California
Native
Grasslands
Association

GRASSLANDS

Published quarterly by the California Native Grasslands Association

Vol. 31, No. 1 Winter 2021

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.

P.O. Box 485, Davis, CA 95617
cnga.org
530.902.6009 **admin@cnga.org**

CNGA Board of Directors

Officers

Jean-Phillippe "JP" Marié, President
Kendra Moseley, Vice President
Michele Hammond, Secretary
Jodie Sheffield, Treasurer

At-Large Directors

Chad Aakre
Emily Allen
Sarah Gaffney
Michelle Halbur
Haven Kiers
Richard King
Billy Krimmel
Justin Luong
Leticia Morris
Patrick Reynolds

Administrative Director
Diana Jeffery

***Grasslands* Editor**
Whitney Brim-DeForest

For membership and other organization information, contact CNGA Administrator via admin@cnga.org.

Grasslands is published quarterly by CNGA.
©2021 CNGA ISSN No. 1540-6857
Layout design: Julie St. John

From the President's Keyboard

Dear CNGA Members, Friends, and Supporters,

This year we have a lot to look forward to:

- CNGA is celebrating its 30th anniversary.
- With the passing of John Anderson last fall, we will have a Grasslands issue dedicated to him.
- We are already planning for our annual Field Day at Hedgerow Farms. It will be virtual again this year.
- We are working diligently on creating more virtual workshops.
- The COVID-19 vaccine is on its way!

Thank you, members, for your continuous support that we now need more than ever. We couldn't exist without you. Whether you are an individual member, a corporate member, or a sponsor, thank you from all of us at CNGA. We will keep working hard to advocate for and preserve native grassland ecosystems and support research and education.

JP Marié

Meet the 2021 CNGA Board of Directors

CNGA welcomes our 2021 Directors and Officers.

Officers 2021:
President: JP Marié
Vice-President: Kendra Moseley
Secretary: Michele Hammond
Treasurer: Jodie Sheffield

New and Re-elected Directors-at-Large (2021-2022):
Emily Allen, Michelle Halbur, and Justin Luong

Continuing Directors-at-Large for another term (2020-2021):
Chad Aakre, Sarah Gaffney, Haven Kiers, Richard King, Billy Krimmel, Leticia Morris, Patrick Reynolds

CNGA salutes contributions of retiring Board members

As we welcome a new Board for 2021, we would like to extend our appreciation to our out-going Board members, Dina Robertson and Kristina Wolf who have served for the good of the organization.

Thank you, all!

Save the Date:

14th Annual Field Day at Hedgerow Farms, Friday, June 11, 2021 — *Details to come soon!*

Please join us for our second online Field Day with presentations and tours featuring the beautiful scenery at Hedgerow Farms Inc. in Winters and, thanks to our virtual format, in other areas of the state!

- **Expert speakers** discuss current research and best practices.
- **Virtual Walking** tours.
- **Virtual Driving** tours of Hedgerow Farms' native grass and wildflower production fields and habitat areas.

Get the latest workshop info at:
cnga.org
Register online
or contact Diana Jeffery at **admin@cnga.org** or 530.902.6009

Ongoing:

Landscaping with Nature: Engaging with Evolutionary Ecology in Your Native Garden

Recorded talks & supporting materials available online

This highly acclaimed workshop from August 2020, is suitable for landscape professionals and anyone interested in maximizing habitat values in their landscaping. Expert instructors present cutting-edge methods of design, installation, management, and maintenance including site evaluation, plant selection, evolutionary interactions, habitat features, and planting best practices to create a wildlife-friendly landscape.

Register online and watch at your own pace: https://cnga.org/Events/

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 the Editor at **grasslands@cnga.org**. Include a caption and credited photographer's name.

Submission deadlines for articles:

Spring 2021: 15 Feb 2021 ❊ **Summer 2021**: 15 May 2021 ❊ **Fall 2021**: 15 Aug 2021 ❊ **Winter 2022** 15 Nov 2021

In this issue

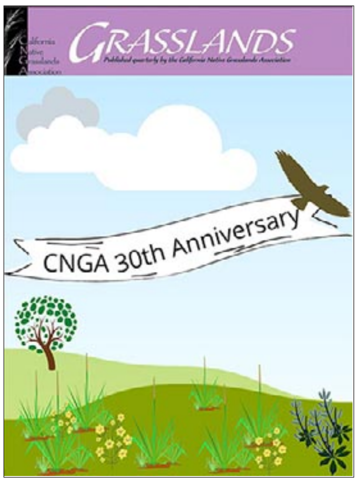
Announcing Two Special *Grasslands* Issues in 2021

John Anderson Memorial *Grasslands* Issue — Spring 2021

Remembering John Anderson

CNGA is honoring John Anderson, one of our founding members who passed last year, by dedicating the Spring 2021 issue of *Grasslands* to him. We are asking folks who knew and loved him to consider contributing a short (150 words or less) quote or statement to be included in this issue. **The submission deadline for the Spring issue is February 15, 2021.**

If you have photos of John, please consider sending them in for possible publication in the issue. If you are sending a photo, please reference our photo submission requirements below or on our website at **https://www.cnga.org/Grasslands-guidelines**.



CNGA's 30th Anniversary *Grasslands* Issue — Summer 2021

CNGA's 30th Anniversary: Tell Us What You Know!

2021 is CNGA's 30th Anniversary and for the Summer 2021 issue of *Grasslands*, we are focusing on **CNGA: Our Past, Present, and Future**. To do this, we would like feedback from our membership. In 150 words or less, please answer one of the following questions:

- **What have you learned about grasses or grasslands in the past 30 years?**
- **What is the biggest takeaway you have learned through CNGA?**
- **Where do you think CNGA and research in grasslands is headed or what should CNGA and research focus on next?**

Please send your responses to us at **grasslands@cnga.org**. **Submission deadline for the Summer issue is May 15, 2021.** If possible, please send a picture of yourself we may publish with your response. If you are sending a photo, please reference our photo submission requirements below or on our website at **https://www.cnga.org/Grasslands-guidelines**.

Photo Submission Requirements:

All photos must be original—please only submit photographs that you took and for which you own the copyright. Please include caption information, including photographer, date, place, and photo description; we will always credit you as the photographer. Photos should be at least 300 dpi and sent as email attachments (not embedded in an email or a document). By submitting a photo, you give CNGA permission to print or display your submitted photo on our website and social media.

wra
ENVIRONMENTAL CONSULTANTS
2169-G E. Francisco Blvd.
San Rafael, CA 94901
(415) 454-8868 tel
(415) 454-0129 fax
info@wra-ca.com
www.wra-ca.com
Rare Plant & Wildlife Species Studies
Environmental Impact Assessment
Wetland Delineation & Assessment
Permits & Regulation
Mitigation & Restoration
Landscape Architecture
Resource Mapping & Analysis
Expert Consultation & Witness Service

Westervelt™
ECOLOGICAL SERVICES

Restoring the habitats that sustain us
Ecological Concerns Incorporated
Central Coast Wilds
CentralCoastWilds.com
EcologicalConcerns.com
831-459-0656
Ecological Landscape Architecture - Habitat Restoration - California Native Plants
Erosion & Sediment Control - Botanical Consulting - Rainwater Harvesting
Site Planning - Mitigation Maintenance - Permitting

STUDENT RESEARCH
CNGA Grassland Research Awards for Student Scholarship Winner, 2019 & 2020
JUSTIN LUONG

Selecting Coastal California Prairie Species for Climate-Smart Grassland Restoration

by Justin C. Luong[1] *and Michael E. Loik*[1]

Abstract

California is predicted to experience warmer temperatures and more frequent droughts in future years, which will increase local and regional climatic water deficit. Understanding how commonly used restoration species will respond to drought may help with approaches to mediate the negative impacts of changing climates on restoration. Associated plant functional traits can increase understanding of how a group of species responds to variable environmental conditions, and aid with selecting broader mixes of drought-tolerant plants for restoration. For this study, we established ambient rainfall, first-year watered and drought treatments (60% rainfall reduction), in a coastal grassland in Santa Cruz, CA. Drought was created using rain-out shelters that simulate a 1-in-100-year drought. We planted 12 California native coastal prairie species to determine which species and life-forms had greater survivorship. We monitored the survival of these plantings annually from 2016 to 2019 and assessed the plant community composition in 2018 and 2019. We found that rhizomatous forbs were ideal candidates for planting coastal prairie restoration sites, especially in terms of drought. Bunchgrasses were also successful in the drought treatment, but to a lesser degree. N-fixers and non-rhizomatous forbs had minimal survivorship by the fourth year. Our findings demonstrate variable survival of planted seedlings in terms of time and drought. Additionally, from our study, the most favorable candidates for restoring California coastal prairie in a drier climate were common yarrow (*Achillea millefolium*), prairie mallow (*Sidalcea malviflora*), and purple needle grass (*Stipa pulchra*).

Background

Interannual rainfall variability, and other site conditions in the planting year, can play an important role in determining the outcomes of grassland restoration (Groves et al. 2020). California is warming and experiencing longer dry periods, portending a greater frequency of drought in future years (Cayan et al. 2007). This will increase local and regional climatic water deficit and increase plant drought stress (Loik et al. 2004), which may negatively impact restoration outcomes. To improve the success rate of restoration efforts, it may prove useful to develop restoration strategies that account for environmental variation, particularly as the climate continues to change.

Plants have adapted by developing functional traits that allow them to survive abiotic and biotic stressors in the environment. Traits can help with selecting species for restoration that are more suitable for establishment in variable and changing climates (Pérez-Harguindeguy et al. 2016). Functional traits can include morphological features of leaves, shoots, or roots; physiological processes such as photosynthetic rates; or life-form descriptions like "bunchgrass" or "shrub." Life-form classification is a framework, readily accessible through the Jepson eFlora, for describing species that tend to have similar overall morphologies (Pérez-Harguindeguy et al. 2016).

The coastal prairie, a special type of grassland that receives coastal fog during the summer, is one of the most diverse grassland types in North America (Ford and Hayes 2007). Restoration of these habitats is often mandated by the California Coastal Commission through the California Coastal Act of 1976, so it is important to understand the factors that limit the success of these restoration efforts. Some species might be better adapted than others for drier conditions in coastal prairies and focusing on those species could help meet strict compliance goals.

In this study, we manipulated ambient rainfall to assess the impacts of extreme drought and first-year watering on 12 native California coastal prairie species. We planted experimental plots with seedlings in 2016 and monitored them for four years to compare survival, to determine whether certain prairie species or life-forms had higher survivorship. We hypothesized that drought would positively benefit planted native species, first-year watering would increase survival of seedlings, and non-rhizomatous forbs would have the lowest survivorship of the life-forms we studied.

Methods

Study Site

Younger Lagoon Reserve is a mesic coastal terrace prairie in Santa Cruz, CA, that has experienced various anthropogenic disturbances (grazing, tillage, row-crop agriculture) since the 1800s. It was protected as part of the UC Natural Reserve System in 1986. The reserve currently has ongoing restoration efforts that include non-native species control and plug plantings with local genotypes of native species. The area is dominated by non-native species such as Italian thistle (*Carduus pycnocephalus*, forb), brome fescue (*Festuca bromoides*, annual grass), Italian rye grass (*Festuca perennis*, annual grass), rip-gut brome (*Bromus diandrus*, annual grass), cutleaf geranium (*Geranium dissectum*, forb), and wild radish (*Raphanus sativus*, forb), with some remnant native species like coyote scrub (*Baccharis pilularis*, shrub) and coastal tarweed (*Madia sativa*, forb). Restoration efforts

continued next page

[1]Environmental Studies Department, University of California, Santa Cruz, 1156 High Street, Santa Cruz CA, 95064

adjacent to the study site have successfully increased the abundance of native prairie species such as California brome (*Bromus carinatus*, bunchgrass), blue wild rye (*Elymus glaucus,* bunchgrass), creeping wild rye (*Elymus triticoides*, rhizomatous grass), purple needle grass (*Stipa pulchra*, bunchgrass), common yarrow (*Achillea millefolium*, rhizomatous forb), pacific aster (*Symphyotrichum chilense*, rhizomatous forb), and many coastal shrub species.

Younger Lagoon Reserve has a Mediterranean climate with summer coastal fog. During the four years of the experiment, rainfall in the hydrologic year (October–September) was around the long-term average (1981–2010) of 796 mm (Western Regional Climate Center: **https://wrcc.dri.edu**). Years 1, 2, and 4 had rainfall within 20% of the long-term average; specifically, years 1 (643 mm) and 4 (695 mm) had slightly below, and year 2 (954 mm) had slightly above average rainfall. Year 3 (521 mm) was a dry year and had 35% less rainfall than the long-term average.

Drought Manipulation

Drought shelters were constructed in summer 2015 following the standardized protocol from the International Drought Experiment (Knapp et al., 2015; **drought-net.colostate.edu**). Drought (rain-out) shelters exclude 60% of incoming rainfall, thereby simulating a 1-in-100-year drought based on historic Santa Cruz precipitation. Shelters were built with metal and wooden frames and polycarbonate troughs that lead water into gutters away from the plots (Loik et al. 2019). Drought plots were trenched 50 cm deep on all four sides and lined with 6-mil plastic to limit influence from lateral water flow and root growth. Drought shelters have little effect on air temperature, relative humidity, and reduce daily total photosynthetically active radiation by 20% (Loik et al. 2019). All plots were 4 × 4 m with a 0.5-m buffer on each side, creating a 3 × 3 m experimental area. Treatment effects on volumetric soil water content were confirmed using one soil moisture probe in each treatment 15-cm deep (METER Environmental; formerly Decagon, Pullman, WA, USA). We set up five plots of each treatment type: drought, ambient rainfall, and first-year watering. First-year watering is a common practice for restoration in arid regions when resources are available (Stromberg et al. 2007). First-year watering was used to determine if it could increase the long-term survivorship of native plantings. Planted natives in first-year watering plots were hand-watered with 4 liters twice in the first growing season (2016) during a rain-gap period in February, then March.

