California Native Grasslands Association

GRASSLANDS

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From the President's Keyboard

Working in grasslands inspires me to dig deeper and helps me develop a sense of place. No other California plant community I have managed or visited has shown me such fascinating detail, such variability between seasons and years, or so much local character.

More attention is being paid to the diversity of what are to us tiny things, particularly above- and below-ground soil flora and fauna. Wherever we look we find more species, more interplay between organisms, more relationships unfolding. Much like the explosion of knowledge from microscopy 200+ years ago, emerging tools such as eDNA paired with the fundamental tool of observation open a new world to us. Even with only a hand lens (or a keen eye), the more you look in a grassland, the more you see.

A sense of place is built over years, and even grasslands I know well remake themselves each season and year. The timing, variation, and interplay of water and temperature on plants produce an astonishing display of variability in native grasslands. One site I frequent has, in some years, shown seven different clover (*Trifolium*) species within a few feet of each other, while in other years, nonnative annual grasses dominate the same site — a purple needlegrass (*Stipa pulchra*) grassland upslope, and California oatgrass (*Danthonia californica*) downslope—variability too fine-scale to be captured at a landscape scale but essential to the site's character.

CNGA's mission to promote, preserve, and restore the diversity of California's native grasses and grassland ecosystems includes passing along knowledge in workshops such as our recent soils and grazing workshops, and through the writings in this journal; promoting research with our GRASS grants; and sharing the importance of local ecotypes—a plant's "sense of place" if you will—during our annual Field Day this spring. Thank you for joining us in this mission, and I hope grasslands and *Grasslands* inspire you too!

Andrea Williams, President

Meet the 2019 CNGA Board of Directors:

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New Directors-at-Large (2019–2020):

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Robert Evans (Alternate), Michele Hammond, Christopher Gardner, Jim Hanson, Richard King, Billy Krimmel, Felix Ratcliff, Patrick Reynolds, Jeffery Wilcox, Kristina Wolf (Alternate)

We extend our thanks and appreciation to retiring Board Member, Jaymee Marty.

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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In this issue

Coming this Summer:

Special Issue on Fire in Grasslands

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. 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 Kristina Wolf at grasslands@cnga.org. Include a caption and credited photographer's name.

Submission deadlines for articles:

Spring 2019: 15 Feb 2019 ❊ **Summer 2019**: 15 May 2019 ❊ **Fall 2019**: 15 Aug 2019 ❊ **Winter 2020**: 15 Nov 2019 ❊

2019 CNGA Workshops & Events

Friday, April 26th, 2019

12th Annual CNGA Field Day at Hedgerow Farms
21905 County Road 88, Winters

Think Globally, Plant Locally: Restoration and Local Adaptation

Join us to celebrate our 28th anniversary at the 12th Annual CNGA Field Day at Hedgerow Farms. Expert speakers will discuss current research and best practices regarding locally sourced plants and ecotypes. Network with others as you enjoy walking and hayride tours through the incredible grassland habitats and native plant production fields at Hedgerow farms.

Speakers: **Valerie Eviner**, Department of Plant Sciences, UC Davis; **Bill Krimmel**, Owner, Restoration Landscaping Company, Sacramento; **Elizabeth Leger**, Associate Professor, University of Nevada, Reno; **Rachael Long,** Farm Advisor, UC Division of Agriculture and Natural Resources; **Joe Silveira** Sacramento National Wildlife Refuge Complex, USF&W; **Neal Williams,** Department of Entomology, UC Davis; and **Jessica Wright**, Research Geneticist, U.S. Forest Service; and others!

Fees: **$75** members
$90 Non-members | **$45** Students

Register **online** at **www.cnga.org** or contact Diana Jeffery at **admin@cnga.org** or 530.902.6009

Get the latest workshop info at: **cnga.org**

Save the Date!

Thursday & Friday, May 9–10, 2019

Grassland Monitoring Methods and Techniques for Vegetation and Wildlife

Contra Costa Farm Bureau Hall, Concord

Registration will open soon!

A diverse pollinator habitat plot providing high quality late spring pollinator resources in the Old Willowbank neighborhood in South Davis. *Photo: Mark Lubell*

Improving Habitat Values in a South Davis Neighborhood: *The Willowbank Habitat Improvement Program (WHIP)*

by Pat Reynolds[1] and Mark Lubell[2]

Introduction

Habitat restoration projects in urban settings have the potential to substantially improve habitat values and social connections in the built environment. The Willowbank Habitat Improvement Program (WHIP) is an example of a neighborhood-based habitat program that has increased habitat values and social cohesion. It involves neighbors working together to improve habitat values in the Old Willowbank neighborhood of south Davis. The program has energized its residents and increased an already strong sense of place.

WHIP originated out of concerns over the rapid decline of non-native Chinese hackberry (*Celtis sinensis*) trees planted in the late 1940s by Old Willowbank's founders. These large trees, which line the streets of Old Willowbank, are a signature feature of this unique, semi-rural neighborhood with its characteristically large lots, low fences, and lack of street lights or sidewalks. The Chinese hackberries began to decline in the late 1990s, prompting residents to develop a plan to replace the fading urban tree canopy. By the fall of 2003, replacement trees composed primarily of native valley oak (*Quercus lobata*), were installed between the existing Chinese hackberries to give the valley oaks an establishment "head-start" so they would be able to grow rapidly when sunlight, plant-available water, and soil nutrients were released with the death and decline of the adjacent hackberries. The Chinese hackberry trees continued to slowly decline after the 2003 oak planting until drought conditions further hastened their demise, with tree losses peaking in the summer and fall of 2015 when more than a dozen large trees died, while many others lost large branches, often resulting in significant property damage and many near-miss incidents. This accelerating decline spurred the neighbors, who greatly appreciate and take pride in the well-developed urban forest of Old Willowbank, to implement a second round of tree planting in 2015, this time using native valley oaks exclusively instead of a mixture of Chinese pistachio (*Pistacia chinensis*), zelkova (*Zelkova spp.*). and valley oak, as in the first round of planting.

[1]Pat Reynolds is the General Manager of Hedgerow Farms and leads the Willowbank Habitat Improvement Program.
reynoldspatrickhenry@gmail.com [2]Mark Lubell is the Director of the Center for Environmental Policy and Behavior, a professor, and creator of the Social-Ecological Connectivity in an Urban Context class at UC Davis. **mlubell@ucdavis.edu**

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Improving Habitat Values in a South Davis Neighborhood *continued*

WHIP subsequently expanded its scope in 2016 to include the planting of native wildflower patches designed to provide habitat for beneficial insects in addition to the valley oaks. The "Central Valley Pollinator Mix" (designed by the Xerces Society, UC Davis, UC Berkeley, Natural Resources Conservation Service, and Hedgerow Farms, to provide habitat for beneficial insects along farm edges in California's Central Valley) was chosen as a straightforward way to add this important habitat component to the neighborhood. In 2017, the pollinator habitat element was expanded to include the addition of native grasses and a greater diversity of wildflower species, and more pollinator habitat sites. The program continued in fall 2018 with a greater emphasis on inclusion of "foundation plants", such as perennial native grasses and perennial native wildflowers to assist with creating a more resilient landscape. In addition, more species that flower in the summer and fall were included to provide pollinators resources for a longer period during the growing season. The beauty and habitat values provided by these pollinator patches are greatly enjoyed by the residents of Old Willowbank.

The WHIP project also highlights the crucial role of social values and relationships in supporting community-based environmental projects. The decline of the hackberries and subsequent planting of native valley oak increased awareness of ecosystem services in urban landscapes. Information about the benefits of WHIP was communicated informally among neighbors and at community events that were already an important part of the social fabric. Leadership provided by a core group of participants was instrumental in motivating the participation of neighbors and providing expertise to reduce costs.

Neighborhood Habitat Project Becomes Subject of UC Davis Class

Dr. Mark Lubell, the Director of the Center for Environmental Policy and Behavior at the University of California at Davis (UCD), recognized that WHIP provided a unique opportunity to create an inter-disciplinary learning environment for analyzing the social and ecological connections that have developed with the implementation of WHIP. Linkages and feedbacks between human and natural systems have received increasing scientific and policy attention in the last decade, including major programs at the National Science Foundation focusing on the dynamics of coupled human-natural systems. WHIP is an example of a coupled human-natural system, or a social-ecological system that has received increasing interest in recent years.

Interdisciplinary classes with real-world applications are often sought by universities but rarely come to fruition because of the complications and logistical issues associated with developing non-traditional classes. By the spring 2018 quarter, Dr. Lubell had convinced UCD administrators of the value of developing this brand-new class, and as a result "Social-ecological Connectivity in an Urban Context" become an offering at UCD in the spring 2018 quarter. The class included undergraduate students from the Department of Environmental Science and Policy, as well as the UCD University Honors Program.

