California Native Grasslands Association

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California Native Grasslands Association

Mission Statement

The mission of the California Native Grasslands Association is to promote, preserve, and restore the diversity of California's native grasses and grassland ecosystems through education, advocacy, research, and stewardship.

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From the President's Keyboard

Fond Farewells, New Beginnings, and Summer Grasslands

by J.P. Marié, President

Dear Members, Sponsors, Supporters and Friends of CNGA,

I wanted to start by saying goodbye to some CNGA Board members and staff who are moving on to new opportunities. On behalf of CNGA, I would like to thank Dr. Andrew Rayburn, Dr. Rebecca Green, and Liz Cieslak for their contributions to our organization.

Andrew has been a key Board member on the Executive Committee, the Editor of our quarterly *Grasslands* publication, and has worked hard to coordinate with grasslands researchers and practitioners to organize sessions at various conferences across the state. I also would like to thank Rebecca for all her contributions to CNGA, first as our Administrative Director prior to Liz Cieslak, then as our grant manager for the past year. CNGA was lucky to have her during this time, and we wish her the best of luck in her next chapter. Finally, a big *thank you* to Liz, our outgoing Administrative Director, for all her great work and support. We wish her luck raising a growing family in Texas.

At the same time, I am very pleased to welcome Diana Jeffery as our new Administrative Director. Diana is a past CNGA Board member and was our contractor last year responsible for coordinating the highly successful New Front Yard workshops. Please join us in welcoming Diana as she transitions into her new position.

Every so often in the summer I travel to beautiful Lake Tahoe and stop at the bottom of Echo Summit on Hwy 50, at the Upper Truckee River in Meyers where a camp used to be. The site has had some restoration done, in particular the open meadow by the parking area. It has been a great experience to witness the native grasses and forbs adapting to the consistently changing environment. The site is covered in snow throughout the winter. Plants start to emerge after the snow melts, only to disappear during the spring snow storms before finally reemerging in early summer. The result is a beautiful mix of native grasses and forbs this time of the year (see the cover photograph), similar to other Sierra or coastal prairie grasslands, while most grasslands in the Central Valley are now in dormancy.

All too often, restoration projects involve weed removal, site re-grading, and planting of trees and shrubs without also including planting of grasses, graminoids, or forbs. These species are crucial for soil health, wildlife and pollinator habitat, and biodiversity of our local ecosystems, so I encourage everyone to include them in all of your projects.

Have a great summer, and please let us know if you manage or know of a grassland site that could be visited by CNGA in the future.

Putah Creek Reserve. *Photo: Emily Allen*

CNGA to Host Field Trip at Natural Areas Conference

The annual conference of the Natural Areas Association will be held Oct. 18–21 at the University of California Davis. The theme of this year's conference is *Climate Change Adaptation and Natural Areas Management: Turning Words to Action*. CNGA has organized a conference session on grasslands and climate change, and will also be leading an engaging field trip to local grassland sites. Registration for the conference is required to participate in the field trip.

The first stop on this trip will be Russell Ranch and the Putah Creek Riparian Reserve, a mosaic of grasslands, oak woodlands, and riparian ecosystems just west of Davis that is adaptively managed for teaching, research, and conservation of wildlife and habitat. The tour will highlight novel restoration efforts, integrated research projects, and adaptive management strategies including timed mowing, managed grazing, and controlled burning to target invasive species and promote native forbs, grasses, and woody plants.

The second stop will be Hedgerow Farms, Inc., a well-known native seed production farm that has supported habitat restoration efforts across California for the past 30 years. Hedgerow Farms produces native seed for over 100 species of native grass, wildflower, and wetland plants in addition to native nursery transplants and native straw. The tour will include seed production fields, seed cleaning operations, seed storage facilities, harvesting and planting equipment, and will provide insight into how the native seed industry supports habitat restoration.

Tour Leaders: J.P. Marié, Manager, UC-Davis Putah Creek Riparian Reserve; Andrew Fulks, Assistant Director, UC-Davis Arboretum; Emily Allen, Sales Manager, Hedgerow Farms; Tanya Meyer, General Manager, Hedgerow Farms

To register for the conference and field trip, visit: **naturalareasconference.org/registration**

Additional $50 registration fee | Capacity: 25
Difficulty: Easy to Moderate

Grasslands Submission Guidelines

Send written submissions, as email attachments, to grasslands@cnga.org. All submissions are reviewed by the *Grasslands* Editorial Committee for suitability for publication. Contact the Editorial Committee Chair, Andrew Rayburn, for formatting specifications: grasslands@cnga.org.

Written submissions include peer-reviewed research reports and non-refereed articles, such as progress reports, observations, field notes, interviews, book reviews, and opinions.

Also considered for publication are high-resolution color photographs. For each issue, the Editorial Committee votes on photos that will be featured on our full-color covers. Send photo submissions (at least 300 dpi resolution), as email attachments, to Andrew Rayburn at grasslands@cnga.org. Include a caption and credited photographer's name.