Plots were mowed to remove all standing biomass and then were planted with 12 native species (three to seven individuals per species) in January 2016. Seedlings were grown in containers in glasshouses for about three months at the UCSC Plant Growth Facility from seeds collected ≤40 km from our site (Table 1). Native species were selected based on reserve recommendations and to maximize life-form diversity. Native seedlings were planted in a randomized grid so that all plots had an identical planted species arrangement at the start of the experiment. Species life-forms were identified using the Jepson eFlora. After planting, research plots were weeded twice during the first growing season and not again after. Weeding included hand removal of non-native species using planks suspended above the plots to reduce plot disturbance.

Table 1. The 12 California native species planted for the study.

Taxa	Common Name	Life-Form
Achillea millefolium	common yarrow	rhizomatous forb
Artemisia californica	California sage scrub	shrub
Bromus carinatus	California brome	bunchgrass
Diplacus aurantiacus	sticky monkey flower	shrub
Ericameria ericoides	mock heather	shrub
Eschscholzia californica	California poppy	forb
Hosackia gracilis	harlequin lotus	N-fixer
Lupinus nanus	sky lupine	N-fixer
Lupinus variicolor	many-colored lupine	N-fixer
Sidalcea malviflora	prairie mallow	rhizomatous forb
Sisyrinchium bellum	blue eyed grass	forb
Stipa pulchra	purple needle grass	bunchgrass

Survivorship & Species Composition

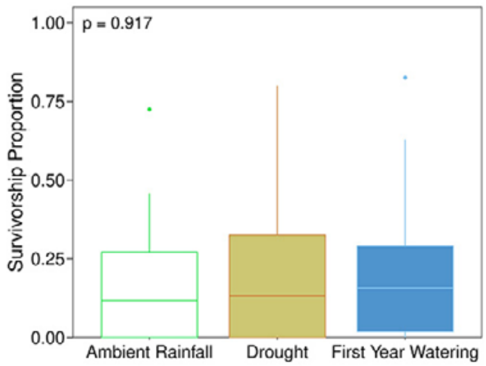
We quantified survival annually every April from 2016 to 2019. Survivorship was determined as the proportion of individuals that survived, as a function of total individuals planted.

In 2018 and 2019 we surveyed plant community composition in six permanent quadrats (0.25 × 1 m) established through randomized grid selection in each plot. Absolute plant cover was estimated to the nearest 5% with a modified Braun-Blanquet method. Absolute plant cover includes multiple canopy heights to ensure that all species are surveyed, so cover values can exceed 100%. We also recorded thatch cover and depth, and the absence/presence of seedling recruitment from the 12 planted species.

Analyses

All analyses were completed with the statistical analysis package, R (v3.6.1). Data were tested for parametric assumptions before using analysis of variance (ANOVA) or generalized linear models (GLM). ANOVAs were used to test for differences between the mean survival of different treatments, and GLMs were used to test for linear relationships between variables. Thatch depth and cover were directly correlated ($R^2 = 0.21$, $p = 0.007$), so we used thatch depth for subsequent analyses. We used Bray-Curtis dissimilarities to compare treatment effects on plant communities between plots from 2018 and 2019, then used the similarity of percentages (SIMPER) analysis to determine the contribution of individual species to the overall degree of community dissimilarity (Qureshi et al. 2018).

continued next page



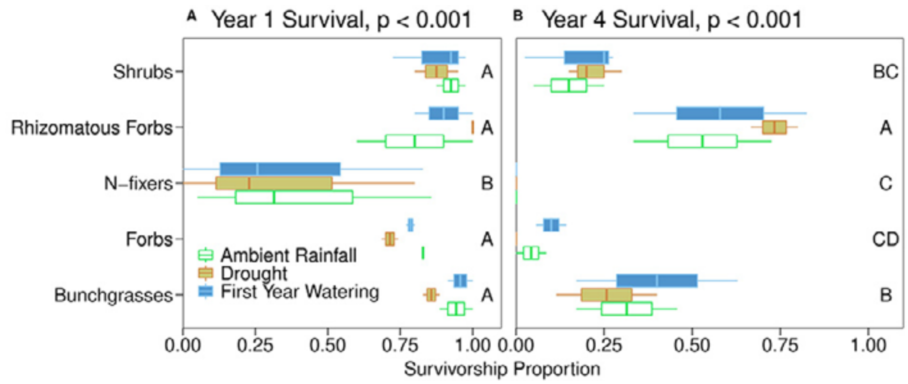


Figure 1. Survivorship compared across treatments for all 12 planted native species combined during year 4. Box represents interquartile range, the bar in the box represents the average, whiskers represent upper and lower quartiles of the data range, points represent outliers.

Figure 2. Survivorship in April of (A) year 1 (2016) and (B) year 4 (2019) compared across treatments for 12 planted species by life-form. Inset p-values are from the ANOVA model test: *'survival~life-form'*. Non-overlapping letters represent significant differences in survivorship between life-forms in respective panels. Survivorship of N-fixers (and forbs on drought plots) in year 4 was zero, thus it is plotted on the y-axis. Differences in survivorship by treatment within each life-form group are not noted in this figure. See Figure 1 for box-plot interpretation.

Selecting Coastal California Prairie Species for Climate-Smart Grassland Restoration *continued*

Results

Planting Survival

We found that both drought and first-year watering had no effect on survivorship compared to ambient rainfall plots four years after planting (Figure 1).

We found that there were significant differences in survivorship between life-forms by the end of the first (2016) and fourth (2019) growing seasons when treatments were combined (Figure 2). Nitrogen-fixing species had lower survivorship than all other life-forms ($p_{all} < 0.001$), but no other differences between life-forms were found at the end of the first growing season. By the end of the fourth growing season, rhizomatous forbs had the highest survivorship (70.1%) across treatments compared to other life-forms ($p_{bunchgrass} = 0.022$, $p_{N\text{-}fixer} < 0.001$, $p_{shrub} < 0.001$, $p_{forb} < 0.001$). Bunchgrasses had higher survivorship than forbs ($p = 0.031$) and N-fixers ($p = 0.004$), but not shrubs ($p = 0.409$). Shrubs, forbs, and N-fixers had similar survivorship by the end of the fourth growing season.

We then looked for treatment effects within each life-form grouping and found only forb survivorship was negatively affected by drought treatment after the first growing season ($F = 9.8$, $p = 0.044$), although not by the end of the fourth. No other survivorship differences by treatment within specific life-form groupings were noted in years 1 or 4.

The nitrogen-fixers (harlequin lotus, sky lupine, and many-colored lupine) and blue-eyed grass had no survivors nor any seedling

continued next page

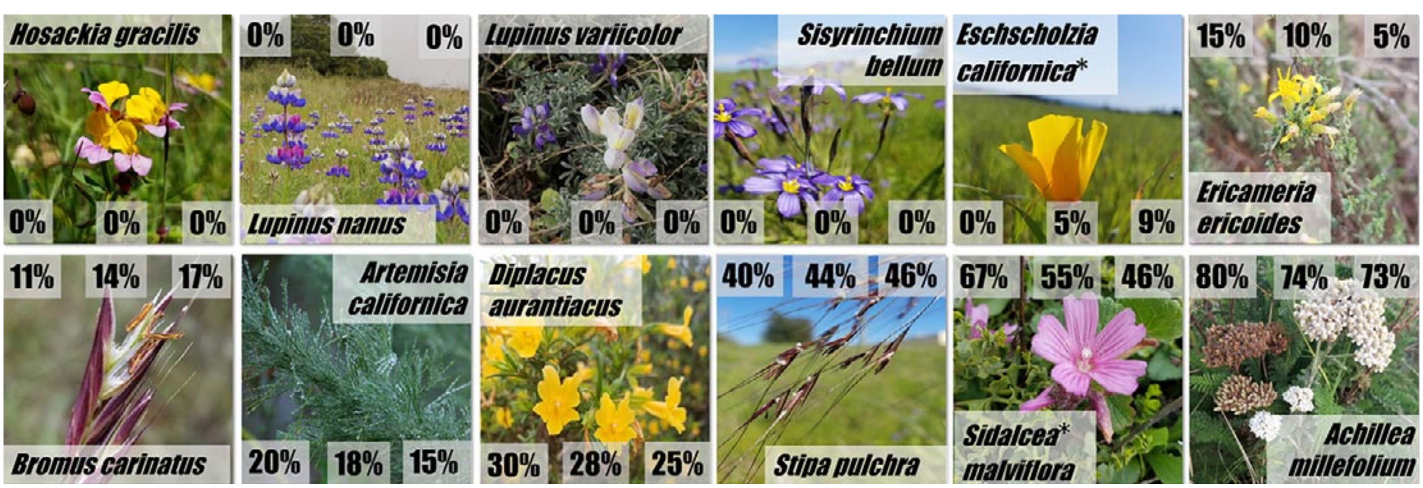


Figure 3. Survivorship of the 12 native species at the end of the fourth growing season. Survivorship from left to right in each panel represents drought (left), overall average for treatments combined (center), and ambient rainfall (right). Survivorship from first-year watering plants is not depicted since there was no effect. Significant differences in survivorship between drought and ambient rainfall plots occurred only for *S. malviflora*.

recruitment by the fourth year (Figure 3). The California poppy had some recruitment, but only 5% of the originally planted cohort survived at the end of the fourth growing season. Notably, the California poppy was the only planted species that was somewhat negatively affected by drought ($p = 0.069$). Mock heather, a fall-flowering shrub, also had low survival and no recruitment. The bunchgrasses, California brome and purple needlegrass, had moderate survivorship, and both showed some recruitment, especially *B. carinatus*. Summer-flowering shrubs, *Artemisia californica* and *Diplacus aurantiacus*, had moderate survival, though lower than bunchgrasses (Figure 3). The rhizomatous forbs, *Sidalcea malviflora* and *Achillea millefolium*, had high survivorship by the end of year 4. *Sidalcea malviflora* showed evidence of seedling recruitment and had higher survivorship in drought compared to other treatments ($p = 0.012$). Both rhizomatous forbs had considerable vegetative spread through rhizomes, especially *A. millefolium*. All other species were unaffected by drought, and the survivorship of no species showed signs of benefitting from first-year watering at the end of the fourth growing season.

Plant Community Differences

We used Bray-Curtis dissimilarities to compare community composition on the plots, and summarized the findings in Figure 4.

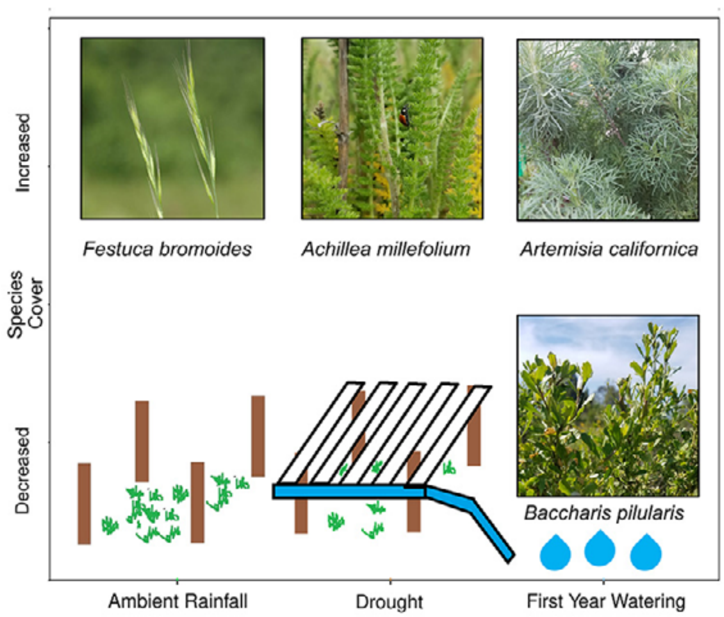


Figure 4. Certain species were found to underlie the differences in plant community composition between treatments (results from similarity percentage breakdown (SIMPER) analysis). Species in each treatment column are significant for determining how their plant communities are dissimilar from others. Species in the top row had greater cover in their respective treatment, and those in the bottom row had lower cover.

Plant communities on drought plots were significantly different from that of ambient rainfall and first-year watering plots, while the latter two had mostly overlapping plant communities ($k = 3$, stress = 0.117). We found that certain species explained the differences in community composition (SIMPER; $p < 0.001$). On drought plots, *Achillea millefolium* had 31% cover, which accounted for 21% of community difference between drought and ambient rainfall plots, which only had 6% *A. millefolium* cover ($p < 0.001$). *Achillea millefolium* explained 18% of the variance between drought and first-year watering plots, which had 11.3% average cover ($p = 0.003$). *Festuca bromoides* (a non-native annual grass) explained 12% of the plant community difference between ambient rainfall and drought plots ($p = 0.011$). Ambient rainfall plots had 21% *Festuca bromoides* where the cover and drought plots had 13% ($p = 0.011$). *Baccharis pilularis* explained 12% of community variation between first-year watering and ambient rainfall plots ($p = 0.050$). First-year watering plots had 9% cover and ambient rainfall had 14% cover. First-year watering plots had greater *Artemisia californica* cover (6%) which explained about 5% of the community difference compared to both drought (1%; $p = 0.011$) and ambient rainfall plots (1%; $p = 0.010$).

Native species cover was negatively correlated with thatch depth (Figure 5). We did not find any significant linear relationships between thatch and total non-native species cover, annual grass cover, nor any specific dominant extant non-native species.

Discussion

Overall, native plant survivorship decreased over the four years for the 12 native species, demonstrating the difficulty of restoring native coastal prairie. It is unlikely that precipitation patterns over the four

continued next page

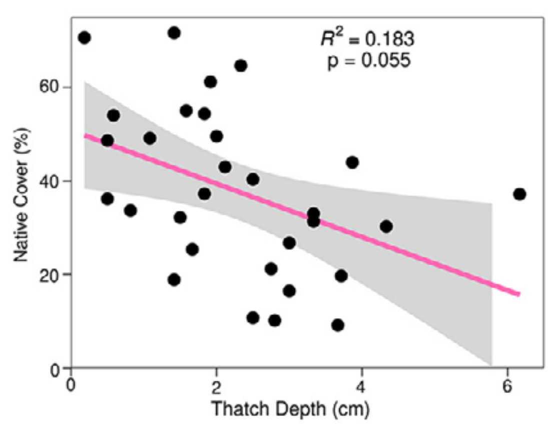


Figure 5. The relationship between native species cover and thatch depth. Points represent plots in 2018 and 2019. The shaded region represents a 95% confidence interval.