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From left: Elegant madia (*Madia elegans*) and Bolander's sunflower (*Helianthus bolanderi*) provide high quality late season pollinator resources in a pollinator habitat plot in the Old Willowbank neighborhood in South Davis, California. *Photo: Pat Reynolds* | Students and faculty from the UC Davis "Social-Ecological Connectivity in an Urban Setting" class held in the spring 2018 quarter. *Photo: Mark Lubell*

Improving Habitat Values in a South Davis Neighborhood *continued*

To adequately cover an interdisciplinary class, several instructors were recruited to assist the students designing the study, implementing data collection, and reporting the findings. Dr. Mary Cadenasso, professor of Landscape and Urban Ecology, and her graduate student, Jasmin Green, were brought on to provide direction to the students regarding data collection and analysis methods relating to pollinator patch habitat and valley oak tree characteristics. Dr. Neal Williams of the Department of Entomology and Nematology, and his research associate Kimora Ward, assisted with the beneficial insect elements of the study. Dr. Patrick Huber, a project scientist with the Agricultural Sustainability Institute provided guidance on spatial analysis (geographic information system/mapping). Pat Reynolds, General Manager of Hedgerow Farms, served as the community liaison and assisted with the valley oak ecology class elements. Dr. Lubell was the primary instructor and provided guidance on the social science portion of the class.

The class collected valley oak and native herbaceous vegetation abundance data as well as data on social science and insect use from 18 different sites within this community-based environmental project. This included mapping of valley oak and pollinator patch locations and attributes, and interviewing participants about their experiences, social networks, and motivations. All background research, training, fieldwork, analysis, and write-up were completed over the 10-week duration of Spring 2018 quarter. The students, most of whom were relatively new UCD undergraduates with limited research experience, quickly got up to speed and began weekly data collection, completing a remarkable amount of work in a brief period. However, due to time constraints the report produced was considered an early draft that could potentially be refined in the future.

Results

Valley Oak Establishment

The class study confirmed that valley oaks of many sizes had established via both planting and natural recruitment in 17 of the 18 sites examined. One hundred and twenty-eight valley oaks were present on the 18 mostly 0.5-acre lots studied, for an average of approximately 7.1 valley oaks per lot. Although a formal assessment of planted trees relative to natural recruited trees was not made, an informal assessment suggests that approximately one-third of the valley oaks were planted and two-thirds were natural recruits. The average diameter-at-breast height (DBH) of the valley oaks was 12.5 inches and the average height of was 33.7 feet. The size distribution of valley oaks included 18 seedlings, 34 saplings, and 76 trees. In addition, none of the 128 valley oaks measured had significant canopy dieback suggesting that overall the valley oaks were very healthy.

Pollinator Use

Pollinator habitat use was collected by observing the number of pollinator types present via timed sampling based on the relative size of each plot. For every 20-m^2 area sampled, 2.5 minutes of sampling were performed.On average, per pollinator habitat patch, the percent of the insect community composition consisted of 36.1% honey bees (*Apis mellifera*), 28.2% native bees, 33.0% flies, and 2.7% butterfly/butterfly-like species. As plant species diversity increased, the number of honey bee, native bee, and fly visitations also increased. When compared to control plots (non-pollinator targeted landscapes), both plant diversity and pollinator diversity were higher in pollinator habitat patches.

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From left: A male valley carpenter bee (*Xylocarpa varipuncta*) foraging on lacy phacelia (*Phacelia tanacetifolia*) in a pollinator habitat plot in the Old Willowbank neighborhood in South Davis. *Photo: Pat Reynolds* | Co-author Pat Reynolds standing next to a 14-year-old valley oak (*Quercus lobata*) with a 50-60-year-old valley oak in the background. The canopies of these native trees, which are rooted approximately 50-feet apart, overlap and are part of an establishing valley oak corridor in the Old Willowbank neighborhood in South Davis, California. *Photo: Amy Hiss*

Improving Habitat Values in a South Davis Neighborhood *continued*

Pollinator Habitat Plots

There were a total of 53 native plant species across all of the combined pollinator habitat patches. Most of the individual study sites had closer to 10 native plant species, which is approximately equal to the number of native species provided to individuals for the project. The overall high level of native species diversity was attributed primarily to the extensive habitat garden in one of the author's yards. The most common native species encountered included California poppy (*Eschscholzia californica*), great valley gumplant (*Grindelia camporum*), elegant clarkia (*Clarkia unguiculata*), and lacy phacelia (*Phacelia tanacetifolia*). The most common species found in the controls included English ivy (*Hedera helix*) and an unidentified grass.

Spatial Analysis

The spatial analysis showed clustering of high insect and plant diversity and high social connectivity in specific parts of the neighborhood. In general, heat maps generated for the project show some degree of overlap between areas of high ecological diversity to areas with high social connectivity. In other words, landowners with many social relationships to other involved community members, appeared to have higher levels of ecological diversity in their yards.

A comparison of historical aerial photos from 1937 and 1952 (*Greater Willowbank News*, March 2011) with contemporary photos showed a substantial increase in valley oak canopy cover over time. The 1937 photo was taken before the Old Willowbank neighborhood was established when most of the area was a grain field. However, at that time, a few large existing valley oaks were present along the edges of the neighborhood, and these large trees have generally persisted to the present day. By 1952, some of the lots in Old Willowbank were developed and the Chinese hackberries had been planted. In the 1952 aerial, it does not appear as though many additional valley oaks beyond those visible in the 1937 photo were present, which is likely the result of the continuation of active agriculture, perhaps into the late 1940s. However, when comparing the valley oak tree canopy between 1937 and present conditions, a clear trend of an expanding valley oak canopy is evident, with all but one of the lots developed. At the home of one of the authors, a relatively large valley oak (39 in DBH) was not present when his house was constructed in 1960, indicating that valley oaks in the Old Willowbank neighborhood can grow very rapidly. This tree, as reported by the previous owners, was established via natural recruitment, as is likely the case for most or all of the moderately large trees that are present today. This natural recruitment, in combination with the planting of valley oaks starting approximately 14 years ago by the neighborhood, are contributing to the preliminary development of a semi-rural/urban valley oak woodland. New published research has shown that valley oaks in urban settings can provide important stopover foraging habitat for Neotropical migrant birds, with abundance closely correlated to valley oak tree canopy and little to no use in areas without valley oak canopy (Greco and Airola 2018). It is reasonable to assume that the

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Improving Habitat Values in a South Davis Neighborhood *continued*

documented trend of an expanding valley oak canopy through time will increase habitat values for Neotropical migrants, among others.

Social Connectivity

The success of community projects like WHIP depend on participation and cooperation from individual landowners, which is facilitated by social relationships among neighbors. The social science element of the study was designed to understand the factors motivating participation in WHIP, and to determine how the project has influenced social networks. Factors identified as potentially contributing to participation in WHIP include but are not limited to: a keen sense of place, positive environmental values, high levels of educational attainment, and strong, community-minded leadership. Residents reported varying awareness of both potential ecosystem services offered by participation in the project, and of ecosystem changes that may have occurred because of participation. Overall, residents reported that the most striking benefit of WHIP was an increased sense of community and connectedness, which further encouraged participation. Levels of participation and forms they took also varied based on aesthetic preferences of households, which was identified by numerous residents as a predominant motivator for participation in WHIP. Most participants completed at least two WHIP-related actions, such as planting trees, planting pollinator habitats, providing additional help by volunteering to plant for others or on unoccupied plots, or utilizing their equipment to help other neighbors. The average number of times that a person was identified by others increased with participation, and the number of times they connected with other people also increased with participation. The core leadership group of WHIP was most central in the network.

A Model for Future Neighborhood Habitat Projects?

The results of this study suggest that beneficial insect habitat values in the neighborhood and the number of valley oaks have increased because of the implementation of the project. Many of the neighbors reported a strengthened sense of place, that they enjoyed participating in a project that would increase habitat values, and that they appreciated working together on a common theme. Thus, the WHIP project seems to have improved both the environmental and social health of the neighborhood. WHIP shows the importance of homeowners and other land managers working together to enhance ecosystem services in urban areas and other regions where land and habitat management is fragmented among multiple individuals.

We believe projects like WHIP implemented in other locations can similarly increase habitat values and social cohesion. Candidate neighborhoods with a high chance of success at establishing their own habitat improvement programs include areas with existing neighborhood groups in place (such as homeowners' associations) with a keen sense of place and strong leadership. However, there is a need for these types of projects in disadvantaged communities as well, though additional resources from government policy or non-profits may be necessary to support implementation given the limited time and financial resources disadvantaged communities may be able to devote to ecological restoration, especially when faced with more pressing economic and social problems. Anyone interested in learning more about WHIP or starting a habitat improvement program is encouraged to contact the authors for guidance. In addition, if you are looking for a habitat project to volunteer for, please feel free to contact Pat and he will be happy to arrange for your participation in WHIP.