Submission deadlines for articles:

Fall 2016 — Aug 15, 2016 ❊ **Winter 2017** — Nov 15, 2016 ❊ **Spring 2017** — Feb 15, 2017 ❊ **Summer 2017** — May 15, 2017

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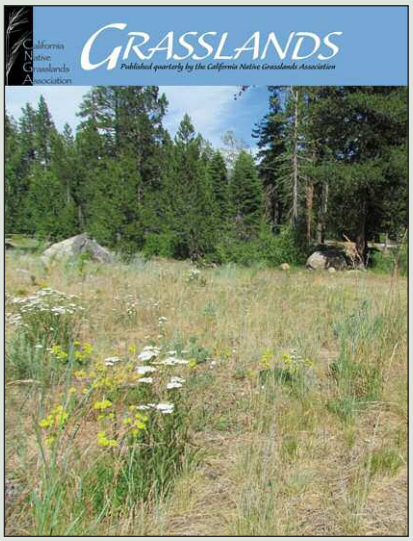

9th Annual CNGA Field Day at Hedgerow Farms: *The Rain Didn't Hold Us Back!*

by Sylvia Delfino, Product Coordinator/Sales Assistant, Hedgerow Farms, Inc.

Field Day attendees braved rainy conditions to enjoy field tours and to learn from experts about grassland restoration and weed management. *Photo: Sylvia Delfino*

The 9th annual CNGA Field Day, held on April 22 in Winters at Hedgerow Farms, was a huge success! This year's theme was "Coping with Competition: Weed Control Strategies in California Grasslands" and despite rainy conditions the seats were packed with sponsors, exhibitors, and a record 133 attendees. The generous sponsors who helped make the day possible included Delta Bluegrass Company, Hedgerow Farms, Pacific Coast Seed, and S&S Seeds. Exhibitors, which included the California Invasive Plant Council, the Putah Creek Council, the Solano County Resource Conservation District, and the Center for Land Based Learning, provided a range of additional resources to attendees. Hedgerow Farms was again an ideal venue for the event, and is well-known as a native seed production farm that has supported habitat restoration efforts across California for the past 30 years. Hedgerow Farms produces native seed for over 100 species of native grasses, wildflowers, and wetland plants in addition to native nursery transplants and native straw. Hedgerow Farms staff also consult with contractors, government agencies, nonprofits, landscape architects, and other groups to provide recommendations and suggestions for a wide variety of projects.

We were very fortunate to host Dr. Joe DiTomaso, well-known weed specialist at the University of California Davis, as the keynote speaker. He provided an overview of the weed control resources available for grassland restoration including his weed identification program, books, and online tools. He was able to share his considerable knowledge and answer questions from attendees related to grassland weed management. Dr. DiTomaso also joined one of the tours as a speaker on herbicide application in grasslands. It was exciting to have a leading weed science expert available for our entire event.

Lunchtime speakers included Dr. Valerie Eviner with the University of California Davis Department of Plant Sciences, and Rachel Long with UC Cooperative Extension. They spoke on active restoration research within California's grasslands and native-planted hedgerows. This event was a great place to connect and discuss ideas for future grassland restoration efforts.

Two tours featured presentations by specialists in the use of prescribed fire, grazing, and both chemical and mechanical weed control. We were fortunate to be able to visit the Yanci Ranch again this year to monitor the progress of the active restoration efforts that John Anderson, the founder of Hedgerow Farms, began in 2013. Dr. Jaymee Marty, with Marty Consulting, was available to answer questions regarding the planning and implementation of prescribed fire. The response of the grasslands to burning could be clearly seen in the native species present in the surrounding landscape. Sheep were actively grazing the site as our grazing specialist, Sheila Barry with UC Cooperative Extension, spoke about the benefits and restrictions of grazing as a weed management tool. On our walking tour, Dr. Billy Krimmel, owner of Restoration Landscaping Company, gave a field talk on mechanical methods of weed control at fine and broad scales. He also shared his research on *Madia elegans* adaptations and interactions with beneficial insects. His recent paper on this topic can be found in the spring 2016 issue of *Ecology*.

Thank you to all of our sponsors, exhibitors, speakers, and attendees for contributing to the success of our largest-ever Field Day. We are already looking forward to our 10th annual Field Day at Hedgerow Farms in April 2017 and the opportunity to interact with others who are passionate about California's iconic grassland ecosystems.

Topography, Nitrogen, and the Growth of *Stipa pulchra*

by Robert Fitch[1] and Erin Questad[2]

Introduction

California grasslands — biodiversity hotspots for animal and plant species — are threatened by land-use change, non-native and invasive plant species, and altered disturbance regimes (Buisson et al. 2008). *Stipa pulchra* (purple needlegrass) is thought to have been the dominant perennial native grass of the Sierra Nevada foothills and the Coastal Ranges (White 1967, Nelson and Allen 1993). However, the current native range of *S. pulchra* has been greatly reduced in recent years (Lombardo et al. 2007). The decline of *S. pulchra* due to competition with non-native, invasive plant species has been well demonstrated (Lombardo et al. 2007, Buisson et al. 2008, Seabloom 2010).