Selecting Coastal California Prairie Species for Climate-Smart Grassland Restoration *continued*

years led to this outcome, as survivorship trends do not match the inter-annual rainfall totals. Survival and cover were unaffected by the drought treatment for most of the native species. Low survivorship could have been a result of other things such as competition or diseases at earlier life stages. Alternatively, low survivorship could have been caused by background weather conditions which could have caused drought stress. But, the competition hypothesis is consistent with previous work that indicates California natives are sensitive to competition as seedlings which could result in low survival (Buisson et al. 2006). However, certain life-forms had higher cover or survivorship on drought plots than others. For example, the rhizomatous forb common yarrow had higher cover, whereas prairie mallow had high recruitment and was the only one of 12 species that had higher survivorship in drought plots. These rhizomatous forbs could be useful in establishing native cover to meet short- and long-term restoration targets or mandated compliance goals, even in drought years.

Some of the native species had minimal recruitment and establishment by year four, including the non-rhizomatous forbs, the California poppy, blue-eyed grass, and the N-fixing forbs. N-fixing forbs had lower survivorship than all other life-forms after the first growing season. Despite obvious benefits from nitrogen inputs, N-fixers may not be the best species for rapidly increasing native cover. The California state flower, the California poppy, was the only species to be negatively affected by drought compared to ambient rainfall plots during all four study years. This could indicate a need for future management of this species if there are more frequent or longer droughts. The responses of bunchgrasses were mixed, with purple needle grass having relatively high survivorship and California brome exhibiting high recruitment. These results are similar to past studies showing the general difficulty of establishing forbs in California grasslands (Copeland et al. 2016).

Since thatch depth is weakly and negatively associated with native species cover, periodic thatch or litter removal could help ensure the persistence of native prairie species. Other studies have found that thatch can suppress California native species growth, especially in the early years (Reynolds et al. 2001). Thatch is often associated with reduced recruitment of natives among non-native species (Hayes and Holl 2003). However, although thatch accumulation was unsurprisingly lower in drought plots (Zavaleta and Kettley 2006), we found no correlations between the native and non-native species and thatch at the study site.

Managing species that drive community change may be a good starting point for restoration actions. In this experimental system, this happened to be common yarrow and brome fescue. Common yarrow accounted for the higher native cover in drought plots, while ambient rainfall plots had a high cover of brome fescue, a non-native annual grass. Brome fescue may be an important target for weed management during average rainfall years whereas common yarrow could be useful for increasing native plant cover in dry years.

Management Recommendations

Our results demonstrate that certain plant species or life-forms may be better suited than others for the restoration of coastal prairies. We recommend managers that have short-term native compliance goals to use life-forms with high survivorship such as the rhizomatous forbs *Achillea millefolium* and *Sidalcea malviflora*. Bunchgrasses can persist for years after planting, and some, like *Bromus carinatus*, had high seedling recruitment. Managers with an immediate compliance goal in the second year might consider avoiding life-forms with low survival and/or seedling recruitment, such as non-rhizomatous and N-fixing forbs. When possible, coastal grassland managers should consider how to further incorporate non-rhizomatous forbs into their planting plans. Lastly, managers may also consider periodic thatch removal to promote higher native species cover.

Acknowledgments

We thank Karen Holl and Kathleen Kay for their contributions to the initial design and implementation of the experiment. We thank Jim Velzy and Sylvie Childress for growing seedlings. We thank Beth Howard, Tim Brown, Vaughan Williams, and Kyla Roessler, Cleopatra Tuday, Patrick Turner, Hallie Holmes, and Alexis Necarsulmer, who assisted in plot maintenance and data collection. This project was funded by the Northern California Botanists and the University of California Natural Reserve System. This project was also made possible by the California Native Grassland Association GRASS scholarship.

References

Buisson, E., K.D. Holl, S. Anderson, S., E. Corcket, G.F. Hayes, F. Torre, … T. Dutoit. 2006. Effect of seed source, topsoil removal, and plant neighbor removal on restoring California coastal prairies. *Restoration Ecology* 14(4):569–577. **https://doi.org/10.1111/j.1526-100X.2006.00168.x**

Cayan, D.R., E.P. Maurer, M.D. Dettinger, M. Tyree, and K. Hayhoe. 2007. Climate change scenarios for the California region. *Climatic Change*, 87(1 SUPPL):S21–S42. **https://doi.org/10.1007/s10584-007-9377-6**

Copeland, S.M., S.P. Harrison, A.M. Latimer, E.I. Damschen, A.M. Eskelinen, B. Fernandez-Going, … J.H. Thorne. 2016. Ecological effects of extreme drought on Californian herbaceous plant communities. *Ecological Monographs*, 86(3):295–311.

Ford, L.D., and G.F. Hayes. 2007. Northern coastal scrub and coastal prairie. Pp. 180–207 in *Terrestrial Vegetation of California*. Berkeley: University of California Press. **https://doi.org/10.1525/california/9780520249554.003.0007**

Groves, A.M., J.T. Bauer, and L.A. Brudvig. 2020. Lasting signature of planting year weather on restored grasslands. *Scientific Reports*, 10(1):1–10. **https://doi.org/10.1038/s41598-020-62123-7**

continued next page

Selecting Coastal California Prairie Species for Climate-Smart Grassland Restoration *continued*

Hayes, G.F., and K.D. Holl. 2003. Site-specific responses of native and exotic species to disturbances in a mesic grassland community. *Applied Vegetation Science*, 6(2):235–244.

Knapp, A.K., D.L. Hoover, K.R. Wilcox, M.L. Avolio, S.E. Koerner, K.J. La Pierre, … M.D. Smith. 2015. Characterizing differences in precipitation regimes of extreme wet and dry years: Implications for climate change experiments. *Global Change Biology*, 21(7):2624–2633. **https://doi.org/10.1111/gcb.12888**

Loik, M.E., D.D. Breshears, W.K. Lauenroth, and J. Belnap. 2004. A multi-scale perspective of water pulses in dryland ecosystems: Climatology and ecohydrology of the western USA. *Oecologia*, 141(2):269–281. **https://doi.org/10.1007/s00442-004-1570-y**

Loik, M.E., J.C. Lesage, T.M. Brown, and D.O. Hastings. 2019. Drought net rainfall shelters did not cause nondrought effects on photosynthesis for California central coast plants. *Ecohydrology* 12(7). **https://doi.org/10.1002/eco.2138**

Pérez-Harguindeguy, N., S. Diaz, E. Garnier, S. Lavorel, H. Poorter, P. Jaureguiberry, … J.H.C. Cornelisse. 2016. New handbook for standardized measurement of plant functional traits worldwide. *Australian Journal of Botany*, 61(34):167–234. **http://dx.doi.org/10.1071/BT12225**

Qureshi, H., M. Arshad, Y. Bibi, R. Ahmad, O.O. Osunkoya, and S.W. Adkins. 2018. Multivariate impact analysis of parthenium hysterophorus invasion on above-ground plant diversity in pothwar region of Pakistan. *Applied Ecology and Environmental Research*, 16(5):5799–5813. **https://doi.org/10.15666/aeer/1605_57995813**

R Core Team. 2020. *R: A language and environment for statistical computing.* **https://www.r-project.org**

Reynolds, S A., J.D. Corbin, and C.M. D'Antonio. 2001. The effects of litter and temperature on the germination of native and exotic grasses in a coastal California grassland. *Madroño*, 48(4):230–235.

Stromberg, M.R., C.M. D'Antonio, T.P. Young, J. Wirka, and P. Kephart. 2007. California grassland restoration." Pp. 254–280 in M.R. Stromberg, J.D. Corbin, and C.M. D'Antonio (eds.), *California Grasslands Ecology and Management*. Berkeley: University of California Press.

Zavaleta, E.S., and L.S. Kettley. 2006. Ecosystem change along a woody invasion chronosequence in a California grassland. *Journal of Arid Environments*, 66(2): 290–306. **https://doi.org/10.1016/j.jaridenv.2005.11.008**

MARIN MUNICIPAL WATER DISTRICT

GRASSROOTS EROSION CONTROL INC
VETERAN OWNED FAMILY OPERATED
(916) 587-1983
www.grassrootserosion.com
info@grassrootserosion.com

Pacific Restoration Group, Inc.
PRG
PO Box 2061 Lake Elsinore, CA 92531
(951) 457-4118

CNGA to Celebrate Milestone Anniversary

by Jodie Sheffield and Diana Jeffery

Giving Back and Looking Forward

Thirty years is a significant achievement. In more normal times, CNGA would have already announced an entire year's worth of events and save-the-date opportunities to celebrate this milestone anniversary. Despite the restrictions and challenges of the COVID pandemic, CNGA is continuing to give back and look forward. We launched our third annual round of Grassland Research Awards for Student Scholarships (GRASS) and continue encouraging and providing educational support for the next generation.

For over three decades, our members have worked tirelessly to make the world a better place! We are currently over 500 members strong, and we reach more than 2,000 through our *Grasslands* journal, Grass Blast email newsletters, CNGA Workshops, and joint ventures with partner organizations. We miss meeting in person and recognizing the long list of those who have made our organization and mission possible over these many years.

We want to hear from you!

This year, we will take the time in the coming journal issues to thank and recognize our members, volunteers, staff, and board of directors (both past and present) for CNGA's many accomplishments. We shall shine a light on all the efforts enacted in the realm of grassland ecosystem conservation, restoration, advocacy, and education throughout California.

CNGA has a story to tell, and that story is not over. Join us in future *Grassland* publications as we seek partners and supporters, new and old, who can help tell our story more broadly.

If you would like to contribute your thoughts and experiences and ways that CNGA has impacted your viewpoint of California native grasslands, please submit them to grasslands@cnga.org. See the announcement on page 5 for details.

Remembering our past

Here are a few quotes from our 20th Anniversary Edition of *Grasslands*. These articles share the narrative that best represents the California Native Grassland Association.

CNGA's contribution to ecosystem restoration and landscaping is real. In the early days when commercial quantities of native seeds were available, it was difficult to get buy-in by public agencies, park and refuge managers, the general public, landscape architects, etc. CNGA became and still is a major catalyst, teaching and promoting the importance and use of native grassland species. Almost all restoration projects now incorporate native grassland species as part of the plant palette. What was an initial vision and struggle has now become an accepted standard. CNGA has played a major role in making this happen. May the next 20 years continue to expand our influence.


Photo courtesy Phil Hogan

– John Anderson, 2011, CNGA founding member and past President; founder of Hedgerow Farms

Clare Tipple Golec, Field Botanist and past CNGA Board Member, shared this quote from Wendell Berry:

"To cherish what remains of the Earth and to foster its renewal is our only legitimate hope of survival."

Every copy of *Grasslands*, every grassland field trip, and every conversation with fellow grassland enthusiasts, teaches me something new about grasslands. When I reflect on the past 20 years of my work with grasslands, a couple of very important concepts come to mind. Grasslands are not just grasses. The diversity and vital ecosystem functions provided by our native forb community cannot be ignored. Secondly, grassland restoration requires patience and persistence. Do not give up on a restoration project after the first year. Stick to your plan, battle your weeds, and enjoy the surprise success of the second year…sometimes third year.

— Bryan Young, 2011, Natural Resource Supervisor, Sacramento Regional County Sanitation District, Bufferlands; former CNGA Board Member

I've learned that after restoring subalpine grasslands, they need to be continuously monitored and managed. If your restored grasslands are surrounded by annual exotic grasslands, there will be continuous invasion pressure. On the other side, I've learned that while much of our remnant grasslands have been invaded by annual grasses, there are still substantial pockets of native grasses within undisturbed areas.

— Andrew Fulks, 2011, Assistant Director, UC Davis Arboretum and Public Garden; former CNGA Board Member

Foreground, left: purple needlegrass (*Stipa pulchra*) in early winter. Background: California native shrub black sage (*Salvia mellifera*) in the sky with assorted Mediterranean shrubs

Using California Native Grasses in Garden Design

by Terri McFarland[1] *Photos courtesy the author. Originally published for the Dogpatch-Northwest Potrero Hill Green Benefit District at https://www.greenbenefit.org/blog. Reprinted with permission from the author.*

When I have been asked why I like to use California native grasses in garden design, the easiest answer is our native grasses are beautiful! Adapted to our dry summers, they are a good low- or no-water choice for gardens. As a garden designer, I use grasses as a canvas upon which to compose showy drifts of flowers. On larger properties, restoration of native meadows can be an economical and appropriate understory for dry shade under oaks. Sweeping meadows draped over rolling landforms is a beloved feature of California.

[1]Terri McFarland is a California licensed landscape architect with 20 years of experience designing public and residential landscapes (California RLA #5310). She opened her design firm in 2019 in San Francisco. She teaches design studios in the Landscape Horticulture Department at Merritt College in Oakland. As a Green Advocate Director on the Dogpatch-Northwest Potrero Hill Green Benefit District Board, she supports planting designs that increase biodiversity in local greening projects. She has been tending her meadow in Potrero Hill, San Francisco since 1992. terrimcfarland.la@gmail.com

As a professional landscape architect, I want to help tell the story of our native grasslands which, according to the California Native Grasslands Association (CNGA), *are among the most important yet most endangered ecosystems in the United States* (CNGA, 2020).

The oak savannah is the quintessential California landscape, but today few pristine prairies remain due to development, poorly managed grazing, fire suppression, and exotic species. The ecological benefits of grasslands include erosion control, water recharge, biodiversity, habitat, and carbon capture.

