two agencies. For example, workers harvested 45 kg (100 lbs.) from 25 species of prairie forbs in 1990, and over 225 kg (500 lbs.) the following year.

For its restoration projects, the PDDMC mixes seeds of the OPSN-grown native forbs with prairie grasses harvested from Huffman Prairie, Ohio's largest remnant tallgrass prairie. The agency has planted over 42 ha (104 acres) of prairie in eight Park District reserves since 1990. The ODOT has distributed their portion of the seed to all 12 ODOT districts and now has several plots planted along Ohio highways.

Over the last five years, both agencies have learned a considerable amount about the various aspects of the nursery operation including the use of: 1) a 1940s-era wheat binder for harvesting forbs such as oxeye sunflower (*Heliopsis helianthoides*), stiff goldenrod (*Solidago rigida*), yellow coneflower (*Ratibida pinnata*), and others; 2) a leaf mulcher for grinding seed heads, freeing seeds; 3) a small, versatile fanning mill for cleaning seed; 4) a small greenhouse for growing plant plugs for seed production beds; and 5) weed-free compost from a mushroom grower to improve soil structure and vitality.

In March 1993, the ODOT renewed its partnership with the PDDMC by issuing a new five-year grant for $224,000. The agencies plan to expand from nursery-scale production to agricultural-scale production, improve their methods of large-scale harvesting and planting, and increase the amount of greenhouse production.

Both agencies realize that this is a pioneer program where information about seed production and planting is limited, and that collecting and recording data from across the state are essential to the success of the program. Thus, each ODOT district horticulturist will keep information on ground preparation, planting methods, soil conditions, time of year planted, survival rates, and any other pertinent information. They will combine this information with evaluations from the PDDMC Land Stewardship Program as well as from other organizations trying to establish similar plantings.

The future of the OPSN appears challenging, exciting, and rewarding. We feel that we are on the threshold of accomplishing a 15-year-old dream while realizing that our dreams for the next 15 years are near at hand.

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Native Grassland Restoration in California: Assessing Suitable Sites

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The Valley Needlegrass Grassland Community once dominated large portions of the California landscape. Today, it exists only in isolated localities throughout the state, where it is recognizable by a significant cover of purple needlegrass (*Stipa pulchra*) and other native perennial bunchgrasses.

Although agriculture and other development destroyed much of the native grassland vegetation outright, a tremendous amount was converted to annual grassland during the early 19th century due to a combination of over-grazing and drought (Heady, 1977). Today, non-native annual species, such as wild oats (*Avena fatua*), brome grass (*Bromus* spp.), annual ryegrass (*Lolium perenne*), fileree (*Erodium* spp.), dominate most grasslands in California.

While people still debate the precise distribution and composition of California's pre-settlement grasslands, one thing is clear—the annual grasslands present today are not all degraded native prairie. In fact, we know that repeated burning and grazing has allowed many annual grasses to overtake former chaparral and coastal sage scrub as well (Cooper, 1922; Hobbs, 1983; Freudenberger *et al.*, 1987; Keeley, 1990; Haidinger and Keeley, 1993).

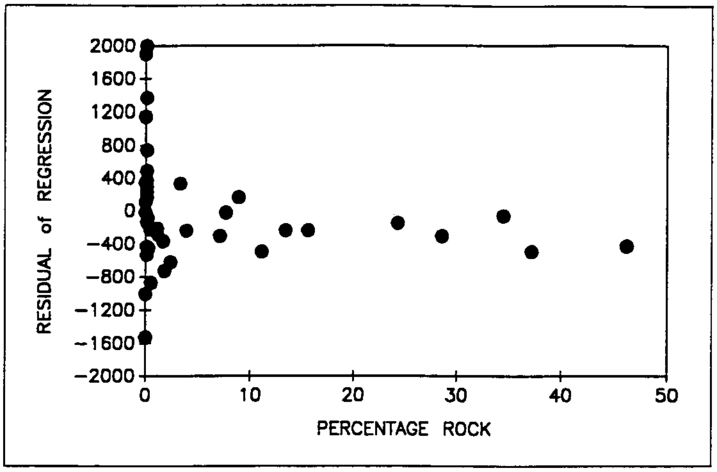
This latter point raises a fundamental consideration when planning the restoration of native grasslands in California. There exists a mistaken notion in the minds of some land managers that any annual grassland is a suitable for restoration with native grasses. However, if the site is a coastal sage community degraded with annual grasses, it would be a mistake to attempt restoration because: 1) the site factors are probably not suitable for the long-term persistence of native grasses; and 2) establishing native grasslands on such sites represents a "type-conversion," rather than a "restoration."