However, another factor contributing to the current decline of *S. pulchra* could be nitrogen deposition. Anthropogenic nitrogen deposition is the input of nitrogen into natural systems mainly from fertilizer and the burning of fossil fuels, in the form of NH_4^+ and NO_x^-, respectively (Fenn et al. 2003). Anthropogenic nitrogen deposition causes numerous ecological problems such as eutrophication, increased greenhouse gases, toxic effects on fresh water fish, increased competitive ability of invasive plant species, and decreased native plant species diversity (Fenn et al. 2003, Wood et al. 2006, Ochoa-Hueso et al. 2011). California, specifically the Los Angeles Basin, has some of the highest anthropogenic nitrogen deposition rates in the entire United States — as much as 30–45 kg/ha/yr (Tonnesen et al. 2007). The main form of anthropogenic nitrogen deposition in Southern California is dry deposition (Fenn et al. 2003), which occurs when NO_x solidifies in the atmosphere and settles on soil and vegetation in the form of particulates. California's dry summer months allow nitrogen to accumulate on the landscape, leading to a pulse of available nitrogen when winter rains begin (Sobota et al. 2009). Using a multivariate modeling analysis, Cox et al. (2014) concluded that undisturbed coastal scrub communities on shallow slopes in Southern California were most vulnerable to conversion to invasive grasslands under high nitrogen deposition rates due to increased invasive grass productivity, even under a normal fire regime.

Nitrogen export is significantly correlated with precipitation and runoff. After rain events, in California watersheds, 90% of the nitrogen on hillsides is removed from within the top 25 cm of the soil and is most likely deposited down slope (Wood et al. 2006, Sobota et al. 2009). Therefore, a topographical gradient is created with lowland habitats containing relatively high amounts of nitrogen and water while steeply sloped uphill habitats contain less of both. Increased nitrogen could create abiotic conditions unsuitable for native plant species, including *S. pulchra*, causing declining populations in valley bottom habitats.

We designed an experiment to analyze the differences in soil moisture and soil nitrogen created by a slope gradient and to determine where along the gradient the most suitable habitat for the persistence of *S. pulchra* could be found.

Methods

In 2015, we established 36 plots (1.5 m x 1.5 m) in the Voorhis Ecological Reserve, a 31 ha wildland reserve on California State Polytechnic University, Pomona campus. Plots were placed in three slope classes: steep 22-32°, moderate 10-16°, and low 0-10° (Fig. 1). Within each slope class, three nitrogen treatments were replicated: nitrogen addition via calcium nitrate slow-release fertilizer, nitrogen removal via carbon amendment, and ambient nitrogen. The nitrogen addition treatment doubled the yearly ambient nitrogen amount for the local area as modeled by the Community Multi-scale Air Quality (CMAQ) modeling system (Tonnesen et al. 2007). The carbon amendment was added to remove the same yearly ambient nitrogen

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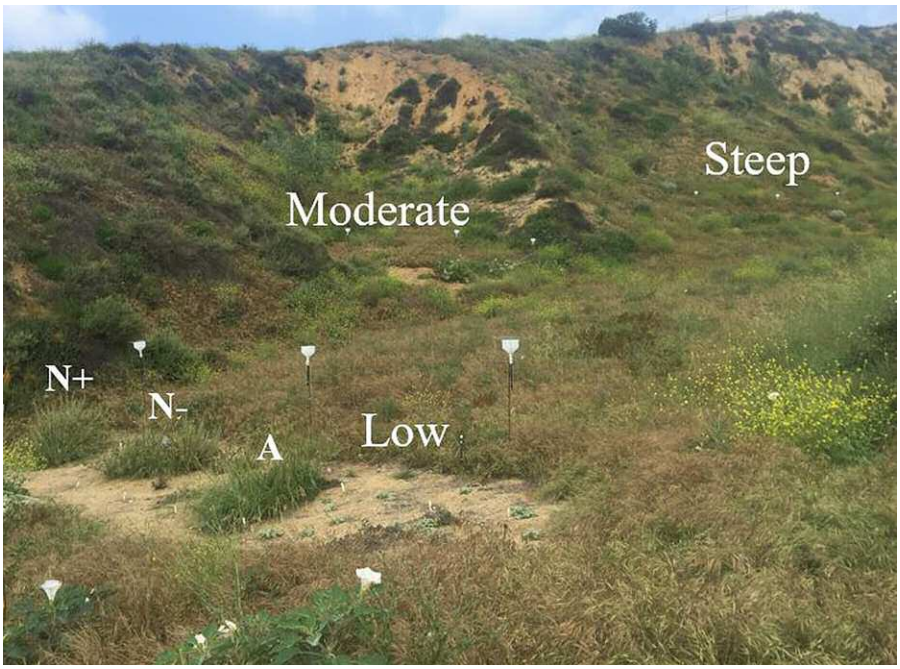

