Sacramento Valley Prairie Project, UC Davis

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California's native grasslands are among the most-threatened natural communities in the United States (Murphy 1990). As an ecosystem, the native Central Valley Prairie has been eliminated (Heady 1977; Barry 1972), but remnant populations of native prairie species still exist in scattered locations. Many of these populations are small and vulnerable and could easily be lost by urbanization, agriculture, roadside-weed control programs, or competition from invasive weeds. Even Jepson Prairie, which includes one of the best remaining stands of native prairie in the Central Valley, is saturated with alien plants that suppress many native species.

As natural areas and native plant populations continue to decline, there is a growing need to locate remnant stands and preserve them when possible. When site protection is not feasible, there is value in safeguarding threatened populations by collecting propagules (seeds, rhizomes, bulbs, cuttings) and establishing plantings in protected areas (Ashton 1988). Patches of various sizes can be created in arboreta, parks, agricultural borders, rural roadsides, and restoration sites to offset partially future losses elsewhere. Home landscapes, too, have been suggested as settings of assemblages of native species for reestablishing or enhancing local biological diversity and ameliorating loss of habitat sustained by some species (Dawson 1990; Marinelli 1992, 1993; Murphy 1990).

With planning and proper management, elements of this decimated plant community can be reconstructed and serve a variety of research, educational, and ecological functions. The U.C. Davis campus is an ideal location to implement these ideas in the Sacramento Valley, for the campus supports an arboretum, agricultural research land, an experimental student farm, and other land suitable for prairie plantings. Selected areas could serve as *in vivo* refuges for native prairie germplasm.

With financial support from the Slosson Horticultural Endowment Fund and the Genetic Resources Conservation Program, UC Davis, we have begun this process by: 1) finding individual populations and assemblages of prairie plants in Yolo and Solano counties, 2) collecting propagules, 3) establishing methods for field evaluation, methods for measuring seed increase, and container plantings, 4) developing an ecological landscape, using Valley Prairie species, and 5) creating a Sacramento Valley Prairie section at the Davis Arboretum. The plantings contain a wide variety of native grasses, perennial forbs, and wildflowers, and are being used to show the beauty and variety of Valley Prairie plants, the value of them as drought-tolerant plants in home landscapes, and the potential of campus land for conservation and restoration programs. In this article we discuss the project development and our progress over the last two years.

Locating Native Prairie Plants

Native floras of arable lands are considered to be the most endangered worldwide (Ashton 1988). The Sacramento Valley is no exception; virtually all of its natural communities—i.e., tule marsh, riparian forest, valley oak savannah, vernal pool, and valley prairie—have been reduced or thoroughly modified (Barbour et al. 1993; Shapiro 1974). Yet, native plant populations do remain, providing opportunities for conservation and education programs.

Before receiving funding for this project, we began searching for prairie species that still occur in our area. Most of the accessions have come from sites not under permanent protection in the Valley, and within a 12-mile radius of the Davis campus. The collection sites were located by examining herbarium records, surveying rural areas, and reading the writings of Beecher Crampton (1979). Crampton, author of "Grasses in California" (1974), collected extensively in the Sacramento Valley from the 1950s to the 1980s during his tenure at UC Davis; his records and collections (located at the Tucker Herbarium, UC Davis) provided important information for this study.

Many of the collections are from weed-infested roadsides; others came from lands that, for a variety of edaphic, topographic, or ownership reasons, have not been intensively farmed and still support small populations of native prairie species. Railroad rights of way have a history of supporting botanical treasures because many of the railroads and their associated right of way strips were established before agriculture reached the area. Crampton (1979) described his botanical discoveries along a Southern Pacific right-of-

California poppy, lupine, woolly sunflower, farewell-to-spring, and mule ears in the tall-statured wildflower section, Sacramento Valley Prairie, UC Davis Arboretum.

way in the Allendale region of Solano County where we have searched annually for remnant species. He wrote,

This area has, over many years, given me much pleasurein "discovering" many of the species I came to feel were very common in the Sacramento Valley before cereal farming and other types of agriculture arrived after 1839. The native perennial bunchgrasses, *Stipa pulchra*, *Poa scabrella* (1020, 9188), *Sitanion jubatum*, along with the annual *Pleuropogon californicus* (3257) did occur in some abundance along the railroad in the 1950s and 1960s but recently severe competition from the naturalized Mediterranean annual grasses, *Lolium multiflorum*, *Aegilops triuncialis* (4049) and *Elymus caput-medusae* have greatly reduced the amounts of these native bunchgrasses.