The theory of "shifting baselines" posits that humans accept the degradation of ecosystems from generation to generation as the original baseline gets forgotten. If we do not know what a healthy ecosystem looks like, how can we restore it? Gardeners who care for these species in home gardens, perhaps as a "museum" of endangered species, can help support the mission of CNGA, *to promote, preserve, and restore the diversity of California's native*

continued next page

grasses and grassland ecosystems (CNGA, 2020). The resilience of our grasslands will be an essential component for adapting to climate change.

Among the challenges of using native grasses in a garden, weed control is number one when trying to get them established. European annual grasses are very successful in out-competing our native species. Even before these introduced species took over, indigenous persons used controlled burns to maintain open grasslands for grazing elks. Fire, grazing, and meadows evolved together. Today, some ranches are having success using cows to restore native grasslands, timing their grazing for exotic weed control. In a small backyard garden, an attentive gardener can easily manage weeds by hand-pulling. I have gotten very adept at distinguishing a weed from a native sprout by subtle differences in the shade of green or texture.

Another challenge for the garden is the dormant period when some grass species may appear "dead" rather than merely dormant. Some species, such as purple needlegrass (*Stipa pulchra*) can be kept greener with irrigation, but some may be harmed or killed with water during their dormant periods. These obligate dormant species include California melic (*Melica californica*), Nevada bluegrass (*Poa secunda*), and big squirreltail (*Elymus multisetus*).

While I enjoy grasses in all phases, including their dormancy, a strategy for those who do not, is to set drier grasses within evergreen plants. I am not a purist, and I also enjoy plants from other Mediterranean climates such as the classics — lavender, rosemary, sage. I also cannot resist lovely summer annuals such as zinnias, sunflowers, cosmos, and poppies which keep the summer garden vibrant. While appreciating the ecological story of native grasslands, as a designer I use grasses as I would any other plant in my garden, placing them to show off the particular charms of each species.

A big advantage of some native upland grasses in Bay Area gardens is that they are adapted for our dry summers, and once established, you won't need to irrigate. California is called the "Golden State" for the color of dry grasslands. In your home garden, you can keep some of these grasses green with extra water, but I like to embrace the season cycles and honor the plant's adaptations. (Note: some

continued next page

Spent flower stalks of purple needlegrass *(Stipa pulchra*) with purple blooms of Ithuriel's spear (*Triteleia laxa*).

Left foreground: CA native junegrass *(Koeleria macrantha*). Background: CA natives purple needlegrass *(Stipa pulchra*) and Ithuriel's spear *(Triteleia laxa*) with non-native Hollyhocks and Mexican Marigold. Right: The "needles" of purple needlegrass *(Stipa pulchra*) blowing in the wind. These will self-sow in the garden.

Using California Native Grasses in Garden Design *continued*

grasses will require water even after establishment, so it is important to understand the needs of each species if you are looking to reduce water usage as much as possible. Also, when used inland, some coastal grasses, such as California oatgrass (*Danthonia californica)* will need water after establishment.)

Having very deep roots to carry plants through dry periods has another important ecological benefit, that of carbon sequestration. Unlike burning forests which release tons of carbon into the atmosphere, burning grasslands keep most of their biomass in deep roots underground, and can quickly regenerate.

I started using native grasses in my garden in 2003 with plugs of foothill needlegrass *(Stipa lepida*) left over from Quintessa Winery, a project in Napa Valley that I worked on as a landscape architect with Lutsko Associates. This project restored an oak savannah that wraps the winery and includes native grass meadows on the roofs. These are still going strong in my garden with minimal, if any, summer water.

Over time, I have planted additional grass species from both seeds and plugs, sourced from Hedgerow Farms, in Winters, or Larner Seeds, in Bolinas. Lately, I have been harvesting my seeds for the magic of the seed-to-seed cycle. In addition to diversifying the grass species, I have been adding flowering native perennials. I was so pleased this spring when the first blooms of western columbine *(Aquilegia formosa*) showed up 3 years after sowing.

continued next page

GOLDEN GATE NATIONAL PARKS CONSERVANCY

Left: California native perennial wildflowers — pink flowers of checkerbloom *(Sidalcea malviflora)* with creamy white flowers of Point Reyes wallflower *(Erysimum concinnum)* within green straps of Ithuriel's spear *(Triteleia laxa)* and purple needlegrass *(Stipa pulchra)*. Right: Baby hummingbirds nesting in CA native hybrid Ray Hartman California lilac (*Ceanothus* 'Ray Hartman').

Using California Native Grasses in Garden Design *continued*

The joy of tending a garden is to connect more deeply with time and to be fully present to life. I tap into this biophilia as I watch the sequence of grasses, beginning in winter with purple needlegrass greening up with the first bit of rain. Early spring features the delicate flowers of prairie Junegrass *(Koeleria macrantha)*, one of my favorites with its soft blue-green foliage. Next come spikes of Idaho fescue (*Festuca idahoensis*), the most lawn-like of our natives. I also love the seeds of California melic and Torrey's melic (*Melica torreyana*) which look like metallic beads glowing in the shadier part of my garden. Another favorite moment is when the purple flowers of Ithuriel's Spear (*Triteleia laxa*) nestle into the spent flower stalks of the purple needlegrass.

I have seen many birds, butterflies, and bees visit my garden. This spring, two hummingbirds hatched in the Ray Hartman California Lilac (*Ceanothus* 'Ray Hartman'). On foggy mornings, I find cute little native bees napping in the sticky yellow flowers of the Central Valley gum plant *(Grindelia camporum)*. On "butterfly TV" last month, I saw about 10 butterflies floating between my and my neighbor's yard, when a noisy northern mockingbird jumped on the fence angling to catch an orange Gulf fritillary. He missed, and all the butterflies immediately hid. Seed-eating birds, such as California towhee, dark-eyed junco, golden-crowned sparrow, or finch, stop by in fall to peck at grass seeds fallen in the soil. I have come to see the fauna as another design element in my garden — if I can make a little bird happy and fat, I am doing something right!

References

California Native Grasslands Association: www.cnga.org
California Native Plant Society: www.cnps.org
Hedgerow Farms: www.hedgerowfarms.com
Larner Seeds: www.larnerseeds.com

Species list [partial] for Terri's Potrero Hill, San Francisco garden:

California native perennial bunchgrasses:

Festuca californica (California fescue)
Festuca idahoensis (Idaho fescue)
Koeleria macrantha (Prairie Junegrass)
Melica californica (California melic)
Melica torreyana (Torrey melic)
Stipa lepida (foothill needlegrass)
Stipa pulchra (purple needlegrass)

California native perennial wildflowers:

Achillea millefolium (white yarrow)
Aquilegia formosa (western columbine)
Asclepias fascicularis (narrow-leaf milkweed)
Eschscholzia californica (California poppy, annual to perennial)
Erysimum concinnum (Point Reyes Wallflower)
Grindelia camporum (Central Valley gum plant)
Sidalcea malviflora (checkerbloom)
Sidalcea calycosa ssp. *rhizomata* (Pt. Reyes checkerbloom)
Sisyrinchium bellum (blue-eyed grass)
Thalictrum fendleri (foothill meadow rue)
Triteleia laxa (Ithuriel's spear)

Seasonal Changes in Forage Nutrient and Toxicity Levels on California Central Coast Rangelands: *A Preliminary Study*

by Royce E. Larsen[1], Daniel Cook[2], Dale R. Gardner[3], Stephen T. Lee[3], Matthew Shapero[4], LynneDee Althouse[5], Michael Dennis[6], Larry C. Forero[7], Josh S. Davy[8], Devii R. Rao[9], Marc Horney[10], Katie Brown[11], Craig W. Rigby[12], Kevin B. Jensen[13]

Introduction

Poisonous plants are a major cause of economic loss to the livestock industry, adversely affecting three to five percent of the cattle, sheep, goats, and horses that graze western rangelands (Panter et al. 2011). In response to calls from livestock operators, we investigated some common toxic plants representative of California's Central Coast rangelands. These lands represent an estimated 60 percent of the land area and provide a wide range of ecological services, including forage production for livestock and wildlife, water quality protection, recreation, and wildlife habitat (Roche et al. 2015). Livestock that graze on rangeland require forages of adequate quality and quantity to meet their biological needs. However, some rangeland forages that are high in nutrients may also contain toxins.

Grazing animals typically consume from 1.5 to 3.5 percent of their body weight in dry forage per day. For example, a mature 1,200 lb cow of moderate milking ability requires approximately 21 lbs of forage per day post-weaning and 22 lbs of forage during early lactation (Oltjen and Ahamadi 2013). While the quantity of forage is similar for the two production levels, the quality required differs significantly. The same 1,200 lb cow with moderate milk production potential requires Crude Protein (CP) levels at 6% (post-weaning) to 11% (early lactation) to maintain body condition and health (National Research Council 2000).

The nutritional value of forage depends on the plant species and the season of use by livestock. Generally, forbs (herbaceous flowering plants) have higher nutrient content than grasses. The nutrient content is highest during the vegetative growth stages (early growth), and then it begins to decline as plants mature. As forage senesces (dries), nutrient content declines rapidly (George et al. 2001, see Figure 1). Once full senescence occurs, livestock may need supplementation, particularly protein, to meet their nutritional requirements. In some areas, the presence of edible browse species or summer annual/biennial forbs may allow animals to continue meeting their nutritional needs into the summer months, a pattern that occasionally leads to consumption of toxic plants.

Annuals make up the dominant plants available for livestock consumption on Central Coast rangelands. Some common annual grasses include rye grass (*Festuca perennis*), annual fescue (*Festuca myuros)*, soft chess (*Bromus hordeaceus*), red brome *(Bromus rubens)*, and wild oat *(Avena* spp. *)*. Some common winter annual forbs include filaree (*Erodium* spp.), bur clover (*Medicago polymorpha*), vetch (*Vicia* spp.) and annual clovers (*Trifolium* spp.) (Forero et al. 2020). After winter annual forages have senesced, some commonly found summer annuals and biennials that continue growing include: summer mustard (*Hirschfeldia incana*), black mustard (*Brassica nigra)*, cheese weed (*Malva parviflora*), and morning glory (*Convolvulus arvensis*). Some commonly found woody browse species (i.e., trees and shrubs) include coyote brush (*Baccharis pilularis*), mule fat (*Baccharis salicifolia*), willow (*Salix* spp.), elderberry (*Sambucus nigra* subsp. *caerulea*), blue oak (*Quercus douglasii*), valley oak (*Quercus lobata*), and sycamore (*Platanus racemosa*). Animals mostly utilize the leaves of woody browse species, and the actual use of these forages by livestock is not known.

continued next page

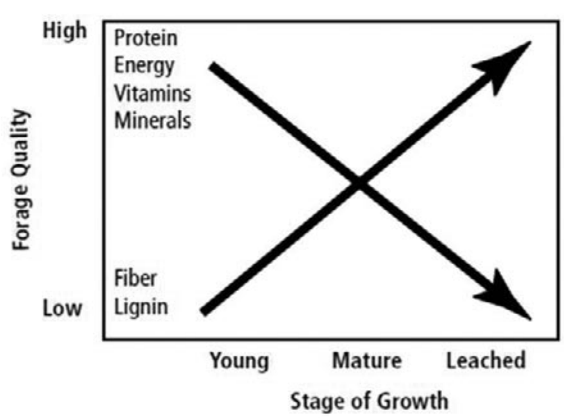


Figure 1. Stages of growth and forage quality (George et al. 2001).

[1]Area Watershed and Natural Resource Advisor, University of California, Agriculture and Natural Resources, Templeton, CA 93465 [2]Research Plant Physiologist. USDA Poisonous Plant Lab, Logan UT 83422 [3]Research Chemist, USDA Poisonous Plant Lab, Logan UT 83422 [4]Area Livestock and Natural Resource Advisor, University of California, Agriculture and Natural Resources, Ventura, CA [5]Principal Scientist, Althouse and Meade, Inc. Paso Robles, CA 93446 [6]Producer Carrizo Ranch, Veterinarian, Santa Margarita, CA 93454 [7]Livestock and Natural Resource Advisor, University of California, Agriculture and Natural Resources, Redding, CA 96002 [8]Area Livestock and Natural Resource Advisor, University of California, Agriculture and Natural Resources, Red Bluff, CA 96080 [9]Area Livestock and Natural Resource Advisor, University of California, Agriculture and Natural Resources, Hollister, CA 95023 [10]Professor, Rangeland Ecology and Management, Department of Animal Science, California Polytechnic State University, San Luis Obispo, CA 93407 [11]Senior Environmental Scientist, Althouse and Meade, Inc. Paso Robles, CA 93446 [12]Agronomist, USDA ARS Forage and Range Research Lab, Logan UT 83422 [13]Research Geneticist, USDA ARS Forage and Range Research Lab, Logan UT 83422

Left: Chick Lupine (*Lupinus microcarpus*) that is just starting to flower in a mix of red brome (*Bromus rubens*) and owls clover (*Castilleja* sp.). This lupine is commonly found on California rangeland and contains quinolizidine alkaloids which are toxic to livestock. Right: Stanislaus milkvetch (*Astragalus oxyphysus*) is commonly found on California rangeland and produces swainsonine, a phytotoxin harmful to livestock.

Seasonal Changes in Forage Nutrient and Toxicity Levels *continued*

In general, livestock (beef, sheep, and goats) require an average of 7 to 15 percent crude protein in their diet to meet their nutritional requirements. Generally, goats and sheep prefer forbs and shrubs (browse species) while cattle prefer grasses (Launchbaugh et al. 2006). Their mouthparts and tongue, as well as body size, impacts diet selection (Van Soest 1994). Also, forage nutrient levels affect animal preference and palatability (e.g. relish which plant is consumed).