Figure 1. One block (a single canyon) of the experiment with plots in different slope classes (low, moderate, and steep) and plots with different nitrogen treatments. N+ is nitrogen addition, N- is nitrogen removal, and A is ambient nitrogen. *Photo: Robert Fitch*

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Topography, Nitrogen, and the Growth of *Stipa pulchra* *continued*

amount by using a mixture of 60% cornstarch and 40% sucrose applied four times throughout the growing season (Seabloom 2010). The varied slope of each location was used to create plots with different rates of precipitation runoff to naturally manipulate soil moisture (steep slope, fast runoff; moderate slope, medium runoff; low slope, slow/no runoff). All invasive plant species were removed from the plots, allowing native plant species to persist, and five *S. pulchra* seedlings were planted in each plot. Soil moisture was measured hourly using underground sensors from January until June. Soil ammonium and nitrate were measured using anion exchange resin bags, and samples were taken once a month in March and June. Leaf water status of *S. pulchra* was measured at predawn and at midday once a month in April, May, and June. Growth of *S. pulchra* was measured monthly January to June. Data were analyzed using a generalized linear mixed effects model with repeated measures and a split plot design. For all analyses, the fixed factors were date, nitrogen treatment, and slope treatment including all two-way interaction terms. Block and plot were both included in the model as random factors.

Preliminary Results

Our preliminary results suggest that the low slope plots, compared to steep slope plots, had more ammonium by the end of the growing season. Soil nitrate did not differ among slope classes. Low slope plots also consistently had the highest soil moisture throughout the entire growing season, whereas the steep slope plots consistently had the lowest. Growth of *S. pulchra* plants was highly variable among slope classes. The preliminary trend suggests that individuals had the lowest mean growth rates in the low slope plots compared to the moderate and steep slope plots, but this difference was not statistically significant (Fig. 2; P = 0.63). Water stress in leaves of *S. pulchra* was highest in the low and steep plots compared to the moderate slope plots (P<0.05). In this first year of the study, there was no effect of any of the nitrogen treatments on any of the response variables.

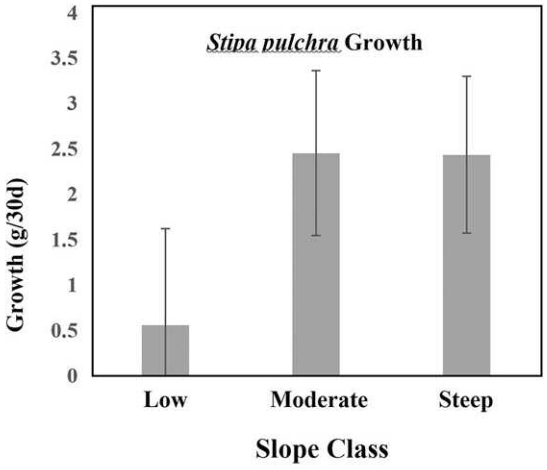

Figure 2. Monthly growth rates for *S. pulchra* plants averaged from three plants of each slope class from all four blocks. Data represent means and errors bars represent standard error. There was not a significant difference in growth among slope classes (P = 0.63).

Discussion

We expected *S. pulchra* to grow the fastest in plots with higher resource levels; i.e., the low slope plots, which contained the highest soil moisture and soil ammonium. However, individuals had low mean growth rates and exhibited increased water stress in the low slope plots, whereas individuals in moderate slope plots experienced decreased water stress and higher mean growth. We hypothesize that other abiotic conditions in low slope areas may increase plant stress in these habitats. One hypothesis is that soil moisture is not readily available to the plants due to soil composition or compaction in low slope areas (e.g., a high clay content). Another possibility could be solar radiation. Low slope areas appear to be in topographical positions that are more exposed to solar radiation, and increased solar exposure could cause increased stress to the plants.

We also found that neither nitrogen addition nor removal affected plant growth or stress. According to the

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Topography, Nitrogen, and the Growth of *Stipa pulchra* *continued*

National Drought Mitigation Center, in 2015 most of California experienced exceptional and extreme drought conditions and this could explain why there was no effect of nitrogen detected (Fuchs and Bathke 2015). If moisture is more limiting than nitrogen, then nitrogen availability will not alter plant photosynthetic activity and growth. Therefore, in this year of the study, our results suggest nitrogen fluxes did not affect *S. pulchra* plant growth or stress under drought conditions, and that water was likely the more limiting resource as found in similar studies (e.g., Evarard et al. 2010). In 2016, we are continuing to collect data while also measuring solar radiation and soil temperature. We will also be measuring soil texture and bulk density at the three slope classes.

