace the removed weeds as it is common for other non-native plants to invade this space.

Most studies report that perennial native grasses are promoted by low intensity fires. However, managers should be careful not to damage bunchgrasses with extremely hot fires if the grassland has a buildup of flammable thatch. There is some evidence from our Tehama County burn data that spring fires can also promote native annual grasses. We

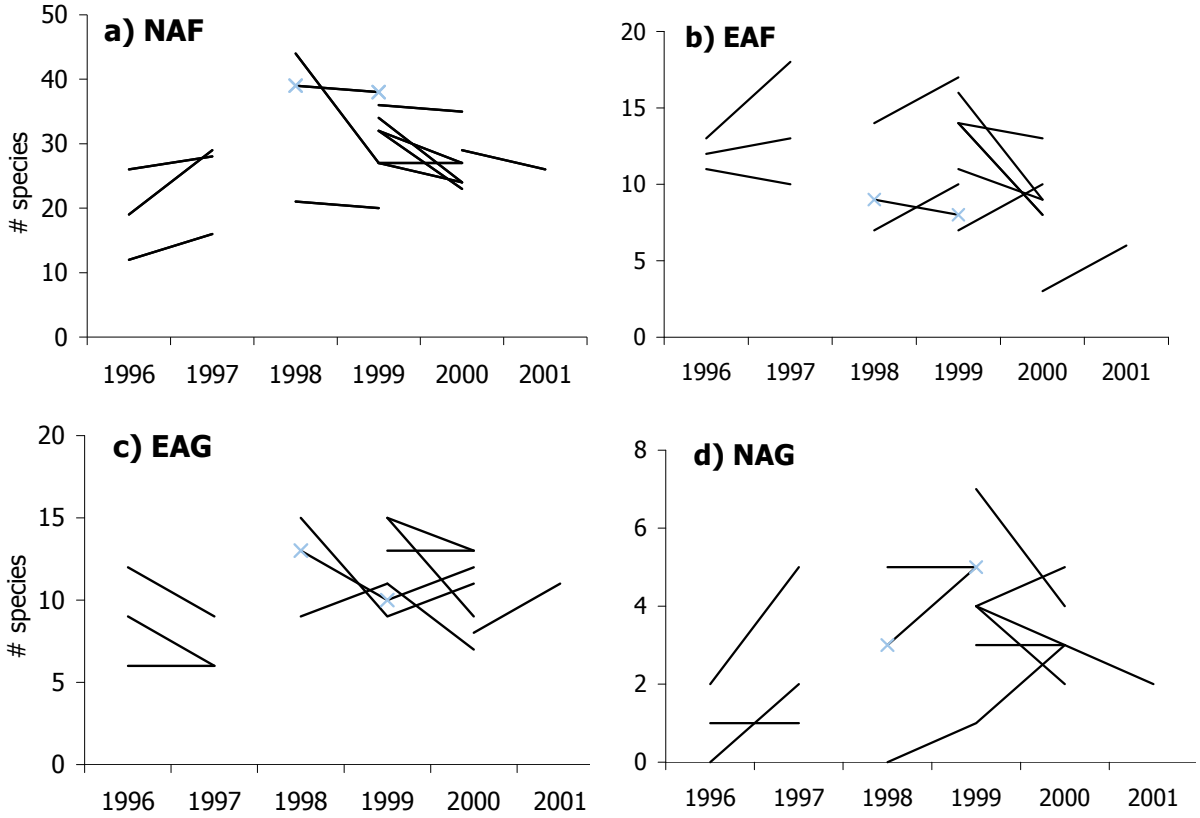

FIGURE 2. Change in richness of major guilds one year after spring fires, a) Native Annual Forbs (NAF), b) Exotic Annual Forbs (EAF), c) Exotic Annual Grasses (EAG), d) Native Annual Grasses (NAG). Each of 13 fires is indicated by a line showing the pre-burn richness at one end and the post-burn richness at the other. Note the change of scale on the y axes (from Pollock, 2006).

found small but consistent increases in the cover of the native *Vulpia microstachys*.

Fire appears to be an effective restoration tool and should be considered as a management option in the California annual grassland type. Three of the assumptions we considered regarding the benefits of burning are supported by both literature and our monitoring data from Tehama County. The last assumption regarding the role of fire and species richness is less clear. Both large increases and decreases in species richness have been reported after fires. Future studies need to explore the specific conditions that promote native plant diversity.

LITERATURE CITED

AHMED, E. O. 1983. Fire Ecology of *Stipa pulchra* on California Annual Grassland. Dissertation, University of California, Davis, CA.

ARGUELLO, L. A. 1994. Effects of prescribed burning on two perennial bunchgrasses in the Bald Hill of Redwood National Park, Humboldt State University, Arcata, CA.

BENTLEY, J. R. and R. L. FENNER. 1958. Soil temperatures during burning related postfire seedbeds on woodland range. Journal of Forestry 56:737-740.

BISWELL, H. H. 1989. Prescribed Fire in California Wildlands Vegetation Management. University of California Press, Berkeley, CA.

BLACKBURN, T. C. and K. ANDERSON. 1993. Before the Wilderness: Environmental Management by Native Californians. Ballena Press, Menlo Park, CA.

D'ANTONIO, C. M., S. J. BAINBRIDGE, C. KENNEDY, J. BARTOLOME and S. REYNOLDS. 2002. Ecology and restoration of California grasslands with special emphasis on the influence of fire and grazing on native grassland species. A report to the David and Lucille Packard Foundation. University of California, Berkeley, CA.