References

Greater Willowbank News, 2011. "1937 and 1952: Future Willowbank Road intersection with Montgomery Avenue." Annotated printout of August 20, 1937, and September 17, 1952, photographic prints from the Map Collection Room of the Shields Library, UC Davis.

Greco, S.E., and D.A. Airolia, 2018. The importance of native valley oaks (*Quercus lobata)* as stopover habitat for migratory songbirds in urban Sacramento, California, USA. *Urban Forestry & Urban Greening* 29:303–311.

Figure 1. Flooded grasslands during winter 2016–17.

VISITING CALIFORNIA GRASSLANDS: *Christopher Gardner*[1] *Photos courtesy the author.*

City of Davis South Fork Preserve

The City of Davis South Fork Preserve is the crown jewel of the City's Open Space Program and a fantastic resource for both people and wildlife. Sitting on 200 acres immediately adjacent to Putah Creek, the preserve is home to valuable, diverse habitat that includes riparian forest, riparian scrub/transition, and valley oak savanna with native grass understory. A recent property acquisition increased the overall preserve by 10 acres and its creek frontage by almost 2000 feet. The property is an important habitat node along a creek that is otherwise constrained by production agriculture.

California native grasses can be found throughout the preserve, but the oak savanna feature is really a showcase of these incredible plants. Dotted with swales and small ridges, the savanna supports a diverse set of annual and perennial natives. These grasses provide cover for numerous small mammals, and therefore are excellent hunting grounds for raptors, egrets, herons, coyotes, and even the occasional bobcat.

The preserve was also designed to mitigate flooding on Putah Creek, and provided that function during the very wet winter of 2016–17. The grassland feature was built to accommodate flooding and act as a relief valve for the creek, providing an area for water to spread out and slow down. This was fascinating to watch (Figure 1), as was the slow recovery of the grasses after the water receded. The long inundation period transitioned some areas of the grasslands away from bunch grasses to thick stands of creeping wildrye (*Elymus triticoides*). In the spring, these stands are the favored nesting areas for western meadowlarks.

South Fork Preserve is located just south of Davis on County Road 104 at Putah Creek. It is open to the public seven days a week, with trailheads on both sides of the county road. A small kiosk and sitting area are available, with interpretive panels that tell about the site history and resources. The city is also excited to implement a new trail construction project that will dramatically increase access for users. Funded by a grant from California State Parks, the project will take visitors close to the creek, allow for ADA access to some areas and increase the educational opportunities through updated signage. Look for new trails to open in fall 2019. For more information on the COD Open Space Program, visit **https://cityofdavis.org/city-hall/community-development-and-sustainability/open-space-program.**

[1]Christopher Gardner is City of Davis Open Space Land Manager and serves on the CNGA Board.

Inset: Vole damage on valley oak shows grassland wildlife activity.

Evaluating Prescribed Fire Effect on Medusa Head and Other Invasive Plants in Coastal Prairie at Point Pinole

by James Bartolome[1], Atalie Brown[2], Peter Hopkinson[3], Michele Hammond[4], Luke Macaulay[5], and Felix Ratcliff[6]

Introduction

Medusa head (*Elymus caput-medusae*) is an annual grass of the wheat grass tribe (Triticeae), native to Mediterranean Europe and Africa. In the United States, it was first recorded in southwest Oregon in 1887, and subsequently spread into California (Kyser et al. 2014). In recent decades, medusa head has spread rapidly across the state. In 1950, the species was known from only six northwestern counties in California (Pollack and Kan 1996), and in 2018, a Calflora search shows occurrence records in 50 of California's 58 counties—with notable absences in the southeastern Sierra Nevada and southern California (Calflora 2018).

Medusa head is listed as a "high" priority weed by the California Invasive Plant Council with severe impacts on plant and animal communities (Cal-IPC 2018). A primary driver of these impacts is that medusa head has high levels of silica deposited in its tissues. This is akin to having thousands of microscopic pieces of glass incorporated into its leaves and stems. The silica — combined with long sharp awns in its florets — makes mature medusa head plants unpalatable to livestock and other herbivores; and also makes the plants resist decomposition (Kyser et al. 2014). This can result in dense stands of dead medusa head thatch that persist on the landscape, which can negatively impact wildlife habitat, native plant germination, and forage production (Nafus and Davies 2014).

There are several ways to control medusa head: mowing, tilling, hand-pulling, prescribed grazing, spraying, and burning are all effective measures. Burning in late spring (when mature seeds are still retained in seed heads) has the double benefit of killing seeds and removing thatch (Kyser et al. 2014), however there are no published studies showing the effectiveness of burning in California's coastal prairies. Coastal prairies support a diversity of native grasses, so it is also important to document the effects of prescribed burning on the native plant community.

In June 2016, the East Bay Regional Park District (EBRPD) conducted a prescribed burn to control medusa head in grassland areas of Point Pinole Regional Shoreline in Richmond, California. Meadows in this park have a rich native grassland component with healthy stands of purple needlegrass (*Stipa pulchra*), California oatgrass (*Danthonia californica*), big squirreltail grass (*Elymus multisetus*), and saltgrass (*Distichlis spicata*). There were two burn areas: the North Burn Patch targeted a small area (approximately 0.09 acres) infested with medusa head; and a larger burn patch in the 37-acre Central Meadow. The Central Meadow did not have medusa head, but had other invasive weeds like velvet grass (*Holcus lanatus*) and purple false brome (*Brachypodium distachyon*). While burning is a well-documented practice for controlling medusa head, effects of burning on these other species are not well documented in California.

Methods

The UC Berkeley Range Ecology Lab measured vegetation in the prescribed burn treatment areas before the burn in 2016 and again in 2017 to evaluate the effects of prescribed burning on vegetation in Point Pinole. Pre-burn monitoring was conducted in late May 2016, with nine transects in the Central Meadow and two transects in the northern burn patch (Figure 1). Post-burn monitoring on all of the 11 transects was conducted in late June 2017. Species of interest included the target invasive grasses, other invasive species such as fennel (*Foeniculum vulgare*), native perennial grasses, and common native forbs (Table 1).

Sampling Transects

Each monitoring plot consisted of one 20-meter transect. Each transect was sampled using a nested frequency sampling approach (see Smith et al. 1987). Nested quadrats were laid out every meter along the transect, and presence of target species inside each quadrat was recorded. Quadrat sizes were: 1-m^2, 1/4 m^2, and 1/16 m^2. In addition to these quadrats, the first plant hit at the "point" along the tape was recorded (regardless of whether it was a target species or not). Comparisons between frequency samples are most powerful when the frequency is between 20 and 80% (Despain et al. 1991). The nested quadrat approach allowed us to simultaneously sample plants with different abundances and still get samples close to the 20–80% range.

Burn Area

The prescribed burn was conducted by the EBRPD on June 9, 2016. In the smaller North Burn Patch, the burn covered the entire area inside the firebreaks. Two sampling transects were located in this area. One transect burned completely, while the first four meters of the other transect did not burn. This unburned portion of the transect gave us the opportunity to make comparisons to areas that did not receive the burn treatment.

The Central Meadow had two internal firebreaks dividing the meadow into three burn areas. Of these three areas, the most northern two areas

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[1]James Bartolome is a professor of Rangeland Ecology at UC Berkeley. [2]Atalie Brown recently graduated from the College of Natural Resources at UC Berkeley, and was an undergraduate research assistant in the Rangeland Ecology Lab. [3]Peter Hopkinson is an Academic Coordinator at UC Berkeley and has conducted rangeland ecology research in the East Bay Parks since 2002. [4]Michele Hammond is the Botanist for the East Bay Regional Park District and worked closely with the Range Ecology Lab to conduct this research. [5]Luke Macaulay is a Cooperative Extension Specialist in Rangeland Planning at UC Berkeley. [6]Felix Ratcliff is a Postdoctoral Scholar studying rangeland ecology at UC Berkeley.

Prescribed Fire Effect on Medusa Head *continued*

burned almost entirely in the prescribed burn. The third area did not completely burn. One of the transects in this area did not burn at all, providing an unburned comparison to the other transects (Figure 1).

The number of burned versus unburned quadrats was obtained by overlaying the transects on Google Earth imagery showing the extent of the burn and determining the length of each transect in burned and unburned areas (Figure 1). A total of 155 quadrats on eight transects in the Central Meadow burned, and 36 quadrats on two transects burned in the North Burn Patch. For all analyses that compare pre- and post-burn data, only portions of the transects that burned (i.e., burned area) were used. All values reported in the results and in tables are also from quadrats in the burned area unless specified otherwise.