We have visited this site many times in the last three years, but have not observed *Poa secunda* ssp. *secunda* (syn. *Poa scabrella*) or *Pleuropogon californicus*. Along with *Nassella pulchra* (syn. *Stipa pulchra*) and a few clumps of *Elymus multisetus* (syn. *Sitanion jubatum*), a variety of infrequently encountered annual and perennial forbs still occurs there. These include: *Agoseris grandiflora*, *Calochortus luteus*, *Chlorogalum pomeridianum*, *Clarkia purpurea* ssp. *quadrivulnera*, *Dichelostemma capitatum*, *Downingia ornatissima*, *Lasthenia* spp., *Mimulus tricolor*, *Navarettia tagetina*, *Triteleia hyacinthina*, and *Wyethia angustifolia*. However, they are clearly losing ground to the exotic species mentioned by Crampton, and now to yellow starthistle *Centaurea solstitialis*. Although Crampton did not mention yellow starthistle, it is now one of the dominant species at this site. As in other areas of the state, this invasive species has increased enormously in the last 20 years, putting ever more pressure on California's native grassland flora.

A variety of species came from narrow floodplain and riparian terraces associated with sloughs, intermittent drainages, and a campus reserve. For example, a remnant patch (1/8 acre) along Chickahominy Slough northwest of Winters supports five species of native grasses: *Melica californica*, *M. torreyana*, *Nassella lepida*, *N. pulchra*, and *Poa s.* ssp. *secunda*. We also made many accessions from a terrace and adjacent slope along Dry Creek, two miles west of Winters. This site, surrounded by orchards and horse-grazed rolling hills, contains a small but rich assemblage of native grasses including *Koeleria macrantha*, *Melica californica*, *Nassella pulchra*, *Elymus glaucus*, *Poa s.* ssp. *secunda*, and *Leymus triticoides*. An array of forbs, many of which have almost been eliminated in this area of the valley, grows in association with the grasses. It includes: *Achillea millefolium*, *Asclepias eriocarpa*, *A. fascicularis*, *Brodiaea elegans*, *Clarkia affinis*, *Dichelostemma congestum*, *Eriogonum nudum*, *Eriophyllum lanatum*, *Lupinus d.* var. *densiflorus*, *Phacelia imbricata*, *Solidago californica*, *Triteleia laxa*, and *Wyethia helenioides*.

Although many of the more disturbed sites each supported only a few species, our total accessions amount to a large number. We now have 227 accessions represented by 87 species from 26 sites of which 22 are in Yolo County and 4 in Solano.

More collections are being made in order to acquire both new species and species from different populations, and to increase the quantity of seed in cases where accessions are in short supply.

Propagation, Evaluation, and Transplanting

Most of the plants we have collected were known to us only from "natural" settings; hence we were unfamiliar with their cultural requirements. We searched the literature, but for many broad-leaved species we had little information other than what is given in *The Jepson Manual* (1993)—i.e., "TRY." We weren't sure we could propagate, grow, and maintain them under other conditions. We conducted propagation tests in outdoor containers and in greenhouses, and established field plantings at the Student Experimental Farm. To different degrees, we have succeeded in growing most of the plants we collected, but some have proved difficult. These will require detailed testing that is presently beyond the scope of this project.

Nearly 100 accessions have been planted at the Student Experimental Farm. These include perennial grasses, annual wildflowers, and perennial herbs, and we are evaluating them for: propagation ease, self-sowing ability, phenology, flowering period, insect visitation, persistence, invasiveness, and management requirements. Most were direct-seeded, but some were plug-planted from greenhouse starts, field-collected corms and bulbs, and rhizomes. With the exception of plants in the Fabaceae, we did not scarify the seeds to enhance germination.