Some plants may have high nutritional value but may also contain plant secondary compounds (PSC) that help defend plants against herbivory and pathogens. Under the right circumstances and doses, some PSC can be beneficial and improve animal health and performance; however, PSC at high concentrations are generally harmful to ruminants (Provenza et al. 2000, Provenza 2008). Common PSC includes condensed tannins, saponins, or alkaloids. In some cases, the negative effects of these PSC can be overcome by having a diversity of plant species available for livestock use. For example, one study found that sheep were able to manage the detrimental effects of PSC in some plants by incorporating other plants without PSC into their diet (Villalba et al. 2011). Some plants may simply contain non-palatable compounds, preventing animals from foraging on them, while other compounds can be harmful, even in small doses. The dose which an animal receives while grazing is influenced by several factors including palatability, density of the plant, the rate of ingestion, and the relative toxicity of the plants being consumed.

Usually, if given a choice, livestock will choose plants that provide necessary nutrients, while avoiding the plants that will harm them (Provenza and Launchbaugh 1999, Launchbaugh et al. 2001). Unfortunately, there are instances of livestock poisonings when toxic plants were not avoided (Varga and Puschner 2012). Relevant research and review articles discussing poisonous plants on rangelands include Litten and Ou (2010), Forero et al. (2011), Panter et al. (2011), Burrows and Tyrl (2013), and Davy et al. (2015).

Toxic plants common on Central Coast rangelands include fiddleneck (*Amsinckia* spp.), lupines (*Lupinus* spp.), milkvetch (also known as locoweed, *Astragalus* spp.), larkspur (*Delphinium* spp.), milkweed (*Asclepias* spp.), turkey-mullein (*Croton setiger*), jimson weed (*Datura wrightii*), curly dock (*Rumex crispus*), and heliotrope (*Heliotropium curassavicum*).

This paper provides an organized source of information on nutrient values and toxin levels for selected plants. A large suite of species was selected to compare nutrient and toxin concentrations.

Methods

This study was conducted on the California Central Coast including Monterey, San Luis Obispo, and Santa Barbara Counties. Sample sites were located on a diversity of soil types and precipitation regimes at elevations ranging from sea level to 5,000 feet. Average annual precipitation at sample sites varied from high of 42 inches in coastal hills, to less than 6 inches for inland valleys (e.g. Carrizo Plain). Forage samples were collected during the spring and summer of 2019 and included individual species of annual grasses, winter annual forbs, and mixed grass/forbs (composite) samples. Summer annuals/biennials

continued next page

and woody browse species were collected throughout the spring and summer months during their mature growth stages.

All samples were oven-dried at 65° C for 24 hours and ground to pass through a 1 mm screen. Samples were analyzed using near-infrared reflectance spectroscopy (NIRS), FOSS model XDS Rapid Content Analyzer (FOSS, Hilleroed Denmark) at the USDA ARS Forage and Range Research Laboratory in Logan, UT. Nutrient values were predicted with the Grass Hay Calibration, 18GH50.eqa, release April 2018b (NIRS Forage and Feed Testing Consortium, Hillsboro, WI). Nutrient values analyzed included crude protein (CP), amylase neutral detergent fiber (aNDF), and *in vitro* true dry matter digestibility at 48 hrs (IVTDMD48).

Plant toxins, from individual species collected, were analyzed using methods described at the USDA Poisonous Plant Laboratory, in Logan UT, and included swainsonine in *Astragalus* species (Gardner et al. 2001); alkaloids in larkspur (Gardner et al. 1999); nitrotoxins in *Astragalus* species (Schoch et al. 1998); pyrrolizidine alkaloids (Colegate et al. 2014); and total alkaloids in Jimson weed (Gardner et al. 1997).

We used PROC ANOVA (SAS), to test winter annual forbs, grasses, and composite forage samples for nutritional quality changes through different vegetative stages. Significant differences were reported within grass, forb, and composite samples, not over all groups. Duncan's multiple range test, at a significance level of 0.05, was used to separate means (Table 1). For all other nutrient and toxin analyses on summer annuals/biennials and woody browse species (Tables 2–6), average values were shown.

continued next page

Table 1. Average nutrient values during different vegetative stages for winter annual forbs, annual grasses, and annual grass/forbs mixed (composite) species. Nutrients analyzed were crude protein (CP), amylase neutral detergent fiber (aNDF), *in vitro* true dry matter digestibility at 48 hrs (IVTDMD48). Values were derived using near-infrared reflectance spectroscopy (NIRS) procedures. Means with different letters were significant at P<0.05. Winter annual forbs sampled were filaree (*Erodium* sp.), bur clover (*Medicago polymorpha*), vetch (*Vicia* spp.), annual clovers (*Trifolium* spp.), deervetch (*Acmispon* spp.), two-seeded milkvetch (*Astragalus didymocarpus*), soap plant (*Chlorogalum pomeridianum*), popcorn flower (*Plagiobothrys* spp.), yarrow (*Achilla* sp.), lomatium (*Lomatium* spp.), western blue-eyed grass (*Sisyrinchium bellum*), pineapple weed (*Matricoria discoidea*), and morning glory (*Convolvulus arvensis*). Annual grasses were wild oat (*Avena fatua*), soft chess (*Bromus hordeacous*), rye grass (*Fesctuca perennis*), annual fescue (*Festuca myuros*), ripgut grass (*Bromus diandrus*), red brome (Bromus rubens), foxtail (*Hordeum* spp.), false brome (*Brachypodium distachyon*), and bulbous bluegrass (*Poa bulbosa*).

Functional Forage Group	Vegetative State	Species[1]/Sites[2]	n	CP (%)	aNDF (%)	IVTDMD48 (%)
		# species				
Winter Annual Forbs	Vegetative	10	68	21.3[a]	34.0[c]	86.6[a]
Winter Annual Forbs	Mature	8	131	19.2[b]	38.8[b]	82.5[b]
Winter Annual Forbs	Senesced	5	41	14.4[c]	45.6[a]	73.8[c]
Winter Annual Forbs	Senesced–Leached[3]	5	24	10.9[d]	46.2[a]	68.9[d]
Annual Grasses	Vegetative	6	102	11.9[a]	57.0[d]	81.8[a]
Annual Grasses	Mature	10	287	7.5[b]	64.1[c]	76.9[b]
Annual Grasses	Senesced	8	118	4.2[c]	70.3[b]	69.9[c]
Annual Grasses	Senesced–Leached	6	47	3.2[d]	75.6[a]	64.1[d]
		# sites				
Composite[4] Samples	Vegetative	21	152	11.5[a]	47.4[d]	81.1[a]
Composite Samples	Mature	61	291	8.1[b]	57.4[c]	75.3[b]
Composite Samples	Senesced	14	64	5.6[c]	58.2[c]	71.2[c]
Composite Samples	Senesced–Leached	13	52	4.4[d]	65.0[b]	62.8[e]
Composite Samples	Weathered	43	172	4.6[d]	71.5[a]	65.4[d]

[1]The number of individual species harvested within Monterey, San Luis Obispo, and Santa Barbara Counties. [2]The number of sites (locations) where samples were harvested within Monterey, San Luis Obisp,o and Santa Barbara Counties. [3]Leached = samples harvested following a rain event of approximately 1.5 inches during mid-May. [4]Composite samples, as harvested on average consisted of rye grass (20%), wild oat (11%), red brome (9%), annual fescue (9%), soft chess (7%), foxtail (5%), ripgut brome grass (2%), false brome (2%), filaree (17%), bur clover (5%), annual clover (5%), deervetch (4%), morning glory (1%), owls clover (1%), two-seeded milkvetch (1%), other forbs (1%).

Results and Discussion

Forage Quality of Annual Grasses, Winter Annual Forbs, and Composite Samples

We found significant declines (P<0.01) in the nutritional quality of winter annual forbs, grasses, and composite samples as plants progressed through their vegetative stages (Table 1). The CP of winter forbs declined from a high of 21.3% to 14.4% as they aged and finally senesced. Annual grasses ranged from a high CP of 11.9% to 4.2%, while the composite sample values ranged from 11.5% to 5.6% CP through the same vegetative stage of progression (Table 1). A 1.5-inch rainfall event during mid-May 2019 may have leached CP as much as 3.5% in forbs, 1% in grasses, and 1.2% in the composite samples (Table 1). A similar precipitation-induced leaching condition was noted by George et al. 2001.

The other nutritional parameters, aNDF, and IVTD48 all had significant changes as plants aged from their vegetative stage through senescence (Table 1). The higher the aNDF means *less* energy available for livestock. The IVTDMD48 decreased for winter forbs, annual grasses, and composite samples as plants aged making them less digestible (Table 1). Once forage senesced, the nutritional quality was below the amount required to sustain a cow and calf, thus requiring supplemental feed on rangeland dominated by dry annual grasses. Once nutrient values associated with annual grasses and winter annual forbs declines below the 7% CP needed, supplementation may be necessary.

Summer Annuals and Biennials

We found that many summer annual/biennial forb species had high CP late into the summer dry period (Table 2). Some of these plants, like summer mustard (*Hirschfeldia incana)*, cheeseweed (*Malva parviflora*), spikeweed (*Centromadia pungens*), morning glory (*Convolvulus arvensis*), and yellow starthistle (*Centaurea solstitialis*),

continued next page

Table 2. Average nutrient values for individual winter annual/biennial species. Samples were collected during the late spring and summer during the mature growth stage. Nutrients analyzed were crude protein (CP), amylase neutral detergent fiber (aNDF), *in vitro* true dry matter digestibility at 48 hrs (IVTDMD48). Nutrient values were derived using near-infrared reflectance spectroscopy (NIRS) procedures. Asterisk denotes the plants that have been reported as toxic to livestock (Burrows & Tyrl 2013).

Species	Common Name	n	CP (%)	aNDF (%)	IVTDMD48 (%)
**Astragalus* spp.	Loco Weed	6	21.7	39.4	84.2
**Lupinus* spp.	Lupine	19	22.4	33.1	86.0
**Amsinckia* spp.	Fiddleneck	33	9.3	48.4	72.8
**Trichostema ovatum*	Blue Curls	4	16.9	33.2	84.5
**Delphinium* sp.	Larkspur	1	9.5	42.6	75.0
**Rumex crispus*	Curly Dock	2	9.6	43.5	61.9
**Croton setiger*	Turkey Muellin	11	18.6	46.4	74.8
**Heliotropium curassavicum*	Heliotrope	3	19.1	40.0	65.7
**Datura wrightii*	Jimson Weed	7	22.8	36.1	81.7
**Erigeron canadensis*	Horse Weed (Marestail)	2	22.3	49.6	70.2
**Asclepias vestita*	Milkweed	3	19.5	24.4	84.3
**Asclepias fascicularis*	Narrow Leaf Milkweed	3	16.4	41.5	82.1
**Conium maculatum*	Poison Hemlock	3	9.0	50.3	74.1
**Castilleja* spp.	Owls Clover	12	9.8	40.5	78.5
**Malva parviflora*	Cheeseweed	16	26.1	34.3	88.4
**Centaurea melitensis*	Tocalote	6	11.7	46.5	77.0
**Centaurea solstitialis*	Yellow Star Thistle	13	13.0	48.0	81.3
**Salsola tragus*	Russian Thistle	4	17.0	44.2	73.7
Hirschfeldia incana	Summer Mustard	16	20.3	45.1	77.1
Verbena bracteata	Prostrate Vervain	6	11.9	44.1	68.8
Eryngium spinosepalum	Button-Celery	4	9.0	53.9	62.5
Helichrysum petiolare	Licorice Plant	3	22.7	23.1	70.7
Convolvulus arvensis	Morning Glory	9	16.9	34.1	83.3
Centromadia pungens	Spike Weed	9	14.7	44.4	70.1

Management Experiences from Three California Central Coast Ranchers

Three ranchers shared personal experiences of how they managed their livestock to avoid toxic plants, or to control undesirable weedy species. In all cases, these practices may have also benefited livestock performance because animals were able to consume forage with higher nutritional quality during the dry summer months on California Central Coast rangelands. First, Steve Sinton, a rancher in Shandon, trained his cattle (following guidelines developed by Kathy Voth, http://www.livestockforlandscapes.com/) to eat yellow star thistle (*Centaurea solstitialis*), cheeseweed (*Malva parviflora*), and summer mustard (*Hirschfeldia incana*). He initially found this to be successful during the first year but was not able continue the project after one year because of the severe drought of 2012–2016 limiting the availability of the targeted plants. Second, Aaron Lazanoff, the beef operations manager at California Polytechnic State University, San Luis Obispo, found that by using high density stocking with his cattle, they learned to eat cheeseweed, summer mustard, Italian thistle (*Carduus pycnocephalus*), milk thistle (*Silybum marianum*), bristly ox-tongue (*Helminthotheca echioides*), teasel (*Dipsacus fullonum*), and fennel (*Foeniculum vulgare*) readily. High density stocking in this case is defined as approximately 150 cows kept in a herd, grazing about 5% of the ranch (2400 ac) at any given time, leaving 95% of the ranch rested. They rotate through each pasture 3–4 times each year. You may contact Aaron Lazanoff for further information on how he manages his livestock. He reported that he had decreased his protein supplementation because the cattle were eating these summer growing plants with higher CP levels. Third, Michael Dennis, a rancher in the Carrizo Plains, whose cattle had problems with toxic plants in the past, began to pay closer attention to what his cattle were eating, and when they were eating certain plants. In one instance, he found it was obvious that cattle were beginning to eat *Astragalus* plants. In response, he changed his pasture rotation, and moved his cattle quickly through pastures before they had an opportunity to select the *Astragalus* plants, some of his pastures contain many of the toxic plants described in this paper. He found that if the cattle had enough other forage to eat, they did not seem to have any problems with the toxic plants.

Seasonal Changes in Forage Nutrient and Toxicity Levels *continued*

all had over 20% CP through April and maintained CP values greater than 15% into June (Table 2). These species have the potential to be utilized during late spring into summer for cattle, sheep, and goats. However, some of these have been reported to have toxic compounds (Table 2). In addition, physical barriers like spines in mature yellow starthistle may make it difficult for livestock to utilize them.