It is interesting that *S. pulchra* appears to be adapted to growing on moderate slopes, even though resources are somewhat more limited there compared to other areas of the landscape. Future restoration efforts can consider this aspect of *S. pulchra* distribution during planning and design. Understanding why moderate slopes are seemingly more suitable habitat for *S. pulchra* is important for improving restoration and management protocols for this species.

Acknowledgements

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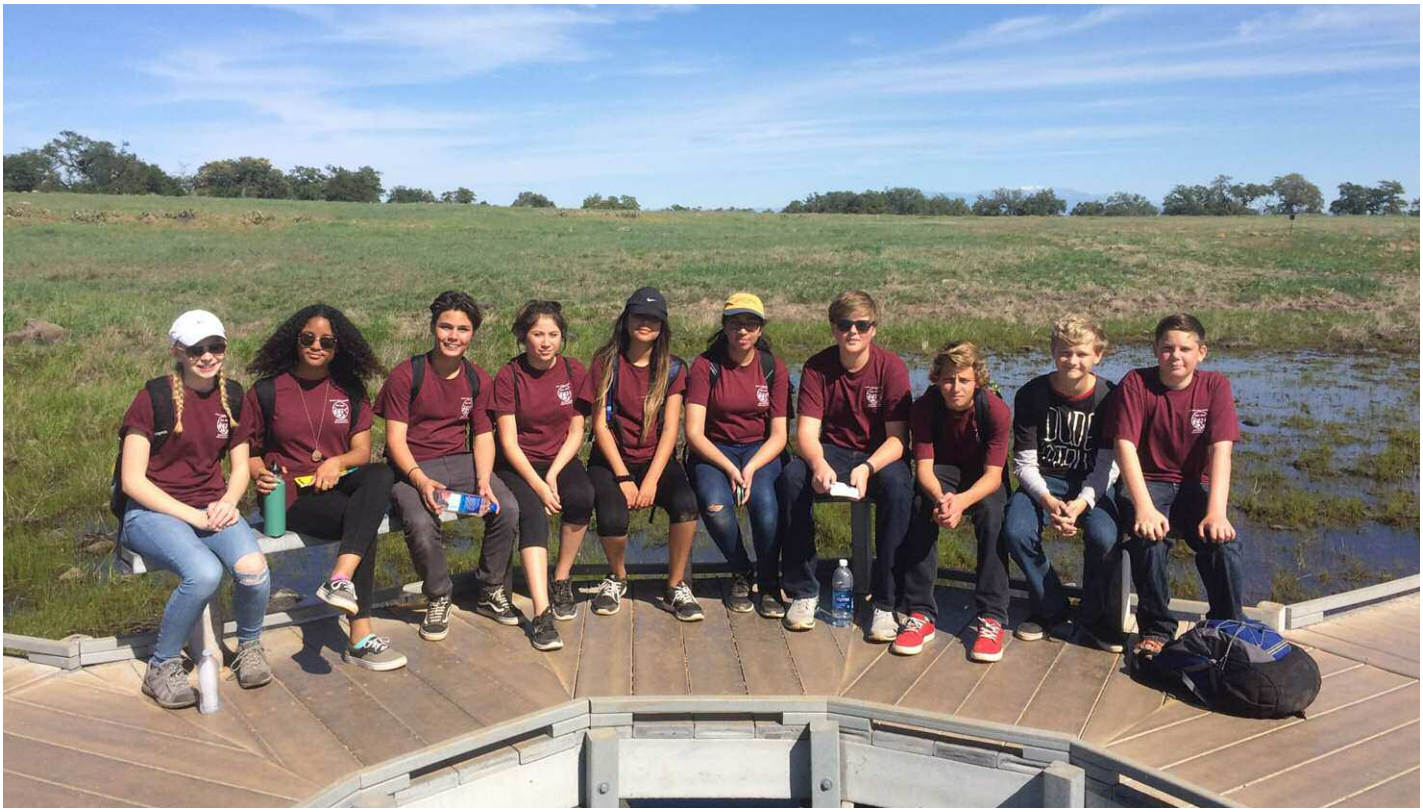

Figure 1. Students enjoy a quick break after a hike up to the Santa Rosa Plateau's vernal pools. In addition to restoration research in the grassland, students also learn about other habitat types of southern California.