With the constraint of our three-year funding period, propagating and evaluating slow-growing species from seed has been problematic. For example, we field-planted mule-ears *Wyethia helenioides* from seed four years ago (before receiving funding), but it has yet to flower. So it is with all the bulb and corm species: *Brodiaea*, *Dichelostemma*, and *Triteleia* take at least three years to flower from seed, and *Chlorogalum pomeridianum* may take up to five (Jernstedt, per comm.).

Initially, we attempted to propagate bulbs and corms from seed only, planning to transplant them during their second or third year to the Valley Prairie section at the Davis Arboretum. After numerous attempts, with mixed results, to collect seeds, start them in containers, store young dormant plants in a cool place through the summer, and transplant second-year plants, we decided to use some field-collected bulbs and corms.

Populations of most species we found large enough for us to collect small quantities of bulbs and corms without appreciably reducing reproduction. And according to ethnobotanist Kat Anderson (1992), conscientious collecting of corm-producing species may actually increase population size. Native American elders she interviewed explained that gatherers took what they needed and then intentionally subdivided, distributed, and replanted large numbers of smaller cormlets to ensure a continual supply. We adopted this approach when we collected corms and also sowed seeds during periods of seed collecting.

In one case we found a site that is threatened by development and did some "salvage" collecting. Two miles west of the rapidly growing town of Winters, there is a population of *Dichelostemma capitatum* in a lot between a restaurant and a market. Of the few valley populations of this species we have seen in our area since we began searching, five years ago, it is the largest. The lot is zoned "commercial," and it is just a matter of time before this population is under concrete. We collected large numbers of mature corms and cormlets and replanted them at our Davis Campus sites and at the Bio-Integral Resource Center's (BIRC) Field Station located near the collection site.

For the reproduction of bulb species that produce fewer vegetative "offspring, " such as *Calochortus luteus*, we have minimized collecting bulbs, relying mostly on propagation from seed. The plants thus produced will be transplanted after the funding for this project ends. We have resigned ourselves to the reality that the biological time scale differs greatly from funding cycles, and that some work can be completed only "in the red." Accordingly, we have developed container stock for slower- growing perennials and established a "bulb bed" where we can nurture and safely maintain bulb and corm species in the field for an indefinite period, transplanting them when they mature. Direct seeding at the site would be preferable to transplanting, but the extra care required to weed around the tiny seedlings eliminated this as a practical option.

Valley Prairie Plants That Serve as Nectar and Larval Host Plants for Butterflies

Many Valley Prairie plants attract butterflies by providing nectar for adults or by serving as host plants for their larvae. By proper plant selection and landscape design, habitat enhancement for butterflies could easily be made a larger part of ecological landscaping, restoration projects, or farmscaping.

To determine the "butterfly value" of individual species, we searched the literature, began a monitoring program, and consulted Dr. Arthur Shapiro, lepidopterist and professor of evolution and ecology at UC Davis. Dr. Shapiro has monitored butterfly activity within the U.C. Davis environs and at other Sacramento Valley locations for 24 years. By means of his publications (1974, 1987), and with his assistance, we compiled a list of butterflies that use Valley Prairie plants as larval host plants or as nectar sources.

We have also started a monitoring program for our evaluation plots on the Student Experimental Farm, at a field site near Winters, and began recording visitation at our prairie planting site in the Davis Arboretum last spring (1996). Among the species that have lured butterflies into the evaluation plots are: *Asclepias fascicularis*, *Eremocarpus setigerus*, *Eriogonum nudum*, *Heliotropium curassavicum*, *Hemizonia congesta* ssp. *luzulaefolia*, *Hemizonia pungens*, and *Lotus purshianus*. We expect that as we obtain and plant additional species, the diversity of butterflies will increase.

To date, *Lotus purshianus* has attracted the most kinds of butterflies—a total of 8 species—within our evaluation plots at the Student Experimental Farm. *Lotus* is a larval host plant to the Acmon Blue *Icaricia acmon* and the Eastern Tailed Blue *Everes comyntas*. The former can commonly be observed visiting *Lotus* through the summer. *Lotus* is also remarkable for its mid- to late-summer growth; in good soils, it produces a dense sprawling mat, or sometimes a more upright "hedge," of pubescent herbage, with a flowering period that extends into the autumn.