The potential loss of extensive grassland on the Ahmanson Ranch in southeastern Ventura County illustrates this situation. The ranch includes more than 800 hectares (2000 acres) of grassland, including approximately 160 hectares (400 acres) of perennial bunchgrasses. Although this site is considered one of the three best preserved native grasslands in southern California (Keeley, 1991), the Ventura County Board of Supervisors recently approved development of the site. Since this development will require the restoration of similar native grassland on another site, it is critical to understand which surrounding annual grasslands have the highest potential for restoration.

In this part of Ventura County, grasslands are distributed across more than a dozen soil types but, with a few exceptions, native perennial grasses persist on only three of these soils, all of which are very deep (1-2 m), slightly acidic clays that are devoid of rocks. Grasslands without native grasses are typically found on slightly alkaline, rocky, shallow (<25 cm) soils (Keeley, 1993).

I suspected that the best way to evaluate the question of where restoration was most likely to succeed was to compare the characteristics of remnants of the original Valley Needlegrass Grassland with other grassland sites in the same region that are dominated solely by weedy annual grasses, which should be either former native grasslands or shrublands.

To test this idea, I sampled 40 grassland sites in the vicinity of Ahmanson Ranch to determine the relationship between the soils and the various grassland types. When I plotted the deviation from the regression line (called the "residual") against the percentage of rock in the substrate, I found that sites with any significant rock component were clearly devoid of perennial



Distribution of regression residuals for regression of percentage of rock and perennial grass cover.

grasses, while sites lacking rocks may or may not have perennial grasses (Figure 1). I interpret this to mean that rocky soils probably never had native grasses, whereas non-rocky soils were potentially all native grasslands, many of which have been replaced with annuals.

This is important for restoration ecologists because in all likelihood rocky, shallow soils will not support native grasses. Unlike annuals, which persist through the mediterranean climate summer drought as seeds, native perennials must sustain their rootstocks. There are good physiological reasons for believing that, while perennial grasses may be able to survive on deep clay soils, they would perish on rocky, porous substrates (Kay *et al.*, 1981). Today, such substrates support coastal sage scrub and chaparral, in addition to annual grasslands. For this reason I doubt that perennial grasses would establish on such sites. Even if one could establish native grasslands on such substrates this would not fulfill the aims of ecological restoration, but rather would be a type conversion. In addition, my study of the distribution of soil types in the Ventura County region indicates that sufficient acreage is not available for the effective mitigation of the threatened native grasslands in southern California.

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Response of Native Bunchgrass to Grazing, Burning (California)

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Various ecologists (Biswell, 1956; Daubenmire, 1968; Mack, 1989) attribute the decline of native California grassland species to the introduction of aggressive exotic species (especially annual grasses), the suppression of natural wildfires, and heavy, continuous grazing by domestic livestock.

In 1988, we began an experiment to study whether a combination of prescribed burning and short-term, appropriately-timed grazing can reduce exotic species and increase natives, especially the once dominant perennial bunchgrass, purple needlegrass (*Stipa pulchra*). Our site was the Jepson Prairie Preserve, which under the joint management of The Nature Conservancy and the University of California-Davis, represents the largest remaining, unplowed expanse of valley grassland in the state.

In two experiments, we observed 20 m^2 plots with treatments of annual, wet-season grazing (April), dry-season grazing (August), or no grazing combined with either burning or no burning. We conducted two dry-season burns in 1988 and 1991. Fifteen dry ewes grazed the appropriate plots for three days per season.

The study provided data for two recently completed masters theses at UC Davis—one by Heather Fossum (1990), the other by Robert Langstroth (1991). Following their thesis research, I continued monitoring the experiment for two years, and can provide some interesting follow-up information.

Planting once in November 1988 and again in November 1989, Fossum sowed a total of 8,640 purple needlegrass seeds into paired transects in all six treatment combinations. She reported that 23 percent of the 1988 planting emerged with only one percent of those seedlings alive after 18 months. Twenty percent of the 1989 planting sprouted. No seedlings survived in control (ungrazed and unburned) plots. The initial trend she found indicated that spring-grazed/burned plots and ungrazed/burned plots were most favorable for seedling survival. However, the low survival rate and the lack of significant results two years after the treatment indicates that this experimental design may not be the best approach for determining a management plan for the area.