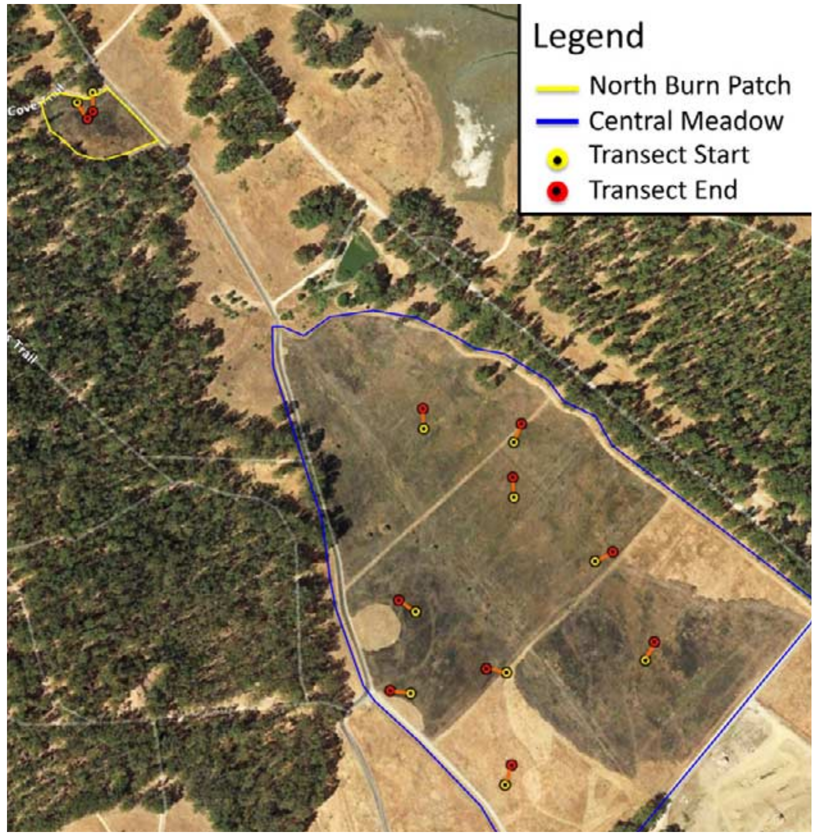

Figure 1. Project area and location of sampling transects. The two transects in the northern portion of the map are in the North Burn Patch. All other transects are in the Central Meadow. Darker areas show the boundaries of the prescribed burn. *Imagery from Google Earth*

Burn Conditions

We observed the following burn conditions during the prescribed burn:

- ❊ **Environmental conditions** — Wind speed was <10 km/hr; air temperature was 20°C; relative humidity was <50%; herbaceous dry fuels were approximately 5000kg/ha; fuel moisture was approximately 30%.
- ❊ **Fire intensity** — Mean flame height was 0.5m (min 0.25m, max 1.5m); rate of spread was 0.5m/20 seconds.
- ❊ **Fire severity** — Moderate severity. Black ash present. 95% of fuel was consumed, leaving a few unburned spots at soil surface. Fuel consumption was continuous except for a few scattered summer annual plants and shrubs.

Statistical methods

No control plots were used to make statistical comparisons between species composition before and after the burn. Instead comparisons were made solely between pre- and post-burn vegetation from transects that burned in the prescribed fire. These comparisons can detect change over time but some caution in the interpretation of the results is warranted because the analysis will not distinguish between changes due to burning and changes due to other inter-annual factors (e.g., rainfall).

Pre- and post-burn results were compared using a generalized linear model with a binomial distribution and a "logit" link function. Because the predictor variable of interest is categorical (pre-burn/post-burn) this is essentially an ANOVA that has a binomial (species presence/absence) response variable. For each species, we tested for differences in frequency between transects and between years. P-values for independent variables were generated by comparing nested models using the anova() function in R. This method uses a Chi-squared test to evaluate the probability of observing the reduction in residual deviance (similar to residual sum of squares) resulting from the addition of each independent variable. Data from the North Burn Patch and Central Meadow were analyzed separately since these areas had different frequency percent of target species, and other important ecological differences.

Germination Trial

After the prescribed burn, medusa head seeds were collected from plants in burned areas of the North Burn Patch, and also from unburned areas adjacent to the burn area. Inflorescences from twelve unburned and ten burned plants were collected. From these samples, 100 unburned and 100 burned seeds were selected for a germination trial. Seeds were placed in petri dishes with a moist paper towel and allowed to germinate indoors by a window. Five seeds were placed in each dish, for a total of 20 petri dishes with unburned seeds and 20 dishes with burned seeds.

Burned seeds no longer had awns attached at the time of the germination trial. Awns, known to inhibit medusa head seed germination (Nelson and Wilson 1969), were removed from half of the unburnt seeds, and left on the other half. Seeds were checked daily for signs of germination, and number of germinated seeds per petri dish was recorded.

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Table 1. Regression results for species in the Central Meadow and North Burn Patch. Analysis was performed on burned quadrats only. Plot p-values show whether there were significant differences in percent frequency between transects in a burn patch. Year p-values show significant differences between years (pre/post burn). Bold values indicate significant differences ($p < 0.05$). Explained and residual deviance columns show how much of the residual deviance is explained by each variable in the regression models. Frequency percent is from 1-m^2 quadrats except for purple false brome (*Brachypodium distachyon*) which is taken from the point hit.

Species	Residual Deviance (Plot)	Explained Deviance (Plot)	P-value (Plot)	Residual Deviance (Year)	Explained Deviance (Year)	P-value (Year)	Percent Frequency 2016	Percent Frequency 2017	% Change Between Years
Central Meadow									
Brachypodium distachyon	231.1	52.9	**<0.01**	231.1	18.0	**<0.01**	27.1	10.3	**-62%**
*Danthonia californica**	139.6	16.0	**0.0250**	139.6	3.3	0.0687	9.68	4.52	-53%
*Elymus multisetus**	52.0	78.2	**<0.01**	52.0	2.6	0.1077	7.10	3.87	-45%
*Eschscholzia californica**	62.1	16.0	**<0.01**	62.1	2.3	0.1273	7.74	4.52	-42%
Foeniculum vulgare	140.7	85.2	**<0.01**	140.7	1.1	0.2928	10.32	13.55	31%
Holcus lanatus	48.7	189.6	**<0.01**	48.7	0.7	0.3979	12.26	13.55	11%
Rubus armeniacus	53.4	83.0	**<0.01**	53.4	1.6	0.2020	7.10	4.52	-36%
*Sisyrinchium bellum**	105.7	144.9	**<0.01**	105.7	5.4	**0.0198**	17.42	10.97	**-37%**
*Stipa pulchra**	195.7	225.2	**<0.01**	195.7	0.3	0.5963	59.35	57.42	-3%
North Burn Patch									
*Danthonia californica**	39.4	**10.3**	**0.0014**	39.4	0.6	0.4272	13.89	8.33	-40%
*Distichlis spicata**	35.3	**29.7**	**0.0000**	35.3	8.5	**0.0035**	8.33	30.56	**267%**
Elymus caput-medusae	43.3	1.3	0.2589	43.3	5.7	**0.0168**	19.44	2.78	**-86%**
*Stipa pulchra**	34.2	0.04	0.8329	34.2	2.1	0.1509	11.11	2.78	-75%

*California native species

Prescribed Fire Effect on Medusa Head *continued*

Results

The 1-m^2 quadrat provided frequency estimates closest to the 20–80% range for all species. All species except purple needlegrass in the Central Meadow (in both years) and saltgrass in the North Burn Patch (in 2017) had less than 20% frequency even in the 1-m^2 quadrat (Table 1). Therefore, frequency from the 1-m^2 quadrat was used for analysis (except for purple false brome — see below). Three target species: coyote bush (*Baccharis pilularis*), spring vetch (*Vicia sativa*), and hairy vetch (*Vicia villosa*) had very low frequency in the 1-m^2 quadrat and were dropped from the analysis because the statistical models did not perform well.

Central Meadow

In the Central Meadow, significant ($p < 0.05$) differences in frequency percent before and after the burn were found for one target species: the native forb western blue-eyed-grass (*Sisyrinchium bellum*). Western blue-eyed grass decreased from 17.4% before the burn to 11% after the burn. One other species, California oatgrass, had marginally significant differences between years ($p = 0.06$), decreasing from 9.7% in 2016 to 4.5% in 2017 (Table 1).

The non-native annual grass purple false brome was not originally considered a target species; however, in 2016 it had the highest percent cover of any species in the burned area of the Central Meadow (27.1%). This high rate of occurrence in the point sample allowed statistical comparisons to be made from that sample. On transects that burned in the Central Meadow, purple false brome cover was significantly ($p < 0.01$) lower after the burn. It decreased from 27.1% cover in 2016 to 10.3% in 2017. It was also present on one additional transect in the Central Meadow, which did not burn in the prescribed fire (Figure 1). This transect, had 25% cover of purple false brome in 2016 and only 15% cover in 2017, so it is possible that some of the decline in percent cover can be attributed to factors other than the fire.