The milkweeds, *Asclepias* spp., are some of the better-known butterfly-attracting plants. Although they are most noted as the larval host genus for the monarch butterfly *Danaus plexippus*, milkweeds also attract an extraordinary array of other butterflies, nocturnal moths and non-lepidopteran nectar-seeking and host-specific phytophages, and phloem-feeding insects (Woodson 1954; Morse 1985). Their value in "farmscaping" (see below) has yet to be adequately studied, but their various insectary, phenological, and aesthetic properties make them excellent candidates for testing.

"Farmscaping" is the integration of non-crop plants on farms to create habitat for beneficial insects or other wildlife, to control erosion, and to enhance biological diversity. The best example in the Sacramento Valley is found at Hedgerow Farms, a 500-acre farm that comprises valley-floor and foothill terrain, 4 miles north of Winters. For 15 years, owner and manager John Anderson, who is one of the few large-scale native-grass-seed producers in the state, has been re-establishing native vegetation on field borders, along irrigation canals, tailwater ponds, and sloughs, and on other land unsuited for farming.

On July 20th, 1995, we monitored a large patch (15' × 275') of narrow-leaved milkweed *Asclepias fascicularis* near Union School Slough that he had planted for seed production. Viewing the patch could be described as attending a multispecies "butterfly dance." We observed remarkable lepidopteran activity and within two hours had collected twelve species. We are planning for more extensive monitoring this year in our Student Farm evaluation plots, at the Davis Arboretum, and at Hedgerow Farms, and are looking forward to the onset of flowering.

Ecological Landscaping

Ecological landscaping is emerging as a new approach to home gardening. Unlike typical home landscapes, it is the result of a deliberate attempt to create habitat for wildlife, reduce inputs such as water, fertilizer, and pesticides, and develop naturalistic plantings that reflect the local bioregion (Francis, per. comm.; Lutsko and Menigoz 1994).

One feature of this gardening movement is to use propagules (seeds, rhizomes, divisions, and cuttings) from locally collected native species and establish plantings to enhance biological diversity (Marinelli 1992, 1993). The extent to which ecological gardening contributes to biological diversity is, however, controversial. Schettler (1990) reminds readers that although gardening can be a means of preservation, rehabilitation, and restoration, the "natural landscape is a patchwork of diverse habitats, organisms, and relationships," and that "ecosystems cannot be concocted like a cake from a mix of ingredients." Pavlik, too (1996), is less than enthusiastic about *ex situ* plant-conservation programs, pointing out the problems from genetic drift, inbreeding, and erosion of genetic variability due to artificial selection. And Shapiro (oral communication) remarked that butterfly gardens are generally of little, if any, value for butterfly conservation. Only rarely, he said, do species breed in gardens, the principle function of which should be viewed, he said, as one of attracting randomly dispersing butterflies so people can watch and enjoy them.

In contrast, Murphy (1990) writes that the reintroduction of natural landscape elements into suburban and urban neighborhoods can play an important role in conservation, and that a well-planned garden of local native species can compensate for the fragmentation of native species elsewhere and serve as a biotic bridge between remaining patches of habitat.

Over a ten-year period, Shapiro (1982) observed 37 butterfly species (58% of the total in Sacramento Valley) in his Davis garden of carefully selected plants. Similarly, the rich nectar supply in the Drum Manor garden, in Ireland, resulted in butterfly numbers much greater than in other areas of northern Ireland (Heal 1973). Owens and Owens (1975) document the diversity of butterflies, hoverflies, and ichneumonid wasps in a garden habitat in England. They conclude that, far from being biologically barren, their 650-square-meter Leicester garden yielded an incredible variety of species, comparing favorably in diversity with natural areas.

These examples make a case for the ecological value of well-planned gardens and the role they can play in providing habitat for certain organisms, especially insects. We have begun to establish an ecological landscape at the Student Experimental Farm, using the Valley Prairie as a model. The plants come from local collections of native grasses and perennial forbs. Butterfly and other insectary plants are featured, as are species that are now very rare on the valley floor. As we labor with seed collection, site preparation, propagation, planting, weeding, and animal deterrence for our plantings, we are constantly reminded of the necessity of preserving as much remaining natural habitat as possible.