Summer-growing forbs generally provide higher CP and greater energy than senesced grass and winter forbs later in the season (Tables 1 and 2). During late May through August, summer annual/biennial forbs can provide an average of 9% to 26.1% CP (Table 2). They have more digestible energy than grasses do at any growth stage as reflected in lower aNDF values. As aNDF increases, total digestible energy and estimated net energy decrease proportionally. The decline is more substantial for higher cell wall plants (i.e., plants with increased fiber) (Van Soest 1994). A contributing factor to decreased estimated net energy is the increased time it takes an animal to masticate and ruminate forages high in aNDF. This is time lost that the animal could spend consuming higher quality forage to meet their nutrient requirements (i.e., rumen fill becomes limiting with diets high in aNDF). Forages low in CP and high in aNDF, as seen in our senesced growth stage winter annual forbs and annual grasses (Table 1), take more energy to digest for less nutrient and energy return. This makes summer annual/biennial forbs a potential source of CP and energy for livestock grazing rangelands.

continued next page

Table 3. Summary of nutrient values for individual samples of woody browse species. Samples were collected during the late spring and summer during the mature growth stage. Nutrients analyzed were crude protein (CP), amylase neutral detergent fiber (aNDF), *in vitro* true dry matter digestibility at 48 hrs (IVTDMD48). Nutrient values were derived using near-infrared reflectance spectroscopy (NIRS) procedures. Asterisk denotes the plants that have been reported as toxic to livestock (Burrows & Tyrl 2013).

Species	Common Name	n	CP (%)	aNDF (%)	IVTDMD48 (%)
**Baccharis pilularis*	Coyote Brush	8	19.0	33.2	70.8
**Baccharis salicifolia*	Mulefat	6	23.6	27.2	75.0
**Ericameria* sp.	Golden Bush	8	19.9	51.9	56.9
**Sambucus nigra*	Elderberry	3	19.8	33.2	73.2
**Quercus douglasii*	Blue Oak	6	17.0	35.6	72.5
**Quercus lobata*	Valley Oak	6	17.6	40.6	64.8
**Quercus agrifolia*	Live Oak	10	13.4	45.9	54.7
**Prunus dulcis*	Almond	4	15.6	21.4	79.9
**Juglans* sp.	Walnut	6	15.3	21.2	82.5
Morus sp.	Mulberry	8	11.2	22.3	91.5
Salix sp.	Willow	6	14.0	35.3	59.6
Adenostoma fasciculatum	Chamise	3	18.7	47.8	70.6
Platanus racemosa	Sycamore	8	17.8	39.0	64.7

Summer Browse Species

Woody browse species were also found to be high in CP and low aNDF values compared with grasses and both winter and summer forbs throughout the growing season (Table 3). However, PSC compounds are more frequently produced by woody browse plants when compared with grasses (Panter et al. 2011). We found that the woody browse plants contain CP values ranging from 11.2% to 23.6% (Table 3). As livestock transition their diet to higher proportions of forbs and browse plants during the summer, the risk of poisoning increases, so careful management is needed to avoid detrimental impacts on livestock.

Toxic Plants

Poisonous plants differ in their relative consumption by livestock, and toxicity is influenced by the availability of other forage. Some plants, like larkspur,, are very palatable and are grazed based upon availability while other plants, like fiddleneck, are very unpalatable and are only grazed under rare circumstances (e.g., drought and limited forage availability) or when they contaminate supplemental feed. Alternatively, plants like *Lupinus* spp. and *Astragalus* spp. are palatable but consumption is influenced by the availability of other more desirable forage. It is important to note the density of potentially toxic plants to determine the risk of livestock toxicity.

The amount of toxic PSC intake that causes poisoning varies by animal and livestock species. Some general guidelines can be found in UC ANR publication Livestock Poisonous Plants of California (Forero et al. 2011). We found varying levels of toxins, along with seasonal variations for many plants sampled on the Central Coast (Tables 4–6). Some plants, such as fiddleneck, appear to be less toxic once senescence occurs. However, we only sampled the whole plant, and not seeds independently. Other plants, such as heliotrope, larkspur, and jimson weed were found to have high levels of alkaloids.

Lupinus species, in the Fabaceae family, are found in a diversity of habitats. Ingestion of lupines may cause acute intoxication most often observed in sheep as well as congenital birth defects in calves termed "crooked calf syndrome" (Burrows and Tyrl 2013). *Lupinus* species may contain a variety of quinolizidine and/or piperidine alkaloids implicated in toxic and teratogenic (birth defect) potential. All of these alkaloids are considered toxic but only ammodendrine, a piperidine alkaloid, and anagyrine, a quinolizidine alkaloid, are considered teratogenic (Lee et al. 2007). All the *Lupinus* species analyzed in this study contained alkaloids, thus posing a toxic risk to grazing livestock, while *L. microcarpus* and *L. albifrons* contained alkaloids (ammodendrine and/or anagyrine) that pose a teratogenic risk (Table 4). The toxic and/or teratogenic dose required for livestock has not been well defined for lupines. Alkaloid profiles of *Lupinus* species are known to vary by species and by population therefore chemical analysis is required to determine the toxic and/or teratogenic potential (Lee et al. 2007).

continued next page

Table 4. Toxin concentrations and nutrient values for selected lupine species. Samples were collected during spring (vegetative state) and summer months (mature stage, but still growing). Nutrients analyzed were crude protein (CP), acid detergent fiber (ADF), amylase neutral detergent fiber (aNDF), water soluble carbohydrates (WSC), digestible neutral detergent fiber at 48 hrs (dNDF48), *in vitro* true dry matter digestibility at 48 hrs (IVTDMD48). Nutrient values were derived using near-infrared reflectance spectroscopy (NIRS) procedures.

Species	Vegetative Stage	Toxins										Nutrients		
		Spartiene	Ammodendrine	N-Acetylhistrine	N-Methylcytisine	5,6-Dehydro-α-isolupanine	α-Isolupanine	5,6-Dehydrolupanine	Lupanine	Thermopsine	Anagyrinie			
Sample Retention Time (min)		*5.6*	*6.3*	*6.9*	*7.3*	*8.4*	*8.8*	*8.9*	*9.3*	*11.3*	*12.2*	CP	aNDF (Percent)	IVTDMD48
		(Concentration µg/mg)												
Lupinus sp.	Vegetative	0.072							0.11			22.6	28.1	86.0
Lupinus sp.	Mature		3.5	0.35	4			0.15	0.18		0.54	19.7	26.9	81.0
Lupinus sp.	Vegetative	0.25							0.24			18.1	33.2	87.1
L. bicolor	Vegetative						2.3	0.33		1		21.9	39.3	83.9
L. bicolor	Vegetative						2.5	0.23		1		20.8	40.1	83.8
L. bicolor	Vegetative						1.9	0.22		1.2		20.3	40.7	79.1
L. microcarpus	Vegetative		0.13		2			0.25	0.21		0.62	24.3	28.2	88.0
L. microcarpus	Vegetative				2.2			0.31	0.29		0.47	24.7	28.8	89.5
L. microcarpus	Mature		0.52		3.6			0.43	0.36		1	17.5	36.1	81.3
L. albifrons	Mature							1.9	4.4		1.6	19.0	37.3	75.8

Table 5. Toxin concentrations and nutrient values for selected lupine species. Samples were collected during spring (vegetative state) and summer months (mature stage, but still growing). Nutrients analyzed were crude protein (CP), acid detergent fiber (ADF), amylase neutral detergent fiber (aNDF), water soluble carbohydrates (WSC), digestible neutral detergent fiber at 48 hrs (dNDF48), *in vitro* true dry matter digestibility at 48 hrs (IVTDMD48). Nutrient values were derived using near-infrared reflectance spectroscopy (NIRS) procedures.

Species	Vegetative Stage	Total Alkaloid (mg/g)		Toxin Type	CP (%)	aNDF) (%)	IVTDMD48 (%)
Amsinckia sp.	Vegetative	0.65		Lycopsomine N-oxide, intermedine N-oxide, lycopsomine, intermedine	15.9	35.6	82.5
Amsinckia sp.	Vegetative	0.59		Lycopsomine N-oxide, intermedine N-oxide, lycopsomine, intermedine	15.6	36.3	81.4
Amsinckia sp.	Vegetative	1.07		Lycopsomine N-oxide intermedine N-oxide, lycopsomine, intermedine	14.1	40.5	84.3
Amsinckia sp.	Vegetative	0.8		Lycopsomine N-oxide, intermedine N-oxide, lycopsomine, intermedine	8.6	41.3	80.3
Amsinckia sp.	Vegetative	0.35		Lycopsomine N-oxide, lycopsomine	12.4	47.7	71.2
Amsinckia sp.	Vegetative	0.34		Lycopsomine N-oxide, intermedine N-oxide, lycopsomine, intermedine	8.6	47.9	75.8
Amsinckia sp.	Vegetative	0.94		Lycopsomine N-oxide, lycopsomine	13.6	38.8	78.1
Amsinckia sp.	Mature	0.33		Lycopsomine N-oxide, lycopsomine	9.5	46.8	74.9
Amsinckia sp.	Mature	0.38		Lycopsomine N-oxide, lycopsomine	17.3	41.9	81.2
Amsinckia sp.	Mature	0.35		Lycopsomine N-oxide, lycopsomine	9.7	45.3	75.3
Amsinckia sp.	Mature	0.18		Lycopsomine N-oxide, lycopsomine	10.3	45.4	75.4
Amsinckia sp.	Mature	0.37		Lycopsomine N-oxide, lycopsomin"	9.2	47.7	74.3
Amsinckia sp.	Mature	0.25		Lycopsomine N-oxide, intermedine N-oxide, lycopsomine, intermedine	10.4	50.8	71.8
Amsinckia sp.	Mature	0.11		Lycopsomine N-oxide, lycopsomine	4.7	50.7	69.5
Amsinckia sp.	Mature	0.09		Lycopsomine N-oxide, lycopsomine	4.4	52.2	68.3
Amsinckia sp.	Mature	0.08		Lycopsomine N-oxide, lycopsomine	4.6	58.2	63.2
Amsinckia sp.	Mature	0.09		Lycopsomine N-oxide, lycopsomine	5.1	54.1	67.1
Amsinckia sp.	Late Mature	0.14		Lycopsomine N-oxide, lycopsomine	5.5	57.1	63.8
Amsinckia sp.	Late Mature	0.19		Lycopsomine N-oxide, lycopsomine	5.2	56.9	64.5
Amsinckia sp.	Late Mature	0.14		Lycopsomine N-oxide, lycopsomine	5.7	58.9	61.8
Amsinckia sp.	Late Mature	0.26		Lycopsomine N-oxide, intermedine N-oxide, lycopsomine, intermedine	11.5	50.1	71.7
Heliotropium sp.	Mature	3.93		Lycopsomine N-oxide, lycopsomine	20.4	41.3	67.0
Datura wrightii	Mature	15		(Scopolamine, demethylatropine, atropine)	24.9	32.9	83.8
		MSAL[1] Alkaloids Total	mg/g				
Delphinium sp.	Mature	4.0	4.2	Methyllycaconitine, Nudicauline, 14-deacetylnudicauline	9.5	42.6	75.0
Delphinium sp.	Senesced	0.6	0.8	Methyllycaconitine, Nudicauline, 14-deacetylnudicauline	3.2	57.9	62.9

[1]MSAL = *N*-(methylsuccinimido) anthranoyllycoctonine (MSAL)-type. This is a specific type of norditerpene alkaloid found in larkspur. The classification is based upon the chemical structure. They are more toxic than the non-MSAL type.

Several Boraginaceae genera, including *Amsinckia* and *Heliotropium*, are reported to contain dehydropyrrolizidine alkaloids. Dehydropyrrolizidine alkaloids are plant toxins associated with disease in humans and animals. Humans and animals are most often exposed to plants containing these alkaloids due to contamination of foodstuffs or when plants containing them are consumed in feed or medicinal herbs (Stegelmeier et al. 1999). Dehydropyrrolizidine alkaloids were detected in the *Amsinckia* and *Heliotropium* species surveyed herein. In this study, concentrations of the dehydropyrrolizidine alkaloids in the *Amsinckia* species surveyed appear to decrease seasonally (Table 5), consistent with other reports (Pfister et al. 1992).

Larkspurs, in the Ranunculaceae plant family, are poisonous plants found on rangelands throughout Western North America (Burrows and Tyrl 2001). Their toxicity is attributed to the norditerpene alkaloids that can be divided into two structural classes, the *N*-(methylsuccinimido) anthranoyllycoctonine type (MSAL) and the non-MSAL-type. The acute toxicity of larkspur is generally attributed to the MSAL-type alkaloid, though recent research has demonstrated that the non-MSAL type can contribute to the overall toxicity but to a lesser extent (Welch et al. 2012). Norditerpenoid alkaloids may differ qualitatively and/or quantitatively between species and within species. Concentrations of norditerpene alkaloids have been reported to decrease seasonally (Ralphs et al. 2000) in other larkspur species consistent with the two timepoints reported for the species investigated herein (Table 5).

Astragalus species in the Fabaceae family may be non-toxic and important forage; however, several species in California are toxic to livestock and wildlife. *Astragalus* is associated with three toxic syndromes: locoism caused by the indolizine alkaloid swainsonine, selenium poisoning due to species that hyperaccumulate selenium, and nitrotoxin poisoning due to species that contain 3-nitropropanol, 3-nitroproprionic acid, and their glycosides (miserotoxin) (Burrows and Tyrl 2001). In this study, *Astragalus oxyphysus* and *A. asymmetricus* contained swainsonine while *A. didymocarpus* did not contain swainsonine (Table 6), consistent with previous reports (Cook et al. 2016). None of these species contain nitrotoxins or have been reported to hyperaccumulate selenium. Importantly, locoism is a chronic toxicity where animals have to consume the toxic plant of interest for two to three weeks before the onset of clinical signs of toxicity. *Astragalus oxyphysus* and *A. asymmetricus* both contain sufficient amounts of swainsonine to pose a toxic risk.

continued next page

Table 6. Toxin concentrations and nutrient values for selected locoweed (*Astragalus* spp.) species. Samples were collected during spring (vegetative state) and summer months (mature, or late mature stage but still growing). Nutrients analyzed were crude protein (CP), amylase neutral detergent fiber (aNDF), *in vitro* true dry matter digestibility at 48 hrs (IVTDMD48). Nutrient values were derived using near-infrared reflectance spectroscopy (NIRS) procedures.