Velvet grass was only detected on one transect in 2016. It was present in 19 out of the 20 quadrats on this transect. In 2017, it was still predominantly found on this transect (18 of 20 quadrats), but was also found in one quadrat on three other transects in the Central Meadow. There were no statistically significant differences in frequency percent before and after the burn. Nevertheless, the appearance of this invasive species on three new transects in 2017 suggests that it might be spreading in the Central Meadow.

North Burn Patch

In the North Burn Patch, we found significant ($p < 0.05$) differences in frequency percent before and after the burn for two species in the 1-m^2 quadrat: saltgrass and medusa head. Saltgrass, a native perennial grass, was more frequent after the burn, increasing from 8.3% in 2016

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to 30.6% in 2017. Medusa head decreased from 19.4% before the burn to 2.8% after the burn, and was only present in one quadrat in the burned area in the year following the burn. This quadrat was on the edge of the burn area so it is possible that a portion of the quadrat did not burn which is why medusa head was present. The evidence suggests that the burn was highly effective at suppressing medusa head where the area burned completely.

Medusa Head Germination Trial

The germination trial demonstrated the effectiveness of burning to kill medusa head seed and verified that the burn was timed correctly to control medusa head. At the end of the week, 97 of the 100 unburned seeds had germinated, while none of the burned seeds had germinated. There were no differences between germination of unburned seeds with and without awns. In conjunction with the monitoring data, these results suggest that the burn was highly effective at reducing presence of viable medusa head seeds and subsequent growth of medusa head plants.

Conclusions

Overall, the prescribed burn was highly effective at controlling medusa head, and generally did not result in collateral damage to native grasses (with the possible exception of California oatgrass). From our germination trial, it is clear that the mechanism for medusa head control was mortality of medusa head seeds that were still attached to seed heads. Since medusa head frequency in the North Burn Patch was reduced from 19.4% to 2.8% after the burn, it appears that if any seeds were already in the soil seed bank at the time of the fire, they were similarly destroyed by the fire.

The burn also may have had the added benefit of controlling purple false brome. This species was significantly less abundant after the burn; however, since it also decreased on our unburned transect in the Central Meadow, it is difficult to say whether the reductions in the burn area were due to fire or some other effect (e.g., weather). Indeed, an earlier study by the Range Ecology Lab showed no clear effect of burning on purple false brome cover at Point Pinole (Bartolome et al. 2012). More research on control methods for this species is warranted, as there is evidence that it is increasing in grasslands in California's coast ranges (Bartolome et al. unpublished data).

Velvet grass did not show significant differences before and after the burn. However, it appeared on three new transects after the burn—suggesting the burn may have encouraged this weedy species to spread. We did not specifically test whether the extent of velvet grass increased as a result of the prescribed burn, but past research has shown that velvet grass is often present and abundant after burns, and readily re-sprouts in burned areas from burned plants, the soil seed bank, or seed rain from adjacent populations (Gucker 2008).

Most native grass species were less frequent after the burn compared to before the burn; however, none of these differences were statistically significant. The only significant difference in native grass frequency was saltgrass, which increased from 8 to 31% after the burn. Previous studies have shown mixed effects of burning on saltgrass frequency and cover (Hauser 2006). The perennial forb, western blue-eyed-grass, was significantly less frequent after the burn.

Prescribed burning is an important tool for managing medusa head in California coastal prairie sites. Despite its effectiveness at controlling medusa head, our study found that it is not a silver bullet for solving all invasive grass problems. Furthermore, if prescribed burning is used in coastal prairies, effects on native grasses and forbs should be closely monitored. While saltgrass increased after the burn, other native species were generally less abundant in the year following the prescribed burn.

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Coming this Summer: **Special Issue on Fire in Grasslands**

Photos of wildfire (Mendocino Complex) and prescribed burns courtesy Emily Allen, Jeffrey Wilcox, and Felix Ratcliff

The Science, Management, Economics, and On-the-Ground Logistics of Managing Fire and Fire Impacts in Grasslands

Cyanonbacterial biocrusts growing on clay soils on San Clemente Island.

SPECIES SPOTLIGHT: *by Brianne Palmer*[1] *Photos courtesy of the author*

It's Alive! The Hidden Microbial Communities Encrusting Grasslands

California grasslands are harbors of biodiversity — filled with blossoming wildflowers, charismatic animals, and imperceptible microorganisms. Walk through a grassland and you might see a vast landscape of knee-high grasses swaying in the wind. Look a little closer and you might see pops of color, fragrant forbs scattered across the soil. Look a little closer still and you might see something strange — a splash of green slime, a thin black blanket on the ground, multi-colored lichens carpeting the gaps between the plants, diverse communities of biocrusts covertly changing the surrounding soil properties and altering communities. These elusive and cryptic biocrust communities are found on every continent and cover about 12% of the earth's terrestrial surfaces (Elbert et al. 2012). Biocrust communities are diverse and variable across the landscape, composed of bacteria, lichens, fungi, and moss, with each community providing a unique set of ecosystem functions. As grassland enthusiasts, we should pay more attention these ecosystem engineers.

[1]Brianne Palmer is a second year PhD student in the joint ecology program with San Diego State and University of California, Davis. The majority of her work is in the grasslands on San Clemente Island, studying the recovery and functional shifts of biocrusts after fire.

In grasslands, biocrusts grow in the interspaces between plants where there is enough exposed soil surface to establish. They are connected to the above- (plants, animals, UV radiation, etc.) and below-ground ecosystems (soil microbes, micro-invertebrates, soil aggregation, etc.). Unlike mycorrhizae, biocrusts form symbioses within the crust itself, rather than with surrounding plants, benefitting the plant community indirectly by shifting nutrient cycles, increasing water content, and improving soil stabilization. Their connection to the soil and the flora, has spurred much research on the interactions of biocrusts with above-ground organisms, primarily vascular plants, and below-ground processes like nutrient cycling and biogeochemical processes.

Biocrusts are vitally important in the soil carbon cycle and fix more carbon than they respire, thus increasing carbon sequestration (Castillo-Monoroy et al. 2011, Li et al. 2012). Additionally, due to their global presence, researchers determined biocrust communities account for 3–4% of global nitrogen fixation rates, acting as a natural fertilizer for the surrounding plants (Belnap 2002). Although it is known that biocrusts increase available nitrogen in ecosystems, in grasslands, we are uncertain how biocrust nitrogen fluxes differentially

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Hidden Microbial Communities *continued*

affect native and nonnative plant species. These shifts in nutrient availability influence the surrounding plant communities, and consequently, ecosystem processes on a landscape scale (Langhans et al. 2009, Garcia et al. 2015, Ghiloufi et al. 2016). In some cases, biocrusts enhance plant growth (Garcia et al. 2015) and promote plant uptake of essential micronutrients (Harper and Belnap 2001). However, biocrusts may also inhibit plant growth by creating a barrier on the soil surface, thus creating heterogeneity across the landscape (Song et al. 2017). These interactions are not fully understood, though some hypothesize that biocrusts may deter plant invasion and maintain community stability (Deines et al. 2007). For example, in the California sage scrub, biocrusts that had been experimentally trampled increased the abundance of exotic annual plants, indicating disturbance of biocrusts may detract from native plant communities because the seedlings that are able to germinate and establish benefit from increased available nutrients (Langhans et al. 2009, Hernandez and Sandquist 2011). The relationship between biocrusts and vascular plants are complex and we don't fully understand how biocrusts are shaping our grassland plant communities.

Given the global importance of these microbial communities, there has been a push for more research and concern regarding the status of biocrusts in conservation and restoration practices as both a community to be restored and a tool for restoration (Bowker 2007, Bowker et al. 2011). Establishing a strong biological soil crust may improve the biogeochemical cycling and relieve stress from the native plant species. In areas where biocrusts have been restored, there is improved soil moisture, reduced erosion, improved soil fertility (Li et al. 2010, Zhao et al. 2016, Gomez et al. 2012). The natural recovery time for biocrusts is slow and inconsistent, ranging from two to hundreds of years depending on the disturbance and the habitat (Belnap and Lange 2003). For example, after a fire in South Africa, it took 8 months for biocrust soil communities to reach a pre-disturbance community composition (Dojani et al. 2011), but in the Great Basin, it took up to fifteen years to achieve the same result (Root et al. 2017). There is currently no published information on biocrust recovery time in California grasslands. However, there have been successful attempts to rehabilitate biocrust communities in the lab and the field. A small field sample was grown in a nursery to re-establish 6000-m^2 of dryland soil in the southwestern U.S. at 1–5% of the historic concentration (Ayuso et al. 2017). Additionally, the restoration of biocrusts improved soil fertility and the micro-environment of the top soil in Chinese semi-arid ecosystems (Wu et al. 2013). The restoration of biocrusts in California grasslands may markedly improve the ecosystem function and enhance grassland productivity.