Valley Prairie Section at the Davis Arboretum

The establishment of a Valley Prairie section at the Davis Arboretum is the fifth phase of our project. The completed plantings will occupy a portion of the arboretum's California Plant Communities section, which presently comprises a Sierra woodland and a riparian community and will also eventually include tule marsh, chaparral, foothill-woodland, and mixed-evergreen communities.

Nine different prairie assemblages are being developed along with several special-feature plantings emphasizing butterfly-attracting species and ethnobotany. The design and species selection are based on Valley Prairie subtypes, available plant material, site factors, management requirements, and interpretive themes such as phenology, growth forms, and biodiversity. There will also be a "hands on" section, a creation of the Arboretum's environmental-education program, that will enable children to grow, maintain, and harvest prairie plants. The assemblages include a bunchgrass—perennial forb association, "fields" of short and tall spring wildflowers, a summer-active forb field, a native-bulb section, a moist-prairie association, a riparian understory featuring appropriate grasses, and a bank and roadside-border planting associated with a service road.

A year before planting, we started a weed control program with a large emphasis placed on depleting the seed bank. The following steps were taken:

1. The site was irrigated in September and October 1994, before fall rains, to initiate an early germination of the resident annual weeds, and Bermuda grass *Cynodon dactylon* was sprayed with the herbicide glyphosate.
2. After the seedlings emerged, a tractor-mounted cultivator was used to destroy them and to bring up deeply buried seeds.
3. The next flush of seedlings, brought up by autumn and winter rains, was eliminated by another application of glyphosate.
4. The summer-maturing weeds, many of which emerged after this treatment, were

Bunchgrass—Perennial Forb Association

Achillea millefolium	*Lomatium utriculatum*	*Agoseris grandiflora*
Melica torreyana	*Asclepias fascicularis*	*Nassella pulchra*
Chlorogalum pomeridianum	*Perideridea sp.*	*Clarkia purpurea ssp.quadrivulnera*
Poa secunda ssp. secunda	*Elymus multisetus*	*Sanicula spp.*
Eschscholzia californica	*Solidago californica*	*Grindelia camporum*
Wyethia angustifolia	*Koeleria macrantha*	*W. helenioides*

Native Bulb Section

Brodiaea elegans	*Koeleria macrantha*	*Calochortus luteus*
Melica torreyana	*Chlorogalum pomeridianum*	*Poa s. ssp. secunda*
Dichelostemma capitatum	*Triteleia hyacinthina*	
D. congesta	*T. laxa*	

Short-Statured Spring Wildflower Field

Calandrinia ciliata	*Poa s. ssp. secunda*	*Castilleja exserta Pogogyne zizyphoroides*
Claytonia perfoliata	*Sidalcea diploscypha*	*Koeleria macrantha*
Sisyrinchium bellum	*Layia platyglossa*	*Triphysaria versicolor*
Lupinus bicolor	*Trifolium fucatum L. nanus*	*T. wildenovii*
Melica torreyana	*Viola pedunculata*	

Tall-Statured Spring Wildflower Field

Achyrachaena mollis	*Agoseris grandiflora*	*Clarkia purpurea ssp. quadrivulnera*
Delphinium hansenii	*Eschscholzia californica*	*Hordeum brachyantherumLupinus*
microcarpus var. densiflorus	*L. m. var. microcarpus*	*L. nanus*
L. succulentus	*Sisyrinchium bellum*	*Wyethia helenioides*

Summer-Active Forb Field

Asclepias fascicularis	*Eremocarpus setigerus*	*Hemizonia congesta ssp. luzulifolia*
Lotus purshianus	*Malvella leprosa*	*Trichostema lanceolatum*

Moist-Prairie Association

Anemopsis californica	*Carex spp.*	*Euthamia occidentalis*
Glycyrrhiza lepidota	*Hordeum brachyantherumJuncus spp.*	*Leymus triticoides*
Sisyrinchium bellum	*Sporobolus airoides*	*Stachys a. var. ajugoides*