DELMAS, A. 1999. The Effect of Fire on California's Native Grassland in the Absence of Grazing at the Nature Conservancy's Vina Plains Preserve, in Southern Tehama County. Masters Thesis, California State University, Chico, CA.

DITOMASO, J. M., G. B. KYSER and M. S. HASTINGS. 1999. Prescribed burning for control of yellow starthistle (*Centaurea solstitialis*) and enhanced native plant diversity. Weed Science 47:233-242.

DYER, A. 1993. Response of native bunchgrass to burning and grazing. Restoration and Management Notes 11:150-151.

FEHMI, J. S. and J. W. BARTOLOME. 2003. Impact of livestock grazing and burning on the spatial patterns of the grass *Nassella pulchra* (Poaceae). Madroño 50:8-14.

FOSSUM, H. C. 1990. Effects of Prescribed Burning and Grazing on *Stipa pulchra* (Hitch.) Seedling Emergence and Survival. Masters Thesis, University of California, Davis, CA.

FOSTER, B. L. and K. L. GROSS. 1998. Species richness in a successional grassland: effects of nitrogen enrichment and plant litter. Ecology 70:2593-2602.

GARCIA-CRESPO, D. 1983. Multiple Treatments to Renovate Depleted Bunchgrass (*Muhlenbergia rigens* and *Stipa pulchra*) Range Sites in Southern California. Ph.D. Dissertation, Loma Linda University, Loma Linda, CA.

GEORGE, M., J. R. BROWN and W. J. CLAWSON. 1992. Application of non-equilibrium ecology to management of Mediterranean grasslands. Journal of Range Management 45:436-440.

GILL, A. M. 1977. Plant traits adaptive to fires in Mediterranean land ecosystems. Pages 17-36 in Proceedings of the Symposium on Environmental Consequences of Fire and Fuel Management in Mediterranean Ecosystems, Palo Alto, CA.

HANSEN, R. B. 1986. The Effect of Fire and Fire Frequency on Grassland Species Composition in California's Tulare Basin. Masters Thesis, California State University, Fresno, CA.

HARRISON, S., B. D. INOUYE and H. D. SAFFORD. 2003. Ecological heterogeneity in the effects of grazing and fire on grassland diversity. Conservation Biology 17:837-845.

HATCH, D. A., J. W. BARTOLOME, J. S. FEHMI and D. S. HILLYARD. 1999. Effects of burning and grazing on a coastal California grassland. Restoration Ecology 7:376-381.

HEADY, H. F. 1956. Changes in a California annual plant community induced by manipulation of natural mulch. Ecology 37:798-812.

HEADY, H. F. 1958. Vegetation changes in the California annual type. Ecology 39:402-416.

HEADY, H. F. 1972. Burning and grasslands in California. Annual Tall Timbers Fire Ecology Conference 12:97-107.

LANGSTROTH, R. P. 1991. Fire and Grazing Ecology of *Stipa pulchra* Grassland: a Field Study at Jepson Prairie. Masters Thesis, University of California, Davis, CA.

MARTY, J. T., S. K. COLLINGE and K. J. RICE. 2005. Responses of a remnant California native bunchgrass population, to grazing, burning and climatic variation. Plant Ecology 181:101-112.

MCNAUGHTON, S. J. 1968. Structure and function in California grasslands. Ecology 49:962-972.

MENKE, J. W. 1992. Grazing and fire management for native perennial grass restoration in California grasslands. Fremontia 20(2):22-25.

MENKE, J. W. and K. J. RICE. 1981. Effects of fire on seeds and nutrients in California annual grassland. Society of Range Management 34th Annual Meeting (abstracts), Tulsa, OK.

MEYER, M. D. 1997. The Effects of Fire Season and Mulch Reduction in a California Grassland: a Comparison of Restoration Strategies. Masters Thesis, California State University, Northridge, CA.

MEYER, M. D. and P. S. SCHIFFMAN. 1999. Fire season and mulch reduction in a California grassland. Madroño 46:25-37.

PARSONS, D. J. and T. J. STOHLGREN. 1989. Effects of varying fire regimes on annual grasslands in the southern Sierra Nevada of California. Madroño 36:154-168.

PETERSON, D. A. 2005. Facilitating Use of Prescribed Fire to Manage Invasive Exotic Grasses on California's Annual Grasslands: Reseeding with Annual Clovers and Grasses to Mitigate First-year Forage Loss. Masters Thesis, University of California, Davis, CA.

POLLAK, O. and T. KAN. 1998. The use of prescribed fire to control invasive exotic weeds at Jepson Prairie Preserve. Pages 241-249 in C. W. Witham, E. T. Bauder, D. Belk, W. R. Ferren, Jr. and R. Ornduff (Editors). Ecology, Conservation, and Management of Vernal Pool Ecosystems—Proceedings from a 1996 conference. California Native Plant Society, Sacramento, CA.

POLLOCK, J. F. 2006. Lassen Foothills controlled burn study 1996-2003, statistical modeling and analysis; a report to The Nature Conservancy, San Francisco, CA. University of California, Santa Cruz, CA.

REINER, R. J. 2007. Fire in California grasslands. Pages 207-217 in M. R. Stromberg, J. D. Corbin and C. M. D'Antonio (Editors), California Grasslands: Ecology and Management. University of California Press, Berkeley, CA.

RICE, K. J. 1985. Response of *Erodium* to varying microsites: the role of germination cueing. Ecology 66:1651-1657.

STONE, E. C. 1951. The stimulative effect of fire on the flowering of the golden brodiaea (*Brodiaea ixioides* Wats. var. *lugens* Jeps.). Ecology 32:534-537.

WHELAN, J. R. 1995. The Ecology of Fire. Cambridge University Press, Cambridge, England.