Inset: Seedling growing out of a moss-cyanobacterial biocrust on San Clemente Island.

So, what can we do to help?

Becoming a crust-odian, a caretaker of crusts, is as simple as being aware of their existence and minimizing damage to them when found. Often, biocrusts are nestled between bunch grasses, or smashed below our shoes, and we aren't aware of the community we are impacting.

Due to the high disturbance in our grasslands from human recreation, grazing, and fire, it is likely that the biocrust communities are remnants of what they once were. However, since biocrusts were largely absent from the literature until the late 20th century, we lack the perspective to restore biocrusts to their historical state (Bowker 2007). Given their influence on ecosystem functioning and the growing support of biocrust research around the world, biocrusts should be considered in restoration plans and could potentially be used as a restoration tool to assist the recovery of degraded ecosystems. We can do our part in conserving them by simply acknowledging their existence, watching where we step, and sharing the importance of these organisms with others.

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From left: Moss biocrust growing in the interspaces of the grasses on clay soil on San Clemente Island. | Lichen biocrusts growing on clay soil in a large gap between the grasses on San Clemente Island.

Hidden Microbial Communities *continued*

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From left: From September 8, 2018, along fenceline; cattle were being moved to right site of photo. A large patch of perennial California oatgrass (*Danthonia californica*) with green leaves is present on the right side. | From September 10, 2018, showing the same fenceline and the severe grazing of *Danthonia* on the right side of fence. Other plant species adjacent to the green perennials were also severely grazed. | Looking upslope at the same severely grazed *Danthonia* patch. Note the boundaries of the patch are clearly visible above and below the photo centerline. New *Danthonia* patches are appearing elsewhere in this general area. Patches such as this one continue to grow in size.

A VIEW FROM THE FIELD:

Invasive Annual Weeds — Problems or Symptoms? Part 3

by Richard King[1] Photos courtesy the author

This is the third part of a series focusing on California's invasive annual weeds, exploring if they are a "problem" or just a symptom of other factors. The first article described the four major ecosystem processes (community dynamics, energy flow, water cycle, and nutrient cycles) occurring in grasslands and how the disruption of any of them can simplify the living (biotic) community (King 2018a). The creation of bare soil is a major factor that can simplify a community and adversely affect the ecosystem processes. The second article in the series described how excessive rest ('over-rest') can also simplify the community and promote invasive plant infestations (King 2018b). The focus of this current article is 'overgrazing' and how it can simplify a community and allow invasive annual plants to thrive.

What is Grazing?

The term 'grazing' is variously used in conversations and scientific literature, and it can be confusing when used to describe what large animals do on the land. It is often difficult to know whether the word is being used to refer to consumption of actively growing plants, dead or dormant plant defoliation, litter consumption, utilization of soil cover, trampling, or the degree of manure and urine left on the land. Unfortunately, these impacts may get lumped together as 'grazing,' and may even mean different things in the very same conversation or article.

To clarify, "*grazing*" simply means "*the consumption of plants or plant parts by herbivores*." While large herbivores graze and impact the land in various other ways, grazing only refers to plant consumption. Trampling plants, litter, and soil surfaces is not grazing, nor is deposition of dung and urine.

When herbivores graze living plant tissue, grazing can stress plants by removing photosynthetic tissue and reducing the amount of sunlight energy being converted to chemical energy (i.e., sugar) needed for plant growth, maintenance, and reproduction. In general, as the severity of grazing increases on a growing plant, the more severe this stress can become, and the longer it will take for the plant to regrow its 'solar panels' and fully recover vigor.

Herbivores can also graze plants and plant parts that are no longer living, whether standing dead material or litter lying on the soil surface. Grazing dead plant material on herbaceous perennial plants will not impair the plant's health and vigor. In fact, perennial grass vigor may improve when excessive dead material is removed and more sunlight can reach the buds and growing tissues. Part 2 in this series emphasized how excessive standing or thick horizontal litter can greatly impair new growth when the new rainy season begins if seeds, seedlings, or growing points are excessively shaded, and how some invasive annuals thrive in such environments (King 2018b).

Great herds of herbivores grazed plants on California grasslands for millennia, and many of our native herbaceous plants are well-adapted to being grazed. All species in the grassland communities co-evolved, including plants, animals, invertebrates, and microorganisms. Large herbivores grazed to obtain energy, protein, micronutrients, and vitamins; they spread fertility via the deposition of urine, feces, saliva, and their own decaying remains after they died; they spread and planted seed; they laid down litter, covering and compacting soil; and

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[1]Richard King is a CNGA board member who worked for 36 years with USDA-Natural Resources Conservation Service as a rangeland specialist. Richard earned a Bachelor's degree in Wildlife Management and a Master's degree in Biology. He enjoys seeing native perennial grasses and forbs 'invading' the non-native annual grasslands on his ranch in Petaluma.

From left: Looking vertically at severely grazed *Danthonia* plants; only 'stumps' remain. Surprisingly good soil cover is still present to protect the soil and ecosystem processes. Adequate recovery time must now be provided for regrowth to restore plant vigor and energy flow from sunlight. | From September 5, 2018; ungrazed litter, mostly annuals, masks *Danthonia* present. Photo shows one plant where some dead litter has been brushed aside. Other *Danthonia* plants are in this photo too. *Danthonia* was still green in September but *only* in the fields on my property that were not former cropland. The exception is where I planted oaks on depleted cropland soils. Deep tree roots help improve soil moisture availability, and *Danthonia* plants still remained green if close to a tree. | From September 15, 2018; blue wildrye (*Elymus glaucus*) with emerging new leaves. Deep-rooted cool season perennials often begin to grow in September even if the rainy season has not yet started. During the fall & winter seasons when growth is slow, cool season perennials and other plants are easily overgrazed when animals stay too long or come back to the area too soon.

Invasive Annual Weeds — Problems or Symptoms? *continued*

they roamed unimpeded by fencing while watching out for predators (Hobbs 1996, Savory and Butterfield 2016). With proper planning and management, herds of livestock can be managed to provide these benefits where needed, even doing so without significantly grazing the plants present (King 2018b).

What Happens When A Plant Is Grazed?

Four things happen immediately after a growing herbaceous plant is grazed by a large herbivore. First, the more severely the plant's green foliage is grazed (i.e., the more of the plant's living tissues that are removed), the more severe the imbalance created between energy demand of the root mass and chemical energy obtained via photosynthesis. Grass root growth immediately ceases if more than half of the photosynthetic portion of the plant is removed (Crider 1955). That is why it takes longer for more severely grazed plants to fully recover than less severely grazed plants. Second, not only can roots stop growing, a large number of fine roots may die within a days of defoliation (Oswalt et al. 1959). This helps reduce the energy demand when there is a sudden shortage of energy from photosynthesis.

Third, growing plants provide energy and many other compounds to soil microbes through root exudates. Plants have complex symbiotic relationships with the microbial community. Evidence shows defoliation can stimulate the plant roots of some species to exude a pulse of energy and other compounds, and this stimulates more microbial community growth (Hamilton and Frank 2001). In return, the soil microbial community provides nutrients and compounds that help the plant regrow. As an example of this symbiotic relationship, mycorrhizal fungi rapidly transport plant-derived energy (sugar) and other compounds from within plant root cells into the plant's soil microbial community. This remarkable fungal hyphae network also transports nutrients, water, and other compounds from the microbial community back to the plant root. An estimated 10–40% of the carbon photosynthesized by plants into simple sugars is exuded into the soil environment (Newman 1985). Further, as plant diversity and functional diversity increases, the diversity of soil microbes present increases (Eisenhauer 2016). The composition and populations of millions of living organisms and the thousands of microbial species found in a single gram of soil have extremely complex interactions that we still know little about. These interrelationships affect the plant's growth and dynamics of the entire community.

Fourth, energy is mobilized and transported from the stem base or root crown (or rhizomes/stolons if present) to build new leaves and stems after grazing. The plant has a limited amount of carbohydrate energy that can be mobilized from this 'bank account' for regrowth. Herbivores moving across a landscape grazing plants will often take just one bite from a plant and move to the next. However, a single bite can be a severe grazing on smaller plants. While regrowth of severely grazed plants won't be a problem as long as growing conditions remain favorable, there is only so much carbohydrate energy in that 'bank account.' Grazing that same plant again can further deplete the account unless the plant deposits more energy in its bank, and that requires adequate regrowth.

What Is Overgrazing?

