RESTORATION AND MANAGEMENT OF CALIFORNIA'S GRASSLAND HABITATS[1]

DAVID AMME and BARBARA M. PITSCHEL[2]

ABSTRACT: *Very little is known of the composition of California prairie vegetation before the arrival of European annual grasses in the 18th century. Conversion of the native perennial prairies and savannas to the "annual type" is a syndrome unique to California and complicates grassland succession patterns and precepts. Early work with native perennial grasses for forage and seeding purposes was eclipsed by the development of more productive introduced perennial grasses. Typically, only exotic annual grass seed is available for site stabilization and large-scale grassland rehabilitation. Because public agencies and nature preserves are beginning to focus on restoration and management of native perennial grassland habitats, there is a growing need for sources of native grasses and seed and for management techniques to enhance native grass habitat.*

INTRODUCTION

California has over 6.5 million hectares of grassland and savanna west of the Sierra Nevada Divide below 1200 meters. Prior to agricultural cultivation and urbanization the original prairies and savannas covered over 9 million hectares (Küchler 1964). The two major prairie habitats in the California Floristic Province (Barry 1972) are the coastal prairie, which occupies a narrow strip from San Simeon in San Luis Obispo County to the Oregon border and includes the bald hills of northern California (Sugihara *et al*. 1987), and the inland valley prairie, which occupies a ring around the Great Central Valley, the valleys and hills of the inner coast range, and the mesa country of southern California below the crest of the Peninsular Ranges. These two grassland types intergrade along California's central coast, most notably at the mouth of the Salinas Valley, the Berkeley/Oakland hills, and the windswept prairie of western Sonoma County just north of the San Francisco Bay. The climate of California's grassland is a Mediterranean type characterized by mild, wet winters and long, hot, dry summers. The California prairie biome receives annual precipitation varying from 25 to 140 cm. The wet season begins in October and ends in early May.

It is the purpose of this paper to discuss the nature of the changes California's grasslands have undergone over the past two centuries, to bring together literature describing studies and projects undertaken to analyze and reverse these changes, to suggest appropriate restoration techniques, and to present projects exemplifying the current status of grassland restoration in California.

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[2]Authors are Open Space Management Specialist, 1504 Beverly Place, Albany, CA, and Head Librarian, Strybing Arboretum Society, 9th Ave. at Lincoln Way, San Francisco, CA 94122.

BACKGROUND

Nowhere else on earth has there been such a dramatic grassland type-conversion as in the California prairie biome. Starting with, and perhaps preceding, the Spanish mission period, a parade of Mediterranean annual forbs and grasses invaded California (Hendry 1931) in animal coats, in soil around plant cuttings, as impurities in crop seed, as forage, and in packing materials, ballast, animal manure, and debris from ships. The settlers also brought livestock; feral herds soon became common. Using the same careless range management practices that had destroyed much of Spain's rangeland, Spanish herders facilitated spread of these exotic annual plants that had evolved in a climatically similar area under centuries of overgrazing (Burcham 1957). This invasion was followed by the introduction of perennial grass and shrub species from Europe and Australia into coastal prairie habitats. By the 1850's, much of the once vast perennial bunchgrass prairie biome was replaced by grasslands dominated by annual and perennial exotics (Burcham 1957).

Herbert Baker (1972, 1976) has carefully documented biological and physiological interactions that elucidate the transformation of perennial grassland to the annual type. The invading plants tend to have slightly heavier seeds and produce a far larger seed crop. These new annuals and perennials, which were preadapted to California's Mediterranean climate, coevolved with the introduced ungulates which largely replaced the native grazers (deer, essentially browsers, remaining the main exception). The native animal community had exerted a negligible effect on plant cover due to a balance between animal populations and natural vegetation, natural chemicals deterrent to native ungulates but palatable to domestic livestock (Elliott and Wehausen 1974), and absence of the selective disadvantage inherent in continuous close-cropping. Very high yearlong stocking rates, first with cattle, then with sheep, were followed by a severe mid-19th century drought, which wrought a permanent change in the grassland composition, redefining the climax vegetation type (Burcham 1957). The chance of the native perennials spontaneously reseeding disturbed soils is limited by sheer seed numbers. Bartolome (1979) found an average of 6.5 germinable annual grass and forb seeds per cm^2 ($65{,}000/m^2$) in an annual grassland at Hopland Field Station in the north coast range. Major and Pyott (1966) found no seed reserve of the perennials in a relict bunchgrass site in the Sacramento Valley. Annual grasses are able to maintain the seed bank during drought periods (Ewing and Menke 1983, Raguse *et al*. 1977).