		Toxins		Nutrients		
Species	Vegetative Stage	Swainsonine (%)	Nitrotoxins	CP (%)	aNDF (%)	IVTDMD48 (%)
A. asymmetricus	Vegetative	0.08	NF	23.9	38.3	86.3
A. asymmetricus	Mature	0.13		15.3	48.8	70.7
A. asymmetricus	Mature	0.15		17.8	46.7	76.9
A. asymmetricus	Mature	0.18		16.5	47.8	73.8
A. asymmetricus	Mature	0.09		17.1	47.5	75.8
A. asymmetricus	Mature	0.09		17.2	47.0	76.9
A. asymmetricus	Mature	0.12	NF	14.8	44.8	69.2
A. asymmetricus	Mature	0.06		17.6	48.7	73.4
A. oxyphysus	Vegetative	0.34		20.1	41.5	81.4
A. oxyphysus	Vegetative	0.33		18.6	39.2	84.4
A. oxyphysus	Late Mature	0.12		7.5	69.7	59.6
A. oxyphysus	Late Mature	0.14		16.4	40.9	83.0
A. oxyphysus	Late Mature	0.17		13.0	42.7	79.8
A. oxyphysus	Late Mature	0.17		16.2	44.1	82.0
A. didymocarpus	Vegetative	NF	NF	24.6	36.6	86.7
A. didymocarpus	Vegetative	NF	NF	24.7	35.8	85.6
A. didymocarpus	Mature	NF	NF	10.2	54.6	66.5
A. didymocarpus	Mature	NF	NF	10.3	53.0	68.8

Conclusions

More studies are needed to better understand relationships between forage nutrients, toxic plants, and grazing animals. Studies examining toxin concentrations as a function of the season may be helpful to better understand livestock poisonings. Some plants found to have toxins may provide beneficial nutrients for livestock if consumed in small portions of the total diet, and/or if nutrient supplementation is provided.

We found that as winter forages (both grasses and forbs) senesce and dry, they no longer meet livestock's nutritional needs. Reduction in nutrient levels happens quickly, especially for annual grasses. Nutrients may also be leached from forage by rainfall anytime the forage is dry; normally this occurs during the fall. During our study, a late spring (mid-May) rainfall on already dried forage caused significant reductions in nutrient values.

Late summer annuals/biennials and browse plants we studied contain high nutritional levels, with CP values for some species remaining higher than 15% late into summer. Some high protein plants may be used by livestock to help maintain nutritional needs during the summer and fall, while others like jimson weed are toxic and should be avoided. Poisonous plants we surveyed all contain sufficient toxin concentrations to pose a risk to livestock if consumed in sufficient quantities, yet some may be utilized under the right conditions.

Good livestock management is necessary to reduce animal exposure to potentially harmful plants found on rangelands. In general, ranchers can mitigate potential losses due to poisonous plants through good range management, especially making sure that livestock can meet their dietary requirements with enough forage and/or supplementation. Ranchers should be attentive to changes in the selection and diet of their livestock as the plants mature and the forage availability changes. This investigation serves as a template for a statewide analysis of toxic plants on California rangelands and the basis for further research on how to mitigate toxicity by livestock supplementation.

Supplemental tables with additional information about each species can be found at: **http://cesanluisobispo.ucanr.edu/**

References

Burrows, G.E., and R.J. Tyrl. 2013. *Toxic Plants of North America.* John Wiley & Sons.

Colegate S.M., S.L. Welsh, D.R. Gardner, J.M. Betz, and K.E. Panter. 2014. Profiling of dehydropyrrolizidine alkaloids and their *N*-oxides in herbarium-preserved specimens of *amsinckia* species using HPLC-esi(+)MS. *Journal of Agricultural and Food Chemistry* 62:7382–7392.

Cook, D., D.R. Gardner, S.T. Lee, J.A. Pfister, C.A. Stonecipher, and S.L.Welsh. 2016. A swainsonine survey of North American Astragalus and Oxytropis taxa implicated as locoweeds. *Toxicon* 118:104–111.

Davy, J.S., L.M. Roche, A.V. Robertson, D.E. Nay, and K.W.Tate. 2015. Introducing cattle grazing to a noxious weed-dominated rangeland shifts plant communities. *California Agriculture* 69(4):230–236.

Forero, L., G. Nader, A. Craigmill, J. DiTomaso, B. Puschner, and J. Maas. 2010. Livestock-poisoning plants of California. University of California, Agriculture and Natural Resources Publication 8398. **https://anrcatalog.ucanr.edu/pdf/8398.pdf**

Forero, L.C., J. Davy, J. Bartolome, S. Barry, and S. Larson. 2020. Range and pasture plant identification. ANR Publication 3550 (in press).

Gardner, D.R., G.D. Manners, M.H. Ralphs, and J.A. Pfister. 1997. Quantitative analysis of norditerpenoid alkaloids in larkspur (*Delphinium* spp.) by Fourier Transform Infrared Spectroscopy. *Phytochemical Analysis* 8:55–62.

continued next page

DEBORAH Shaw
RESTORATION + LANDSCAPE

JONI L. JANECKI
& ASSOCIATES
Landscape Architect
515 Swift Street, Santa Cruz
www.jlja.com (831) 423-6040

HRS
HABITAT RESTORATION SCIENCES, INC.

Design-Build landscape and general engineering contractor specializing in wildland and wildlife habitat mitigation, biological monitoring and restoration
hrsrestoration.com | 916.408.2990

DUDEK
PLAN | DESIGN | PERMIT | CONSTRUCT | MANAGE
California Focused Environmental Planning
- Biological Studies
- CEQA/NEPA
- Contract Planning
- Cultural Resources
- Fire Protection Planning
- Hazardous Materials
- Mitigation Monitoring
- Natural Resources Management
- Native Habitat Design/Restoration
- Water Resources Development
- Wetlands Delineation

Dudek.com | info@dudek.com
800.450.1818

Gardner, D.R., R.J. Molyneu,x and M.H. Ralphs. 2001. Analysis of swainsonine: Extraction methods, detection, and measurement in populations of locoweeds (*Oxytropis* spp.). *Journal of Agricultural and Food Chemistry* 49(10):4573–4580.

Gardner, D.R., K.E. Panter, J.A. Pfister, and A.P. Knight. 1999. Analysis of toxic norditerpenoid alkaloids in *Delphinium* species by electrospray, atmospheric pressure chemical ionization and sequential tandem mass spectrometry. *Journal of Agricultural and Food Chemistry* 47(12):5049–5058.

George, M., G. Nader, N. McDougald, M. Connor, and B. Frost. 2001. Annual rangeland forage quality. ANR Publ. 8022, Division of Agriculture and Natural Resources, University of California, Oakland CA. 13 pgs.

Launchbaugh, K.L., F.D. Provenza, and J.A. Pfister. 2001. Herbivore response to anti-quality factors in forages. *Journal of Rangeland Management* 54:431–440.

Launchbaugh, K., J. Walker and R.L. Daines (eds.). 2006. Targeted grazing: A natural approach to vegetation management and landscape enhancement. Centennial, CO, USA: American Sheep Industry Association, 199 pgs. **https://www.webpages.uidaho.edu/rx-grazing/Handbook/ASITargetGrazingBook2006.pdf**

Lazanoff, A. 2020. Personal communication. Beef Operations Manager Office: Bldg. 127D (805) 801-7058 **alazanof@calpoly.edu**

Lee, S.T., D. Cook, K.E. Panter, D.R. Gardner, M.H. Ralphs, E.S. Motteram, J.A. Pfister, and C.C. Gay. 2007. Lupine induced "Crooked Calf Disease" in Washington and Oregon: Identification of the alkaloid profiles in *Lupinus sulphureus*, *Lupinus leucophyllus*, and *Lupinus sericeus*. *Journal of Agricultural and Food Chemistry* 55(26):10649–10655.

Litten, S., and A. Ou. 2010. Poisonous rangeland plants in San Luis Obispo County. **https://digitalcommons.calpoly.edu/ascisp/4/**

National Research Council. 2000. Nutrient requirements of beef cattle, seventh revised edition. The National Academies Press: Washington, DC. **https://www.nap.edu/catalog/9791/nutrient-requirements-of-beef-cattle-seventh-revised-edition-update-2000**

Oltjen, J.W., and A. Ahmadi. 2013. Taurus: A ration formulation program for beef cattle. *Natural Sciences Education* 42:145–159. **https://doi.org/10.4195/nse.2011.00003**

Panter, K., M. Ralphs, D. Gardner, B. Stegelmeier, S. Lee, K. Welch, B. Green, T. Davis, and D. Cook. 2011. Plants poisonous to livestock in the Western States. USDA ARS Agricultural Information Bulletin Number 415. **https://www.ars.usda.gov/is/np/PoisonousPlants/PoisonousPlants.pdf**

Pfister, J.A., R.J. Molyneux, and D.C. Baker. 1992. Pyrrolizidine alkaloid content of houndstongue (*Cynoglossum officinale* L.). *Rangeland Ecology & Management/Journal of Range Management Archives* 45(3):254–256.

Provenza, F.D., and K.L Launchbaugh. 1999. Foraging on the Edge of Chaos. *Wildland Resources Faculty Publications.* Paper 1737. **https://digitalcommons.usu.edu/wild_facpub/1737**

Provenza, F.D., E.A. Burritt, A. Perevolotsky, and N. Silanikove. 2000. Self-regulation of intake of polyethylene glycol by sheep fed diets varying in tannin concentrations, *Journal of Animal Science* 78(5):1206–1212. **https://doi.org/10.2527/2000.7851206x**

Provenza, F.D. 2008. What does it mean to be locally adapted and who cares anyway. *Journal of Animal Science* 86(E. Suppl.):E271–E284. **https://doi.org/10.2527/jas.2007-0468**

Grassland Research Awards for Student Scholarships (GRASS):

Opportunities for Students and Donors to further our understanding of California's Native Grasslands

STUDENTS! The deadline for applications is January 31, 2021

Eligibility: Students from an accredited college or university doing research within California may apply (home institution may be outside CA). **Visit https://cnga.org/GRASSgrants for application information for 2020 Grants.**

Awards: CNGA will fund four or more $500 awards per year. These awards are designed to support basic undergraduate and graduate research in native grassland ecosystems.

DONORS! We need your help to support the Next Generation of Grassland Researchers

For more information or to make a donation visit **https://cnga.org/GRASSgrants**

Questions? Email admin@cnga.org or call (530) 902-6009

Ralphs, M.H., D.R. Gardner, and J.A. Pfister. 2000. A functional explanation for patterns of norditerpenoid alkaloid levels in tall larkspur *(Delphinium barbeyi*). *Journal of Chemical Ecology* 26(7):1595–1607.

Roche, L.M., T.K. Schohr, J.D. Derner, M.N. Lubell, B.B. Cutts, E. Kachergis, V.T. Eviner, and K.W.Tate. 2015. Sustaining working rangelands: Insights from rancher decision making. *Rangeland Ecology & Management* 68(5):383–389. **https://doi.org/10.1016/J.RAMA.2015.07.006**

Schoch, T.K., D.R. Gardner, G.D. Manners, J.A. Pfister, and M.H. Ralphs. 1998. Fourier transform infrared spectroscopy for the rapid analysis of toxic compounds in larkspurs and milkvetches. Pgs 243–248 *In:* Toxic Plants and Other Natural Toxicants, T. Garland and A.C. Barr (eds). CAB International: Wallingford, UK.

Sinton, S. 2020. Personal communications. Rancher, Rangeland Trust Founding Chairman. Avenales Cattle Co., PO Box 112, Shandon, CA

Stegelmeier, B.L., J.A. Edgar, S.M. Colegate, D.R. Gardner, T.K. Schoch, R.A. Coulombe, and R.J. Molyneux. 1999. Pyrrolizidine alkaloid plants, metabolism and toxicity. *Journal of Natural Toxins* 8(1):95–116.

Van Soest, P.J. 1994. Nutritional ecology of the ruminant. Comstock Publishing Associates, Cornell University Press: New York, NY.

Varga A, and B. Puschner. 2012. Retrospective study of cattle poisonings in California: Recognition, diagnosis, and treatment. *Veterinary medicine (Auckland, N.Z.)* 3:111–127. **https://doi.org/10.2147/VMRR.S28770**

Villalba, J.J., F.D. Provenza, A.K. Clemensen, R. Larsen, and J. Juhnke. 2011. Preference for diverse pastures by sheep in response to intraruminal administrations of tannins, saponins and alkaloids. *Grass and Forage Science* 66:224–236.

Welch, K.D., B.T. Green, D.R. Gardner, D. Cook, J.A. Pfister, and K.E. Panter. 2012. The effect of 7, 8-methylenedioxylycoctonine-type diterpenoid alkaloids on the toxicity of tall larkspur (*Delphinium* spp.) in cattle. *Journal of Animal Science*, 90(7): 2394–2401.

Photo 1: Excellent medusahead control 14 months after application in a plot treated with Esplanade. There is little vegetation growing in the plot and a lot of bare ground where the invasive annual grass population was controlled.

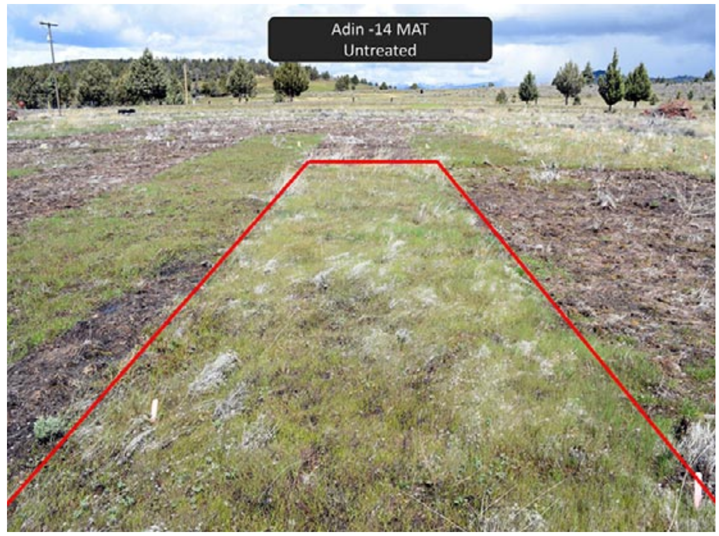


Photo 2: No medusahead control in the untreated check where no herbicide was applied. Observe the thick medusahead seedings growing through the previous year's thatch.