Langstroth measured the growth and clonal fragmentation ates of 648 mature purple needlegrass plants as a function of our ›urning and grazing treatments and their topographic location mound or intermound). He found that fire together with spring ;razing increased bunchgrass fragmentation while fire alone re- luced basal area by burning the dead material in the center. ₋angstroth also found that fire reduced seed quantity, but in- :reased seed weight, and that new seedling densities were much ıigher on burned and/or spring-grazed mounds than on other ›lots. In addition, both fire and spring grazing substantially re- luced the number of exotic annual grasses while increasing the ıumber of needlegrass tillers. Like Fossum's, his preliminary re- ults indicate that prescribed burning and short-term, wet-season ;razing may be useful in restoring purple needlegrass grasslands.

Beginning in 1990, I continued the experimental treatments ›n the planted plots and monitored Langstroth's purple needle- :rass targets. By 1992, I found only 23 of the original 1854 purple ıeedlegrass seedlings in Fossum's plantings with 48 percent of the urvivors in either burned or spring-grazed plots. Twenty-one of :he 23 remaining plants were very small and difficult to find, ıowever, indicating that hand-sowing was a very ineffective nethod for increasing purple needlegrass dominance under these :onditions. My own experiments indicate that plant plugs have ı much better survival rate (50 percent) after two years when ›lanted in variable density fan-shaped designs (Antonovics and ₋owler, 1985).

My monitoring of Langstroth's experiment leads me to con- lude: 1) the health of existing purple needlegrass, the survival f its seedlings, and the removal of exotic annual grasses depends ›n disturbances such as fire and light grazing that reduce the ccumulation of dead plant material both within the bunch and n the soil surface; 2) his reports of increased fragmentation and eduction in basal area due to fire and grazing may have been ›nly temporary effects related to a sudden, intense management indeed, I now find that the purple needlegrass has regrown to a ›oint where these reductions are no longer statistically signifi- ant); and 3) while summer grazing reduced the numbers of pur- ›le needlegrass more than spring grazing, summer grazing com- ined with burning increased the presence of native forb species. believe that other long-term patterns may still emerge and that e must remain flexible and cautious in developing and imple- ıenting our management or restoration plans.

I would be happy to send copies of these two theses to in- :rested readers (include $5.00 each for photocopying and post- ge). Fossum's thesis includes a very good chapter on the history nd conversion of California valley grasslands.

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Big Bluestem and a Tallgrass Prairie Dream. 1993. Gayton, D. **Equinox** 12(1):30-39.

Gayton reports on John Morgan—botanist and owner of Prairie Habitats Nursery in Argyle, Manitoba—and his efforts to restore tallgrass prairie in the Red River country of southern Manitoba. Despite his success, Morgan points out that "To call ourselves prairie restorationists is pretty arrogant . . . What we are really doing is replicating what we think was the original plant distribution of the tallgrass prairie."

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Denitrification in a Tallgrass Prairie Landscape. 1993. Groffman, P.M., Dept. of Natural Resource Science, University of Rhode Island, Kingston, RI 02881; C.W. Rice, and J.M. Tiedje. **Ecology** 74(3):855-862.

In studies conducted over three years on a tallgrass prairie in central Kansas, these researchers found that the microbial conversion of nitrate to nitrogen gases (denitrification) was higher in unburned areas than in either burned or burned and grazed sites. They also confirmed the annual denitrification is quite variable and regulated by the amount of soil moisture.

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Prairie Plant Guilds: An Ordination of Prairie Plant Species Based On Ecological and Morphological Traits. 1991. Kindscher, K., Doctoral dissertation, University of Kansas. **Dissertation Abstracts International** 53(8):3894B-3895B.

Kindscher studied the plant habit, leaf types, stem structures, root structures, and reproductive processes of 158 native prairie species he sampled in three upland tallgrass prairie in northeast Kansas. Using a detrended correspondence analysis, he identified eight guilds of tallgrass prairie species—C_4 grasses, C_3 grasses and sedges, annuals, ephemeral spring forbs, spring forbs, summer/fall forbs, legumes, and woody plants. Further statistical analysis indicated that these guilds do exist and that there are significant relationships between each guild and its environment.

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Interactive Effects of Fire, Bison (Bison bison) Grazing and Plant Community Composition in Tallgrass Prairie. 1993. Vinton, M.A., Dept. of Forest Sciences, Colorado State University, Fort Collins, CO 80523; D.C. Hartnett, E.J. Finck, and J.M. Briggs. **American Midland Naturalist** 129(1):10-18.

After a two-year study at the Konza Prairie in Kansas, these authors found that bison grazed burned areas during the spring, moved to areas dominated by C_4 grasses during the summer, and used both burned and unburned tracts to feed on C_3 grasses during the autumn and winter. Bison were selective in their grazing, preferring patches dominated by big bluestem (*Andropogon gerardi*) and avoiding those dominated by forbs. This interaction of herbivores, fire, and plants obviously creates a shifting mosaic on the landscape.