Parallel to the change in species composition was a corresponding change in soil development: the loss of the upper soil horizons due to overgrazing and agriculture. Exotic annual grasses and forbs are quick to occupy eroded sites and begin the slow process of soil formation. The exotic annual fescues (*Vulpia* spp.), red brome (*Bromus rubens*), and deep taprooted filaree (*Erodium* spp.) tend to dominate on the thinner soils and drier sites, while ripgut brome (*B. diandrus*), soft chess (*B. mollis*), and wild oats (*Avena* spp.) dominate on deeper soils with more clay content. The findings of competition studies show that alien annuals and perennials, almost without exception, grow faster than many native grass species and are more competitive for light, moisture, and nutrients (Evans and Young 1972).

The physical structure, productivity, and rates of decomposition of grassland litter differ greatly between adjacent perennial and annual grasslands (Savelle 1977, Evans and Young 1970). The loss of aboveground litter through grazing or fire is an important element in determining species composition. Secondary succession after cessation of grazing on a previously heavily grazed coastal prairie in Sonoma County has resulted in a grassland

dominated by European pasture grasses, velvetgrass (*Holcus lanatus*) and sweet vernalgrass (*Anthoxanthum odoratum*), where the litter builds up because of protection from further grazing (Foin and Hecktner 1986). Nearby, on similar sites with moderate grazing, where the litter does not build up as much, California oatgrass (*Danthonia californica*) and purple needlegrass (*Stipa pulchra*), both natives, are the dominant perennials.

In an annual grassland at Hopland Field Station where no native perennial grasses existed, 612 purple needlegrass plants naturally established after three years in a 600 m^2 plot undergoing mulch removal treatments (Heady 1956). While there was no statistically significant relationship to any one treatment, there was a corresponding increase in purple needlegrass in the surrounding seasonally grazed (sheep) grassland. In ungrazed grasslands nearby, purple needlegrass densities have not increased in over 20 years (Bartolome and Gemmill 1981). This pattern is seen throughout California's grasslands (Biswell 1956, White 1967, Talbot *et al.* 1939, Saenz and Sawyer 1986). Native perennials stabilize and spread with some form of biomass harvesting and recycling, either with mowing, fire, or grazing. Complete rest of areas disturbed by heavy grazing or tilling results in the dominance of introduced annual grasses (*B. diandrus*, *B. mollis*, *Avena* spp., etc.) in the dryer grasslands, and exotic perennial grasses *Holcus*, *Anthoxanthum*, *Arrhenatherum*, *Danthonia pilosa*, etc.) in the moister north coastal prairies.

Despite all that has been written on the subject, little is known of the exact species composition of the perennial prairie. Moreover, there is a good chance that the driest prairies of the southern San Joaquin Valley may originally have contained only a minor bunchgrass element. In this region the desert-like conditions probably supported mostly native annual grasses, forbs, and wildflowers as reported in the journals of the early explorers, including John Muir who crossed the valley on his walk to the Sierra Nevada (Wester 1981).

Fortunately California has large areas with outcrops of a soil type (serpentinite) so high in magnesium and other heavy metals that fewer exotic annuals or perennials are able to survive (Kruckeberg 1984, Edwards 1988). Serpentinite outcrops, which are dispersed primarily in the central and north coast ranges of California, give the ecologist a glimpse, albeit narrow, of original prairie species composition, cover, and community structure (Fiedler and Leidy 1987): a rich mixture of perennial bunchgrasses interspersed with flowering bulbs and herbs.

As far as is known, no native perennial bunchgrass has gone extinct as a result of the introduction to and dominance of the grassland by alien species. However, there are indications that the cover and frequency of some species of perennial bunchgrasses have been dramatically reduced from predisturbance levels. One such plant, pine bluegrass (*Poa scabrella*), is found throughout California (Crampton 1974), yet it is no longer abundant except in the driest of sites. This grass was not even mentioned in Beetle's seminal work (1947) on the distribution of California native grasses. Indeed, today pine bluegrass is difficult to find below 1200 meters, perhaps because it exploits the same niche as the annual grasses and is outcompeted. Pine bluegrass grows quickly in the winter and early spring as do the annuals; it goes into complete obligate dormancy in the early summer like the annuals, yet, unlike annuals, its dry matter remains nutritious to grazing animals; it begins to grow in the fall before the annuals germinate; and, finally, its seeds are very small in comparison to the seeds of annuals. The California melicgrasses (*Melica californica* and *M. imperfecta*) have similar attributes.