From the plant's point of view, overgrazing occurs when fresh regrowth is grazed before the plant has *fully recovered* from the first grazing. When new regrowth is grazed before the root and leaf tissue has been fully restored and before another deposit of energy into the 'bank account' occurs, the plant remains stressed much longer. The plant is far less productive as the growing season continues, and less regrowth can occur. The root mass further shrinks because inadequate energy is available to support the living tissues. Plants that are not

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From left: Drought year on January 23, 2014, on my property in Petaluma. The far distant field was fertilized with dairy manure, then tilled and planted to a silage crop. Only a hint of green is present on the dark-colored soils. Foreground shows growth on annuals when good soil cover is present to conserve soil moisture. Note the dramatically better growth on perennial bunchgrasses in center of photo. The four ecosystem processes function more effectively with perennial species. | All four ecosystem processes in field on left are clearly functioning better when overgrazing is minimized year after year. Field on right typically has continuous or season-long grazing. When this photo was taken April 11, 2017, neither field had been grazed since December. Note the dramatic difference in productivity. Not easily seen in this photo is much greater diversity of perennial grasses, perennial forbs, and the darker green colors are present on the left side of the fence. Marin County. | From December 18, 2012, Marin County; plants suffer from overgrazing on the upper right side of the fence with conventional season-long grazing management. Many species on the left side suffer from over-rest where livestock are excluded. Both overgrazing and over-rest can simplify the community and invite invasive annuals (and invasive perennials).

Invasive Annual Weeds — Problems or Symptoms? *continued*

overgrazed are able to continue growing, taking advantage of available sunlight, moisture, and nutrients. Overgrazing can even kill the plant if the 'bank account' is overdrawn. However, some species are surprisingly tolerant of repeated grazing by livestock during the growing season. These plants respond to repeated grazing by growing very close to the soil surface to avoid being significantly defoliated. Plant productivity, seed production, and the root mass may suffer despite the tolerance of repeated grazing if the plant's bank account is overdrawn by overgrazing.

If a perennial plant is severely grazed late in the spring growing season, it may not have enough time to fully recover and still produce seed prior to summer dormancy. This plant cannot fully recover until it resumes growth the *following* growing season, when it can create new 'solar panels,' replace lost root mass, and rebuild its carbohydrate 'bank account.' Grazing a weakened perennial plant early in the new growing season is overgrazing from the plant's point of view because it has not yet fully recovered from the severe grazing in late spring. The additional plant stress will further suppress growth, even with plentiful rains. If entering the new growing season with an inadequate reservoir of carbohydrates to mobilize and transport to buds and new shoots, the perennial plant is at a great disadvantage relative to more vigorous neighboring plants or seedlings, including invasive annuals. Thus, overgrazing perennial plants can occur either during the growing season, or it can occur in the subsequent growing season. Keep in mind that the perennial plant must also use any stored energy remaining in its 'bank account' throughout the dormant season to keep all living cells and tissues alive. When the rainy season returns, it will need stored energy to build the first new leaves.

It is worth emphasizing that perennial grasslands are far more effective than annual grasslands at sequestering soil carbon, at least in part because of more effective root distribution in the soil profile and the amount of carbon they invest in root production, root turnover, and root exudates in both time and space. And since about 50% of soil organic matter is carbon, overgrazing a significant proportion of plants in the community, whether perennials or annuals, can transform the grassland soil from a carbon 'sink' to a carbon 'source'. This is because the microbial decomposition of soil organic matter produces gaseous carbon dioxide that exceeds replacement of soil organic carbon when deeper soil carbon is not maintained or improving (Jones and Donnelly 2004).

Annuals too can be overgrazed when regrowth is grazed prior to full recovery of plant vigor. Yet many grassland annual species still produce adequate seed year after year even when suffering from overgrazing and reduced productivity. Unlike perennials that maintain living crowns and root systems during the dormant season, annuals and their roots simply die at the end of their growing season, and do not require an energy reserve. Whether your grassland is annual, perennial, or a mix of both, overgrazing plants provides an opportunity for invasive, weedy annuals to establish and spread more aggressively. Overgrazed plants or populations have poor productivity and are unable to access or efficiently use resources, or they may die. As plant vigor, species diversity, or functional diversity decline from overgrazing, the biotic community becomes less complex, inviting invasive annuals to thrive wherever their seed is present.

Note that overgrazing as defined here does not refer to the *severity* of grazing on a plant. Severe grazing and overgrazing are thus two

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From left: June 14, 2015, Santa Barbara Co.; severe grazing of litter on the left side of the fence has exposed soil to increased evaporation, extreme soil temperature changes, and erosion. This is overutilization of soil cover. Ecosystem processes are impaired. The photo by itself does not tell us whether overgrazing of plants is also occurring on either side of fence. Overgrazing only occurs when plants are growing and regrowth is grazed too soon. | April 19, 2017; lower half of photo shows light to moderate grazing of plants. Herd has just been moved into the field in the upper half of photo. Plants grazed less severely will recover more quickly, be more productive, and reproduce more effectively. They will also tend to minimize or prevent invasive annuals from invading. | April 22, 2017; cattle on right side of fence were moved to left side after this photo taken. Plants on right side vary from ungrazed to moderately grazed. Adequate recovery is planned for the most severely grazed plant in every field. Moving livestock from place to place quickly does not entirely eliminate severe grazing of small or especially desirable plants. One bite can be a severe grazing.

Invasive Annual Weeds — Problems or Symptoms? *continued*

different things. Overgrazing does not occur unless regrowth is grazed before the plant has fully recovered. Even in pastures or fields where plant grazing appears to be uniformly severe, you will almost always find plants that have not been grazed, either because they are very small or they are not very palatable. Nor does overgrazing describe how much plant cover is being removed by the herbivores. Moreover, *over-utilization* describes the excessive loss of soil cover due to grazing, which may be accompanied by severe grazing, but it does not tell us whether plants are being overgrazed from the plant's point of view. Plants whose leaves and stems are no longer living cannot be overgrazed. However, the dead material can be over-utilized if adequate soil cover is not maintained. As described in Part 1 of this series, inadequate soil cover impairs all four of the ecosystem processes (King 2018a). It is those simplified communities that particularly benefit invasive annuals. Not only does increasing bare soil simplify the living community, overgrazing plants does too. The higher the proportion of plants being overgrazed in an area, the more simplified the living community will become.

Plant Recovery

While grassland plants being grazed by large herbivores is a natural phenomenon, not enough attention is given to *plant recovery*. A plant that is severely grazed during the growing season initially will not recover quickly because there is a tremendous imbalance between the energy demands of the root tissues and the greatly reduced energy available from photosynthesis. It takes time to shunt remaining mobile carbohydrates to the growth buds and/or shoots and rebuild photosynthetic tissues. As green leaves and stems grow and increase photosynthesis, the rate of regrowth and recovery increases. When the plant approaches full recovery, this previously severely grazed plant now looks very similar to one that was not grazed or was only lightly grazed (Crider 1955).

Abiotic conditions also strongly control how quickly a stressed plant will recover. When temperature, soil moisture, or soil aeration are not ideal for the plant's regrowth, the rate of recovery will be slower. Spatial heterogeneity of slope, aspect, temperature, soil type, and soil moisture are factors that influence localized growing conditions. Plants on one site may recover rapidly, while those on a nearby site may recover more slowly because of inherent differences in abiotic environments. Grassland managers need to consider all of the variables influencing plant recovery to minimize overgrazing of plants, improve ecosystem processes, and obtain the ecosystem services desired.

Minimizing Overgrazing of Plants

André Voisin discovered that overgrazing not only reduces plant vigor and productivity, but also that altering animal numbers (i.e., stocking rates) in the herd only affected the *proportion* of plants being overgrazed (Voisin 1988). That is, Voisin's data showed that *overgrazing is a function of inadequate recovery time between grazing events, not the number of animals in the herd.* Even relatively few animals on lightly stocked grasslands will overgraze plants if animals can repeatedly access fresh, highly digestible regrowth before those plants have fully recovered from the first grazing. Small populations of desirable species are easily suppressed or even eliminated if plants are palatable and readily overgrazed.

Whether a manager has animals grazing year-round, seasonally, or uses some form of rotational grazing, all of these grazing strategies will result in overgrazed plants unless the most severely grazed plants in the area are provided adequate recovery time to restore vigor and root mass and reproduce. Great herds of wild herbivores that once roamed the world's grasslands unrestricted by fencing have now been replaced with relatively small herds of livestock widely scattered over fenced land. This has resulted in animals being allowed to overgraze

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From left: January 23, 2017; showing annuals on left side of fence suffering from both close grazing and trampling on wet soils. As shown in photo, animals can still graze under the single electric wire fence. Perennial grass root strength provides great resistance to the trampling damage on plants and soil health in comparison to annual grasses. | September 6, 2013; native perennial lupine patch is still green after a long, dry summer. This patch is slowly spreading on my property. Palatable perennials that are still green during summer are easily overgrazed without planned recovery periods. Native perennial forbs removed by overgrazing, tillage, herbicides, over-rest, or a combination of factors will simplify the community, inviting invasive annuals. | Green litter from trampling on April 28, 2018. Plants were lightly to moderately grazed during rapid spring growth. Most trampled plants continue growing after trampling when adequate soil moisture remains present. By watching ground nesting bird behavior during the nesting season, I can easily avoid allowing this much trampling where birds are nesting.