Santa Rosa Plateau Habitat Studies and Restoration Program

Working to restore California grasslands through research and education

by Justin Valliere[1], Bridget Hilbig[2], and Edith Allen[1]

Native California Grasslands of the Santa Rosa Plateau

The Santa Rosa Plateau of southern California is home to some of the finest remaining examples of native perennial bunchgrass prairies. Here, grasslands contain beautiful and expansive stands of purple needlegrass (*Stipa pulchra*), as well as a diverse array of native annual and perennial flowering forbs, including chocolate lilies (*Fritillaria biflora*), lupines (*Lupinus* spp.), mariposa lilies (*Calochortus* spp.), California poppies (*Eschscholzia californica*) and shooting stars (*Dodecatheon clevelandii*). However, as with other grassland ecosystems throughout California, the Plateau has been heavily invaded by a number of nonnative plant species, largely Mediterranean annual grasses and forbs (Heady et al. 1977), such as wild oats (*Avena* spp.), brome grasses (*Bromus* spp.) and redstem filaree (*Erodium cicutarium*). These invaders pose a significant challenge for the management and conservation of native perennial grasslands, and threaten the biodiversity, function and ecosystem services of this important habitat. Thus, there is a strong need to develop effective, efficient, and sustainable methods of control and restoration.

Educational Challenges in California

In addition to issues related to natural resource conservation, California also faces statewide educational challenges that could influence training of the next generation of scientists, land managers and policy makers. California's public school systems educate over 6 million students from K-12, including a high percentage of low-income students. Unfortunately, we frequently lag behind nationally in student performance, particularly in the sciences and mathematics (Keaton 2013). Hands-on environmental education programs can increase problem-solving skills and improve student performance in math and science (Palmer 2002, Bierle and Singletary 2008, Cachelin et al. 2009). These programs can also increase students' sense of place and connection with nature, resulting in long-term educational and emotional benefits as well as increased environmental awareness (Taylor et al. 2006, Kudryavtsev et al. 2012). With some creativity, and the necessary partners and participants, it may also be

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Santa Rosa Plateau Habitat Studies *continued*

possible to align the aims of such environmental education programs with research and restoration goals.

The Habitat Studies and Restoration Program at the Santa Rosa Plateau

The Santa Rosa Plateau Habitat Studies and Restoration Program is a place-based outdoor environmental education program that seeks to address both environmental and educational challenges in California through field-based, hands-on, outdoor education programs for multiple age groups. The program is funded by the Santa Rosa Plateau Foundation and supported by a number of partners including the California Department of Fish & Wildlife, Riverside County Regional Parks, The Nature Conservancy, and researchers from the University of California, Riverside. We currently engage local elementary, middle, and high school classes from Murrieta Unified School District in long-term field experiments exploring different techniques for perennial grassland restoration, including seed bank studies, a mulching experiment, and a multi-year mowing experiment, while also educating them on the ecology and natural history of the Plateau (Fig. 1). We also align our programs with EEI (Environmental Education Initiative), NGSS (Next Generation Science Standards), and STEM (Science, Technology, Engineering and Math) curriculum components. Our mission is to empower youth to appreciate, preserve, and protect nature, while also increasing students' scientific literacy and working to restore invaded grasslands at the Plateau.

Mulching Experiment

High school students, led by teacher Scott Hanson from Murrieta Mesa High School, are exploring effects of mulching on the composition of native and nonnative grassland species. Early in the development of the program, students noticed that some natives seemed to be more abundant in areas with higher soil moisture. They then hypothesized that mulching would benefit natives by promoting soil-water retention. In 2012 and 2013, we installed matched pairs of 1 m^2 mulched and un-mulched plots in invaded *S. pulchra* grassland. Plots receive a layer of rice straw annually in the fall. Throughout the growing season, students measure cover and density of plant species within plots. Due to low replication, we have not observed any significant effects to date. However, data collected in 2015 suggested that mulch might reduce cover of both native and nonnative grasses. Thus, the

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Figure 2. 8th grade students from Shivela Middle School, Murrieta, take data on litter cover in an un-mowed control plot in the early fall.

efficacy of this treatment as a restoration method seems unlikely. While the initial hypothesis put forth by the students is logical, annual grasses may suppress co-occurring natives through the production of thatch (Meyer and Schiffman 1999), and therefore adding straw may only exacerbate this problem. A similar study conducted using sawdust amendments found no net benefit to native grasslands after two years (Corbin and D'Antonio 2004), and in fact mulch removal through grazing or mowing may be a preferable alternative.

Mowing Experiment

Our 8th grade group, led by teacher Sue Balch from Shivela Middle School, is investigating the use of mowing as a restoration method for perennial grasslands at the Plateau. The removal of nonnatives through burning, grazing, or mowing may benefit the survival of native bunchgrasses (Dyer and Rice 1997, Hatch et al. 1999). Since 2012, students have monitored grassland vegetation in mowed and un-mowed plots at our restoration site. Carole Bell, Reserve Manager, mows the plots each spring. Mowing provides two services that may benefit native bunchgrasses. First, by mowing before exotic annual grasses have set seed, we hope to reduce the number of annual grasses present in the seed bank over time. Second, the reduction in annual grass biomass reduces the amount of thatch that accumulates. The timing here is key. Middle school students measure abundance and cover of native and nonnative species in plots multiple times throughout the year while receiving training in botany and plant ecology (Figs. 2 and 3). After two years, mowing significantly reduced annual grass cover. Overall, there was a slight increase in mean percent cover of *S. pulchra*, though this was not statistically significant. This year, qualitatively, bunchgrasses in mowed areas appear more vigorous and abundant, and we are excited to analyze the data from this growing season with students this spring.