PAST STUDIES

Research for California rangeland improvement began in the early 1940's with the pioneering work of Burle Jones and Merton Love of the University of California's Division of Agronomy. The list and number of native perennial grasses they worked on is impressive (Kay *et al.* 1981). Promising strains of *Stipa pulchra* and nodding stipa (*S. cernua*) were certified (Love 1948) and a robust variety of California brome (*Bromus carinatus*), Cucamonga brome, was introduced soon after (Lemmon *et al.* 1950). California oatgrass was also a promising candidate for coastal range and pasture improvement (Jones 1948), but its delayed germination strategies (Laude 1949) and paltry seed production disappointed seed growers.

Seed produced under cultivation was limited because seeds were difficult to harvest and clean, especially those of the stipas, whose awns turned the harvested seed into a "rat's nest" jumble. In addition, the native perennials produce seeding culms over a period of time, thus limiting the amount of seed harvested in one cutting. These problems have been largely solved by recent advances in cleaning equipment (Dremann 1987), harvesting, and seeding equipment (USDA 1980). Finally, perennials, both native and exotic, were too slow-growing for erosion control, where quick cover and low cost were the criteria for species selection. Here the exotic "resident" annuals could not be beat. Blando brome (Bromus mollis), annual ryegrass (*Lolium multiflorum*), and Zorro fescue (*Vulpia myuros*) gradually dominated the revegetation trade (Kay 1985).

Perennial grass development shifted to the more productive exotics for range improvement, particularly orchardgrass (*Dactylis glomerata*), Hardinggrass (*Phalaris tuberosa stenoptera*), and, most recently, Perlagrass (*P. t. hirtiglumis*). Part of the reason for this was their greater economy of seed production and ease of handling. These grasses are used primarily on the most favorable range sites where agricultural and range equipment can be employed. Perennial irrigated pasture grass introductions included orchardgrass, Hardinggrass, Dallisgrass (*Papsalum dilatum*), tall fescue (*Festuca arundinacea*), and perennial ryegrass (*Lolium perenne*).

Despite these factors favoring the use of exotics in revegetation and range management, the native perennial grasses still performed as well as, or better than, the exotic perennials in range and wildland seeding trials (Green and Bentley 1957, Edmunson and Cornelius 1961, Cornelius 1966) prompting the researchers to lament the fact that seed was not commercially available.

Perhaps the most significant early experiment comparing the effects of management on the establishment of native and exotic perennial grasses was carried out by Love in California's Sacramento Valley (Love 1944, Jones and Love 1945). *S. pulchra* and *S. cernua* along with 11 other perennial grasses were broadcast seeded in November (6.9 kg/ha) into separate plots that had already been prepared and seeded earlier with annual ryegrass (3.4 kg/ha), perennial ryegrass (6.7 kg/ha), and annual bur clover (11.2 kg/ha). The rainfall during the first year of establishment totaled 45 cm. It was found that early grazing, in this case 275 ewes on a 3.6 hectare field, from April 2 to April 20, resulted in a superior perennial stand compared to late grazing (April 20-May 21) or late mowing with litter removal on April 16. In this experiment, the frequency of live plants of stipa, particularly the nodding stipa (*S. cernua*), exceeded all the exotic perennial grasses tested, including orchardgrass, tall fescue, perennial ryegrass, and tall oatgrass (*Arrhenatherum elatius*). The results of this experiment have important implications for grassland restoration in providing procedures for successfully establishing native perennial grasses on unirrigated sites already occupied by annual grasses and forbs. Love's conclusion

merits restatement here: "The fact that, during this critical period, the grazing animals did not damage the seedlings but, on the contrary, reduced the competition provided by the annuals is a fundamental one and points the way to the improvement of the California range."

TECHNIQUES

The techniques for restoring and managing perennial grassland habitat in California are similar to those used in Midwestern prairies. Even after the most careful planting or seeding of a grassland habitat, the restoration process ultimately becomes an ongoing management process to control the faster growing exotic annual grasses and herbaceous weeds and to usher in a stable native perennial grass habitat. The stability is dependent upon a host of biological and physiological principles, which include soil development, nutrient cycling, fire, and grazing events.