Invasive Annual Weeds — Problems or Symptoms? *continued*

many of the plants during the growing season by being kept too long in a field, or by being moved from a field and then returned to that same area before all of the plants in the field have fully recovered. If all individuals of a plant population are grazed, adequate recovery time should be provided for the *most* severely grazed plant to ensure that the *entire population* will receive adequately recovery (Crider 1955).

Overgrazed plants abound in our grasslands with livestock (or wildlife) when animals stay too long or return too soon. Because animal numbers (i.e., stocking rates) only affect the proportion of plants being overgrazed, conventional livestock grazing methods produce a mix of grazed plants, overgrazed plants, un-grazed plants, and over-rested plants in our grasslands — even when animal numbers are deemed 'appropriate' given the productivity of the site. Annual plants, including invasive annual weeds, can thrive even when overgrazing and over-resting of plants are occurring in the same field (King 2018b). Managers who plan and monitor adequate recovery periods can improve the vigor, productivity, reproduction, and populations of previously overgrazed plants. And managers who keep soil covered (King 2018a) and avoid over-resting the land (King 2018b), can further accelerate improvement of grassland community dynamics, energy flow, water cycle, and nutrient cycling as the entire living community changes.

On my own property, I raise livestock and have planned and implemented plant recovery periods since 1991. More recovery time is provided when growing conditions allow only slow regrowth; less recovery time is provided when plants are recovering quickly during the spring flush of rapid new growth. I first estimate the plant recovery time that grazed plants will need to fully recover. Then I determine how many grazing fields are available and the amount of forage available in each field. Finally, I calculate how long the herd will need to stay in each of the different fields so that all plants in all the fields will receive adequate recovery time after being grazed (Butterfield et al. 2006, Savory and Butterfield 2016).

Plant species diversity, functional diversity, and distribution are increasing over time, including some of the native perennial grasses and forbs such as *Danthonia californica*, *Lupinus* spp., *Stipa pulchra*, *Elymus triticoides*, *Perideridia* spp., and non-native perennial species such as *Dactylis glomerata*, *Phalaris arundinacea*, *Convolvulus arvensis*, *Trifolium fragiferum*, *Lotus corniculatus*, and *Rumex* spp. The diversity of mushrooms I observe has also increased over time. Not a single tree or shrub was present in 1991, so I planted acorns and willow cuttings in various places. Coast live oaks (*Quercus agrifolia*) are now producing abundant acorns and are spreading on the property with the help of scrub jays. The diversity and number of nesting birds are similarly increasing over time along with other wildlife species. Lab data show soil organic matter is increasing, and I have observed improved aggregate stability on the adobe clay and loamy uplands that were former cropland during my family's previous generations. Minimizing the overgrazing of plants, keeping good soil cover year round (King 2018a), and minimizing over-rest and excessive litter accumulation over plants and on soil surfaces (King 2018b) is transforming the ecosystem processes.

In summary, overgrazing plants reduces their vigor, root mass, and reproduction, and can kill them. The greater the proportion of overgrazed plants in the community, the greater the negative impact will be on the four ecosystem processes (King 2018a). Community dynamics are directly affected when plants are overgrazed. As plant productivity, root mass, root turnover, and root exudates decline, plant species richness, and/or plant functional diversity may be reduced along with other species dependent upon them. Productivity in the community can decline, and energy flow from sunlight that is

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supporting the entire living community can be reduced when the amount or duration of photosynthesis declines. The effectiveness of the water and nutrient cycles can also decline as community dynamics and energy flow are negatively impacted. When overgrazing impairs the four ecosystem processes and the community is simplified, invasive annuals can become dominant, especially species that herbivores find less palatable than other forage species present.

This series has now identified three factors that can either alone or in combination provide invasive annuals the simplified community they need to thrive: bare soil, over-rest, and overgrazing. Over-fertilization is another factor that can similarly invite invasive annuals and will be addressed in the fourth part of this series.

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GETTING TO KNOW GRASSLAND RESEARCHERS **Kendra Moseley**

What is your study system?

In my current position, I work for the Soil and Plant Science Division of the NRCS as a Regional Ecologist in charge of Ecological Sites (ESs) and Ecological Site Descriptions (ESDs) for our Regional Offices located in Palmer, AK, Portland, OR, and Davis, CA. This means my study system is essentially every ecosystem within the states of Alaska, Washington, Idaho, Oregon, Nevada, Hawaii, the Pacific Basin, and of course, California. I feel fortunate that I get to work in all types of ecosystems from the tropical rainforests to the frozen tundra — I find it fun and challenging to cover such an extensive area of diverse ecosystems. My educational background is in rangelands, and riparian and wetland ecosystems, but I feel most at home in native grasslands. Most of my undergraduate and master's research/degrees focused on native plant restoration and land management on Idaho rangelands. I also spent a year as research faculty at UN-Reno assisting in the research projects attempting to reduce invasive species competition to favor native plant establishment using pure cane sugar to tie up soil nutrients. Although my current position requires me to expand my study system beyond my beloved native rangelands, I always try to find ways to ensure I am working on some projects every year in grasslands.

What are your primary research goals?

I have a passion for all types of ecosystems and learning, through both research and applied science, how they function and interact. My primary goal is to understand and synthesize the complexity of existing information and research related to soil-water-plant interactions, and how these interactions and relationships affect their response to disturbances both natural and man-made. I am fascinated by the various ways that plants adapt to their specific environments and how they respond to internal and external pressures and I believe understanding what is at the core of these adaptations and responses will assist in making better land management decisions. I believe that ESs and their ESDs are a unique tool that provides an easily accessible, organized framework to house, synthesize, and explain the complex variety of scientific information that is available to us regarding these ecosystems and that is why I have dedicated most of my professional career towards the development of these products.

Who is your audience?

My primary audience would be fellow ecologists, rangeland and grassland managers, agency colleagues, and researchers who want to apply land management strategies in a more ecologically based approach. I truly believe that land management is most successful when you understand these foundational abiotic-biotic relationships and can communicate land management decision-making through that lens.

Who has inspired you, including your mentors?

I have been fortunate in my career to work with several amazing professionals that have inspired me in many ways. None more so than my rangeland professor and graduate school advisor, Jim Kingery. I started college as a Wildlife major, but we were required to take some introductory courses in two other natural resources disciplines within the College of Natural Resources, so I decided to take the Intro to Rangelands course and he was my professor. I have never met, before or since, someone that can talk all day about rangelands and native plants with so much enthusiasm and dedication as Jim can. His passion for native plants, his passion for rangelands, and his love of all living things, his work, and students, had an incredible impact on me. After just that one semester, I changed majors and I've never looked back. He helped me discover a passion I didn't even know I had for both native plants and restoration ecology. It's been almost 20 years and I will be forever grateful to him for sharing that devotion and enthusiasm with me and so many others, because he opened my eyes and mind to a world that brings me great joy and purpose and it makes me want to do the same for others.

How has or will your research align with the mission of CNGA "to promote, preserve, and restore the diversity of California's native grasses and grassland ecosystems through education, advocacy, research, and stewardship"?

California's grassland ecosystems are some of the most prominent, productive, and intensely pressured ecosystems in the state and I believe strongly that in order to promote, preserve and restore these grasslands, as well as all native ecosystems, one must have a solid understanding of the foundational ecological interactions that make each ecosystem unique. I believe that my work promotes the mission of CNGA through the vehicle of ESs and ESDs because they are intended to provide an easy-to-understand synthesis of the current scientific understanding of the soil-site relationships of each ecological site. They communicate how each native ecosystem functions and why diversity in functional groups are important, as well as how different native species provide key functions to ecological processes and dynamics and how these systems may respond to disturbance or management. They provide a common basis for decision-making that will ideally lead to improved coordination and

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Kendra Moseley *continued*

more consistent, transparent, and useful application of science and land management.

Why do you love grasslands?

I love grasslands for a lot of reasons. I love the diversity of species you find within them, from dainty forbs to giant, imposing grasses. They provide me with a feeling of serenity and peace when standing on a hillslope with the wind blowing gently, creating an upland wave of grasses and forbs in a multitude of colors and structures. I also love the diversity of wildlife and livestock that depend on the various species you find in grasslands. Most of all, the super "nerdy" side of me loves all the various ways grassland species have adapted to these environments in order to survive and provide ecological function for other resources like clean water, clean air, and productive and healthy soils.

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Front cover: June 7, 2011. Ring Mountain Open Space Preserve, Marin County. *Photo by Jim Coleman*

Back cover: *Stipa pulchra* in a production field. *Photo by Emily Allen, Hedgerow Farms*