While early results from this experiment may be promising, they must be interpreted with caution, and long-term monitoring is necessary. In addition to the inherent limitation of low statistical power, this trial is only being tested at a single grassland site. The success or failure of restoration treatments, such as mowing, will likely be site-specific, and while some efforts may be successful in controlling nonnatives, previous attempts to identify management strategies for California grasslands that consistently promote natives have been unsuccessful (Corbin et al. 2004). The benefit of mowing will also be highly dependent on the initial composition of species, and this method may work best in invaded areas where bunchgrasses are still relatively abundant. Managing grasslands for a single species, in this case *S. pulchra*, may have unintended and detrimental effects on other equally important members of the plant community (Hatch et al. 1999). We are also concerned about the impact of mowing on nonnative forb species present, especially species of *Erodium*. While mowing may be successful at reducing annual grasses over time, others have observed increased cover of exotic forbs in semi-arid grasslands (Prevéy et al. 2014).

Seed Bank Study

Our 5th grade group, previously led by Laura Hanson of Murrieta USD, conducts an annual seed bank study to understand the effects of our mowing experiment on the composition of seeds in the soil. Seed bank studies can be an important tool for understanding the long-term consequences of restoration techniques (Bakker et al. 1996, Rayburn et al. in press). Each fall, students visit the Plateau to collect soil samples from mowed and un-mowed plots. Back in the classroom, soils are sown in trays, watered and monitored. As seedlings sprout, students work to identify them and calculate the proportion of native vs. invasive grasses. In 2014, undergraduate student Daniel Sanchez conducted a parallel seed bank study in greenhouses at the University of California, Riverside, with more replicate samples/trays than the 5th grade classroom experiments. After three years of mowing we found no significant differences between treatments. This could indicate mowing is unsuccessful at reducing inputs of annual grass seeds, or that seeds are able to persist for multiple years in the seed bank. It is still possible the number of annual grasses in the seed bank will decrease over time with continued mowing, and we will continue to monitor species composition both above and belowground.

Conclusions

This program shows promise on multiple levels. Our students exhibit a tremendous amount of enthusiasm and understanding of the ecological principles driving their work. For many, this program provides them with their first experience being immersed in nature. The students take pride in actively participating in research aimed at restoring the Plateau's grasslands, and their results can provide valuable insight for land management. We propose the integration of environmental education programs with research, management and restoration priorities could be a creative solution to both educational and environmental challenges in California.

Acknowledgements

We thank Susan Balch (Shivela Middle School), Carole Bell (Reserve Manager, Santa Rosa Plateau), Ginger Greaves (Executive Director, Santa Rosa Plateau Foundation), Laura Hanson (Murrieta Unified School District), Scott Hanson (Murrieta Mesa High School) and Robert Hicks (Riverside County Parks).

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Figure 3. Middle school students prepare their datasheets prior to collecting data.

Santa Rosa Plateau Habitat Studies *continued*

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Diversifying Revegetated Native Grassland Communities with Native Wildflowers *by Adrian Frediani*[1]

Increasing native plant species diversity within restored perennial grasslands presents unique opportunities and challenges for conservationists. The complexity of habitat patchiness that drives ecological processes important to many wildlife species is difficult to achieve through establishment of native perennial grasses alone. Empirical evidence has shown that adding wildflowers to planting designs can improve the ecological function of grasslands. Wildflowers provide variation in vertical habitat structure and food sources in the form of seeds and insects, which increase habitat quality and wildlife diversity (Fisher and Davis 2010). Birds that are dependent on grassland habitat select for complex vegetative structure like bare ground and variation in standing vegetation height, which are qualities significantly diminished in stands of dominated by perennial grass (Patterson and Best 1996). A report on songbird use of grasslands within the Pine Creek unit of the Sacramento River National Wildlife Refuge (Refuge) revealed a positive relationship between bird use and cover of wildflowers and bare ground (Young and DiGaudio 2011).