To restore a California perennial grassland habitat the manager has several tools and treatments available. These include tilling, herbicide spraying, seeding, planting, mowing, grazing, and fire. Note that irrigation and fertilization are absent from this list of treatments. A temporary irrigation program is a double-edged sword, which, if used at all, must be used very carefully and usually only to simulate natural rainfall in times of drought (Tyson 1984). Fertilization favors the weeds and annuals and actually depresses the establishment of the important native perennial bunchgrasses (Green and Bentley 1957).

Grassland restoration can take two forms: till and no-till. The first form is an intensive effort that begins with a clean slate. This is when the tilling and herbicide treatments are used for site preparation, and seeding and planting follow to introduce the new grassland vegetation. However, this intensive grassland restoration effort must be followed by mowing, grazing, and/or fire treatments to assure establishment and sustainability. The second form of restoration does not physically disturb the on-site vegetation, but rather relies on the management treatments to tip the vegetative successional direction toward native perennial-type cover and composition over a gradual period of time (several years).

Much information concerning grassland establishment and management exists in the range literature. Grazing management programs have been shown to shift grassland vegetation toward greater stability and increased cover of perennials (Sampson 1952, Burcham 1957, Cooper 1960, Savory 1988). These types of grazing programs or systems mimic natural periodic grazing events coupled with appropriate periods for plant regrowth. Where grazing is not desirable, other methods of weed control or biomass (mulch) control are necessary. Here the use of periodic mowing coupled with the removal of the cut material is an indispensable technique. Similarly, periodic prescribed burning is another "harvesting" technique that has been shown to encourage perennial grass establishment in California.

Perennial grass seedings need special attention during the establishment period. Weed competition is a major concern. Unlike annual grasses, perennials grow slowly the first year and take two years to develop into a good stand. The optimum time to seed native perennial grasses in California is in the fall when moisture and temperatures are favorable for plant establishment. Herbicide treatments, both before and after seeding perennial grasses, are commonly used in agricultural situations to reduce weed competition during the establishment period. This practice is applicable to grassland habitat restoration projects (Rogers 1981) and enables soil disturbance to be kept to a minimum, but the effect on other native herbaceous annuals and perennials will be

detrimental. Care must be taken to use herbicides only where native plant communities do not exist.

The best technique for seeding native perennial grasses is one that ensures good, firm contact of the seed with the soil, preferably just below the soil surface. If the seed is broadcast on the soil surface, it needs to be covered, either by raking, harrowing, or mulching. Often the most successful establishment occurs in the area compressed by the tractor tires or tracks. Ring rolling or cultipacking the soil surface after seeding enhances perennial grass germination because of the firm seed contact with the surrounding soil. This provides the maximum number of small capillary pores in the soil which feed moisture up to the seed from below. Planting seed with a seed drill is, by far, the most economical and successful seeding technique, but it can only be employed on relatively flat surfaces with minimum rock and woody plant obstructions.

Perhaps the greatest limiting factor in grassland habitat restoration in California is the availability of native perennial grass plants and seed. Currently most seed for native grassland restoration is collected by hand. The expense is great, and seed quantities are often not sufficient for the project. For small projects, planting of container grown grass transplants (liners) has been shown to be successful and economical, especially with the rhizomatous creeping wild rye (*Elymus triticoides*) and the vigorous long-lived bunchgrasses (*Stipa*, *Danthonia*, and *Elymus* spp.) (Amme 1985). When properly managed, the plants seed-in and spread. Today, larger quantities of native perennial grass seed are just beginning to become available from seed growers in California. The primary grass species currently available include meadow barley (*Hordeum brachyantherum*), purple stipa, California brome, blue wildrye (*Elymus glaucus*), a drought tolerant native red fescue (*Festuca rubra*). The Soil Conservation Service is investigating creeping wildrye, blue wildrye, stipa, squirreltail (*Sitanion jubatum*), California fescue (*Festuca californica*), California brome, and the melics (*Melica imperfecta*, *M. californica*, *T. torreyana*).

CURRENT PROJECTS

Attempts to restore native grassland habitats represent a relatively recent phenomenon in California. Interest in establishing and maintaining native grasslands, both for high-use urban park settings (Rogers 1981, Amme 1987) and for the preservation and management of existing grassland open-space lands and nature preserves (McClaran 1981, McClaran and Bartolome 1981, Pitschel 1984) has grown in the past ten years. Moreover, people's interest in grassland restoration is rising. The ranching community is becoming more aware of California's perennial grass resource both from the standpoint of wildlife habitat and increased forage production. State and Federal agencies, local park districts, and nature preserves are giving serious consideration to the possibility of restoring and maintaining California's perennial grassland habitats.