Riparian Grassland Understory With Trees, Shrubs, and Vines

Aesculus californica	*Agropyron trachycaulum*	*Aristolochia californica*
Elymus glaucus	*Lathyrus jepsonii*	*Rosa californica*
Sambucus mexicana	*Vitis californica*	

Bank Association

Elymus multisetus	*Eriogonum nudum*	*Eriophyllum lanatum*
Koeleria macrantha	*Lupinus microcarpus var. densiflorus*	*L. succulentus*
Nassella cernua	*N. lepida*	*N. pulchra*
Phacelia imbricata	*Solidago californica*	*Wyethia angustifolia*
Melica californica	*W. helenioides*	

Road Border

Aristida hamulosa	*Castilleja exserta*	*Eremocarpus setigerus*
Heliotropium curassavicum	*Lomatium* sp.	*Nassella cernua*

These species will be or are now planted at the UC Davis Arboretum.

removed manually with hoes.

5. We repeated the first part of this program in October 1995 by irrigating the site before the rains and by applying glyphosate to surviving Bermuda grass *Cynodon dactylon*. The site was cultivated for removal of the emerged weeds.

Having gone through these weed-removal cycles, portions of the site had weed populations that were reduced sufficiently for us to begin planting. This we did in November 1995 by direct- seeding the spring-wildflower field and several other sections where there were relatively few weeds in the seed bank. Other sections were left unplanted because we wanted to eliminate another cycle of weeds before planting. After germinating rains, we removed emerged weed seedlings in these sections by hoeing and began plug-planting starts in February 1996. We will add more species to the planted sections as we obtain them and begin planting the other sections as the seed bank is further reduced. Although we don't expect to eliminate the resident weeds utterly, this approach is reducing the post-planting manual-weeding requirements that can demoralize unsuspecting restorationists.

Conclusion

The Valley Prairie section, at the Davis Arboretum, will be interpreted by signs, information sheets, and insect collections, and through arboretum tours. Although many years will need to pass for the Arboretum prairie to "mature," the first-year plantings have been rewarding. Most of the plants are doing well, and we are optimistic that the plantings will fulfill the educational objectives of the project. Portions of the spring-wildflower field bloomed profusely, *Nassella pulchra* produced its attractive panicles, and the summer-active forbs are supporting a diverse insect fauna. Butterflies such as the acmon blue *Icaricia acmon*, common hairstreak *Strymon melinus pudicus*, and orange sulphur *Colias eurytheme* are being lured by their respective host plants, *Lotus purshianus*, *Eremocarpus setigerus*, and *Glycyrrhiza lepidota*. Monarchs have visited *Asclepias fascicularis* and laid eggs, and their voracious larva have feasted on the alkaloid-laden milkweed leaves to be sustained through pupation. Because some plants such as *Lupinus* spp. are certain to spread beyond their borders or become dominant and overshadow others, management will be necessary to maintain the intended character of the assemblages. Because of the location and small size of the plantings, neither fire nor ungulate grazing will be used as a prairie-management tool; so clipping the thatch that builds up on the perennial grasses and manual removal of other senescent material that accumulates will also be required to keep the plantings healthy and maintain the desired species diversity.

The plantings at the Student Experimental Farm will be used for further screening and demonstration purposes. Several other demonstration gardens are also featured there, among them a large collection of native grasses, a xeriscape, and various "permaculture" plantings. These figure in their ecological- agriculture program, which now includes organic food production, aquaculture, vermiculture, large-scale compost production, student internships, and a summer course in sustainable agriculture.

This project is also contributing to a genetic-resources conservation program for Valley Prairie plants. Seed collections, field plantings, seed increases, vegetative propagation, and planned re-introductions will help insure against the extinction of local plant populations, many of which are very vulnerable. We are now working with the Yolo County Resource Conservation District on their "model farm" project. One of the objectives of the project is to increase on-farm biological diversity along field borders——in which category are included tailwater ponds, used for catching sediment and recycling irrigation water. Wetland and moist-prairie species are well suited to the sloping wetter portions of these ag-border "ponds," and xeric prairie species can be established on the upland, drier pond borders. Through this model-farm initiative, we now have an opportunity to establish off-campus plantings and have found another home for a variety of prairie plants that have lost ground elsewhere.

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