Within the floodplain of the middle Sacramento River, The Nature Conservancy (TNC) has successfully restored nearly 900 acres of native perennial riparian grasslands that have proven resilient to weed invasions, serve as critical habitat to birds and small mammals, and provide seasonal forage to local livestock operators. However, not a single one of those acres included native wildflowers in the original planting mix. To date, the largest hurdle to adding native wildflowers to native perennial seeding mixes has been the unavoidable reliance on agrichemicals during the plant establishment phase. When planting smaller sites with native herbaceous species, the use of manual weed control can be both effective and affordable, allowing for selectivity when removing target weed species. However, when attempting to convert hundreds of acres of ruderal lands or agricultural fields to native perennial grasslands, strategic employment of herbicides is critical to restoration success, and is often the only feasible approach given typical budgeting constraints. After herbicide application, and once a restoration site has been deemed clear of significant weed pressure from both non-native grasses and broadleaf species, native perennial grass seed is drilled into the soil following the first inch or so of winter rainfall. After the first growing season, perennial grasses are quite competitive and can be resilient against encroaching weed species. During the first year of growth, however, spraying the newly seeded native perennial grasslands with herbicides that target broadleaf weeds is vital to ensuring rates of germination that will lead to a mature stand of native perennial grasses. This step precludes incorporating native wildflowers into the original seed mixes for grassland revegetation, and has contributed to communities dominated by native perennial grasses within habitat restoration projects.

Grasslands dominated by native perennial grasses have high primary productivity and infrequent disturbance, creating small and few gaps in the canopy (Williams et al. 2007). Thus, robust native perennial grasses tend to out-compete native wildflowers, which prevents the

continued next page

[1]Sacramento River Project Director, The Nature Conservancy.

Wildflower bloom at La Barranca Unit, Sacramento River National Wildlife Refuge. *Photo: Luis Ojeda*

Diversifying Revegetated Native Grassland Communities *continued*

propagation of both native and nonnative plants (Holl and Crone 2004).

In collaboration with the Refuge, TNC developed a pilot program based on an active relay floristic (ARF) model to increase species richness within the native perennial grasslands. The ARF model dictates that a subset of native plants be introduced to a site, as suitable habitat conditions develop, in the attempt to mimic successional community dynamics. For example, seral vegetation communities can benefit from soil development initiated by pioneer species and increased cover from maturing mid and upper canopy trees and bushes. Employing the theory of the ARF model, TNC first seeds an entire restoration site with native perennial grasses, then looks for thinly vegetated patches within the larger seeded area. In our experience, the small patches where native grasses have weak establishment correlate to coarse, shallow soils, which tend to also yield weak non-native plant establishment because introduced species are not well adapted to fine-scale nutrient- and moisture-constrained edaphic (produced or influenced by soil) conditions. Coincidentally, we have observed that most native wildflowers extant on the floodplain are relegated to sandy or gravelly soils, likely due in part to the lack of competition.

Alluvial deposits from floodwaters can vary dramatically between flood events as surface water velocities cause the meandering river to redefine the channel and terrace elevations, resulting in a matrix of edaphic conditions that are the primary determinant of riparian habitat assemblages. Just as soil texture, depth to water table, and elevation in relation to the channel determine species mixes for upper and mid-canopy riparian communities, wildflowers and native perennial grasses can be similarly stratified, but on a much finer scale.

Within a 100-acre area suitable for grasses, only 5-10 acres may be appropriate for seeding native wildflowers. These areas are difficult to detect during typical soil survey work or by analyzing historical aerial imagery. However, one or two seasons after seeding native perennial grasses, these coarse, shallow soil lenses are revealed. Once mature, native perennial grasses have improved capacity to decrease vectors for new invasions through competition, and are more tolerant of site preparation activities that benefit the wildflower seedlings like mowing, grazing and spraying. Although it would be preferable from a funding cycle perspective to complete the seeding in a single effort, a two-phased implementation allows the native perennial grasses to come in first, which in turn helps to create and maintain suitable habitat for introducing robust native wildflower populations that can self-propagate.

Many of the wildflower species collected from and replanted within the floodplain, such as *Acmispon americanus* (Spanish lotus), *Grindelia camporum* (Great Valley gumweed), *Trichostema lanceolatum* (vinegarweed), *Heterotheca grandiflora* (telegraph weed), and *Calycadenia* sp. (rosin weeds), are summer blooming plants that serve as the some of the only sources of pollen and nectar during the hottest and driest phase of the growing season. Our goal moving forward is to enhance the wildflower guilds by incorporating wildflower species of varying phenologies and those that can be competitive in richer soils. *Lupinus nanus* (sky lupine) and *Calandrinia ciliata* (redmaids) are reliable spring bloomers, and both *Eschscholzia californica* (California poppy) and *Layia* sp. (tidy tips) have proven resilient and aggressive enough to survive amidst both perennial and annual grasses and weedy broadleaf species.

The two-phased method of native grassland revegetation requires a relatively intensive horticultural restoration approach. What remains to be seen, and we are hopeful, is whether or not our efforts to enhance the site and seed availability that typically constrain native wildflower species dispersal will improve native wildflower establishment within microhabitats throughout the floodplain and facilitate autogenic propagation of diverse grassland communities.

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Front cover: Native grasses and forbs soaking up the the summer sun in a Sierra Nevada meadow. *Photo: J.P. Marié*

Back cover: Marin checkermallow (*Sidalcea hickmanii* ssp. *viridis*) flourishing in a Marin County grassland. *Photo: Marin Municipal Water District*