Prescribed grazing programs (Clausen pers. comm.), designed to favor perennial grass development are being researched by the University of California's range science departments at Berkeley and Davis. These projects are being conducted at the U.C. Hopland Field Station in the north coast range and at The Nature Conservancy's Jepson Prairie in the lower Sacramento Valley. The Hopland study is addressing grazing management of upland grassland habitats for application to State Parks management programs (Bartolome 1986). The Jepson Prairie project is seeking to preserve and expand one of the last remnant prairies in the Central Valley (Menke

and Langstroth 1987). Seasonal grazing, burning, protection, and combination treatments are being closely analyzed.

The California State Department of Parks and Recreation has taken the lead in native grassland habitat restoration (Barry 1984). Prescribed burn programs conducted at Point Lobos State Park have greatly enhanced the extent and native perennial grass composition of this coastal prairie near Monterey. Detrimental continuous grazing is being curtailed at Mount Diablo State Park and Henry Coe State Park, two major grasslands in the inner coast ranges. At Malibu Creek State Park, the Parks Department is undertaking an oak savanna restoration project that includes the planting and seeding of native bunchgrass species in an oak/grassland setting (Allen 1986). The Northern Region Headquarters is investigating the preservation and management of several prairies along the north coast. At Crystal Cove State Park on California's south coast, the Parks Department has seeded and planted purple and foothill (*S. lepida*) stipa (Hillyard 1987). The California Conservation Corps nurseries, especially the Napa facility, have produced many thousands of native perennial grass liners for State Park site stabilization and restoration projects throughout the state.

The Nature Conservancy is studying restoration possibilities on a disturbed serpentinite prairie at Ring Mountain Preserve in Marin County (Strahan and Wolley 1986). A coastal live oak savanna restoration project at the Elkhorn Preserve is currently underway (Betz 1988). At Redwood National Park, Point Reyes National Seashore, and Golden Gate National Recreation Area the National Parks Service is growing, planting, seeding, and managing grassland restoration projects.

The Bernal Hilltop Native Grassland Restoration Project, begun in January 1987 on an urban parkland/natural area in the middle of San Francisco, is an example of a volunteer effort put together by a coalition of neighbors, with broad-based support from the California Native Plant Society and local botanists, horticulturists, and conservationists. Hilltop vegetation is a mix of native bunchgrasses, wildflowers, Mediterranean annual grasses, escaped exotics, and other weeds, with some areas remaining more pristine than others. The hill has not been grazed for at least 40 years, but the dry summer vegetation is subjected to irregular, but frequent, fires. Using no-till methods, a test plot in the weediest area was planted with bunchgrasses grown from seed collected on the hill. After two years of maintenance restricted to minimal hand-weeding, no irrigation (despite drought), and no fertilization, observations not only showed a high percentage of establishment and survival, but also showed natural re-establishment of native grasses, bulbs, and herbs in an area where they had not previously been noted. On other parts of the hill, control of invasive exotics by selective cutting or hand-weeding and replacement with natives appropriate to the niche, as well as attempted reintroduction of species last reported on the site in the 19th century, are other techniques employed. Only seed from the hilltop or from the nearest ecologically similar site is used. In an effort to help the hill restore itself, participants are looking to the hill itself to prescribe appropriate species composition and associations for each area (Clinebell 1987, Pitschel 1988).

FUTURE NEEDS

As demonstrated by the studies cited, most past California grassland research has been conducted from the standpoint of range management; interest from the perspective of pure restoration is relatively new. Because California grassland restoration ecology is a new science and because its implementation involves new technology and new applications of existing

technology, there is a great need for new materials and techniques. Additional facilities for production of seeds and plants of native prairie species, with consideration given to appropriate indigenous genotypes, are a major necessity. The paucity of available data makes it imperative that restoration practitioners monitor their projects and share technical data on their successes and failures with the restoration community. The current trend of public agencies to recognize the value of habitat restoration over horticultural landscaping should be encouraged and expanded. Incentives should be provided to encourage the practice of restoration techniques in the private sector. And, of course, there will always be the need to educate the public about the aesthetic and ecological value of attempting to restore historical native ecosystems.

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