Multiple-Year Control of Medusahead on the Modoc Plateau

by Tom Getts[1]

Introduction

California is one of the most ecologically diverse states in the nation, as are its native grassland communities. Many of these native grassland communities are now under threat of invasion by weeds such as medusahead (*Elymus caput-medusae*), an invasive winter annual grass introduced to North America from Eurasia. While multiple introductions of medusahead are thought to have occurred, it was first recorded in Oregon (Howell 1903, Kyser et al. 2013). It has become a problematic species throughout many rangeland systems of California, Oregon, Nevada, Washington, and Idaho. Recently, the first populations of the grass were detected in the Great Plain ecosystems in northern Wyoming (Mellor et al. 2019). Medusahead is found on over 100,000 acres in California and continues to expand its range, displacing populations of more desirable species (Duncan et al. 2004).

Why is medusahead a problem? Like many other invasive winter annual grasses, such as cheatgrass (*Bromus tectorum*), red brome (*Bromus madritensis*), ripgut brome (*Bromus diadrus*), and ventenata (*Ventenata dubia*), medusahead can outcompete native plants and other more desirable forage species. Often being much more competitive on clay soils, medusahead can create a thick, persistent thatch layer that favors its own germination and growth while deterring the germination and growth of more desirable species (Young 1992). Old plant material (thatch/litter) decomposes slowly because medusahead can accumulate up to 10% silica in the aboveground plant parts (Bovey et al. 1961, Swenson et al. 1964). Silica is a major factor limiting its palatability for livestock and wildlife (Swenson et al. 1964). Another factor limiting palatability is the seed heads, which have long awns that can cause physical injury to the mouths of animals that eat them.

While medusahead is problematic throughout many of California's grasslands, it is one of the most invasive winter annual grass species in high elevation rangelands of the Intermountain Region. The Intermountain Region of California consists of parts of Lassen, Modoc, Plumas, Siskiyou, and Shasta counties, but is part of a larger geographic region including pieces of Oregon, Washington, Nevada, Utah, Idaho, Colorado, and Wyoming. Many of the ecosystems in the Intermountain Region historically were dominated by perennial bunch grasses and shrubs with very few annual grasses. Introduced winter annual grasses fill an empty niche by growing and capturing moisture and nutrient resources before perennial species break dormancy at these higher elevations. Medusahead, along with cheatgrass and ventenata, often exist as an intermixed complex, growing throughout the Intermountain Region of northern California. Their litter leads to an accumulation of fine fuels, which can carry fire in systems not historically adapted to frequent fire regimes. Ultimately, more frequent fires favor the establishment and persistence of the invasive winter annuals, forming a cycle of self-perpetuation (Janet 2017, Balch et al. 2013, Dustin and Davies 2012). Many other factors play into the invasion of winter annual grasses in these ecosystems, such as historical grazing regimes and other human-

continued next page

[1]Tom has worked for University of California Cooperative Extension for the past five years as Weed Ecology and Cropping Systems Advisor for Lassen, Modoc, Sierra, and Plumas Counties. His research and extension program is focused on weed control in the cropping systems and rangelands of the Intermountain Region of California.

Photo 3: In this plot treated with Panoramic (imazapic) 14 months after application there is good medusahead suppression in this replication. However, observe some medusahead seedlings coming back into the stand.

Photo 4: Twenty-five months after application there was still a lot of bare ground in treatments where Esplanade had suppressed medusahead. A no-till drill was used to make a second planting through this bare ground in April of 2018. (Seeded for the first time unsuccessfully in 2017.)

Multiple-Year Control of Medusahead on the Modoc Plateau *continued*

influenced disturbances on the landscape (Brandt and Rickard 1994). Impacts of these invasive annual grasses are widespread, creating monocultures that alter vegetation structure, fire regimes, and corresponding wildlife habitat.

Herbicides are often relied upon for invasive winter annual grass control. While burn down herbicides (activity on green plant tissue) can be used, products with soil residual activity (seed germination suppression) are often relied upon for extended control. It is a balancing act between controlling the invasive annual grass long enough while creating conditions favorable to release or establish more desirable species on the landscape. Throughout the Intermountain West, one of the most widely used and effective herbicides has been Plateau or Panoramic (imazapic). However, Panoramic is not registered for use in California, leaving landowners and land managers in the state with limited options. Matrix, or Laramie (rimsulfuron), is another herbicide that can be effective and was recently allowed for use on Bureau of Land Management properties. Both imazapic and rimsulfuron have soil residual activity but also can be effective at controlling very small recently emerged seedling grasses. While both of these products can be useful, they typically offer one year of annual

continued next page

Photo 5: This is a picture of red stem filaree, which came into some of the areas which had been treated with Esplanade. In the areas where other weeds took over (like filaree), there was little to no establishment of seeded perennial grasses.

Photo 6: These are intermediate wheatgrass seedlings that germinated in 2018 after adequate precipitation occurred following planting. Seedlings only germinated in areas where medusahead and other species were suppressed.

Photo 7: At the Willow Creek site, while Esplanade provided excellent control of medusahead, in two of the replications the non-desirable perennial broadleaf species (poverty weed and field bindweed) were released. Either established desirable or undesirable perennial species can be released from annual grass suppression following Esplanade application. The herbicide treatment to the left of the red line provided no medusahead control 27 months after application.

Photo 8: Intermediate wheatgrass plants 16 months after planting only established where there was bare ground created by Esplanade applications. Where medusahead was not controlled, or where other species grew, little desirable perennial grass establishment occurred.

Multiple-Year Control of Medusahead on the Modoc Plateau *continued*

grass control before the annual grass populations rebound, leaving a short window for releasing or reestablishing desirable species.

A new seed-germination-inhibiting herbicide, Esplanade 200 SC (indaziflam), has the potential to control medusahead effectively for multiple years. Sebastian et al. (2017) found Esplanade offered multiple-year control of cheatgrass with a single application, significantly longer than other herbicides tested. Greenhouse studies have shown high efficacy of Esplanade on medusahead seeds (Sebastian et al. 2016), but it was unknown if medusahead would be controlled in the field at the time this study was implemented in 2016. The primary purpose of conducting the research presented in the rest of the article was to test the long-term efficacy of Esplanade for medusahead control in two field trials.

While long-term control of invasive winter annual grasses is desirable, shifting the plant community to desirable species is ultimately the goal

continued next page

Photo 9: At the Adin site, medusahead began to break through Esplanade treatments 38 months following application, specifically encroaching on the side of the plots. However, there was still some annual grass suppression at this timepoint in the middle of the plot.

Photo 10: While Panoramic initially provided medusahead suppression, no long-term control was observed. On either side of this plot at the Willow Creek site, long-term medusahead suppression can be observed 38 months after Esplanade application.

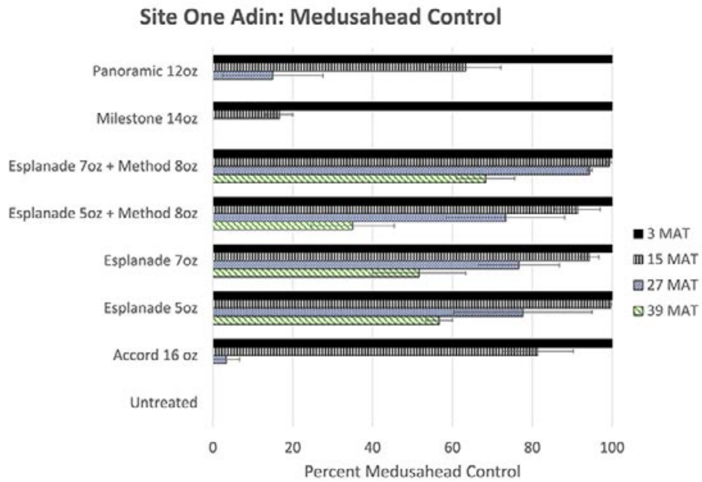


Figure 1: Visual estimate of medusahead control is depicted 3, 15, 27, and 39 months after treatment (MAT) at the Adin site. One hundred percent control indicates no medusahead growing within the treatment. Herbicides are listed as the amount of product per acre, and all were applied at 20gal/acre with 0.25% NIS in March of 2016. 3 MAT solid black bars, 15 MAT bars with vertical black stripes, 27 MAT bars with blue hash marks, and 39 MAT bars with diagonal green stripes. Error bars indicate standard error of the mean.

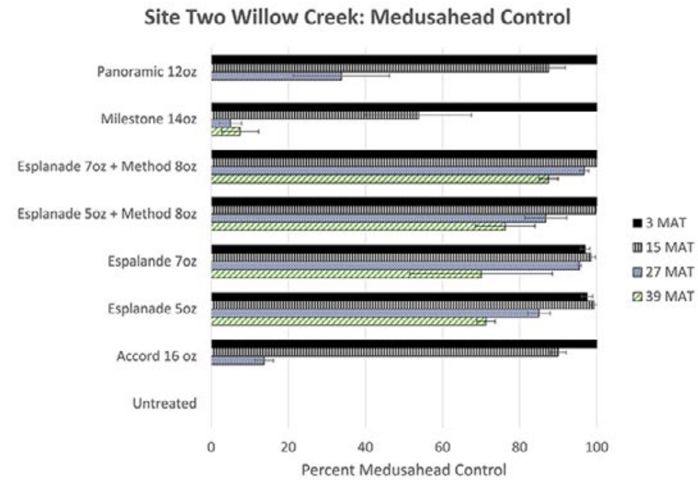


Figure 2: Visual estimate of medusahead control is depicted 3, 15, 27, and 39 months after treatment (MAT) at the Willow Creek Site. One hundred percent control indicates no medusahead growing within the treatment. Herbicides are listed as the amount of product per acre, and all were applied at 20gal/acre with 0.25% NIS in March of 2016. 3 MAT solid black bars, 15 MAT bars with vertical black stripes, 27 MAT bars with blue hash marks, and 39 MAT bars with diagonal green stripes. Error bars indicate standard error of the mean.

Multiple-Year Control of Medusahead on the Modoc Plateau *continued*

of any management action. In areas where perennial grasses and forbs are already established, applications of Esplanade may release desirable species from invasive annual grass competition, as in research conducted in Colorado (Clark et al. 2019, Sebastian et al. 2017). However, many areas that are dominated by invasive annual grasses do not have a remnant perennial plant community to be released. In areas without remnant desirable vegetation, shifting the plant community to desirable species may require seeding or transplanting the desirable species on site. Given this, a secondary factor of interest was to evaluate the ability to re-establish desirable perennial grass species by drill seeding areas that had been sprayed with herbicides.

Methods

Field trials were implemented at two locations (Willow Creek and Adin) in the Intermountain Region of California in March of 2016. Both sites were in medusahead-dominated pastures, with few other species visible during site selection. The Willow Creek site was directly adjacent to Goose Lake in Modoc County, and the other site was south of the city of Adin in Lassen County. Seven herbicide treatments and an untreated control were laid out in a randomized complete block design, with four replications of each treatment in 10*40 ft. plots. The total plot size was 80*160 ft. at each study location. Applications were made with a CO_2-pressured backpack sprayer with a handheld boom with 6, 11002 flat fan nozzles, at 20gal/acre. Accord XRT (glyphosate) at 16oz/acre was applied with all residual herbicides in March and again in May of 2016, to kill the emerged medusahead and prevent seed production during the growing season of 2016. Residual herbicides tested included two rates of Esplanade 200 SC (indaziflam), two rates of Esplanade 200 SC + Method 240 SL (aminocyclopyrachlor), Panoramic (imazapic), and Milestone (aminopyralid). All herbicide applications included Induce, a non-ionic surfactant at 0.25% v/v. The percent of medusahead control was visually evaluated compared to untreated control plots during June in 2016, 2017, 2018, and 2019 (Figures 1 and 2).

Five native and three introduced perennial grasses were strip-seeded at a depth of 0.5 inches with a Truax® no-till drill in May of 2017. Species names and seeding rates can be found in Table 1. Species were selected after conversations with the local land manager, based on previous seeding efforts. Little germination of seeded grasses occurred during the growing season of 2017, so plots were reseeded in April of 2018. Seeding strips were made perpendicular to the herbicide treatments, with each species being planted separately in a 4 ft. swath through the herbicide treated areas. Stand counts were conducted in 2017 and 2018 at the whole plot level (we counted every seedling per plot in the 4*10 ft. seeded area). In 2019 where intermediate wheatgrass (*Elymus hispidus*) had been planted, in each plot, the aboveground biomass was harvested in a $0.5m^2$ quadrat at the ground level with a sickle and separated into classes of species.

Results and Discussion

Medusahead control was initially achieved at both locations in all herbicide treatments three months after application (Figures 1 and 2). The excellent control could be attributed to the applications of Accord XRT in March and May of 2016 to kill all emerged vegetation and prevent seed production in order to prepare for planting. In 2017,

continued next page

fifteen months after treatment (MAT), not all herbicide treatments offered the same level of medusahead control. Milestone provided some suppression of medusahead (50% control) at the Willow Creek site, but little suppression at the Adin location. Panoramic provided good suppression (65–85% control) at both locations 15 MAT, which is consistent with results from Panoramic applications in other research. Esplanade provided excellent control of medusahead in all treatments at both locations 15 MAT (greater than 80%). Twenty-seven MAT, only herbicide treatments that included Esplanade provided any medusahead control, as all other treatments had lost efficacy. In the third growing season after treatment, 39 months after application, the 7oz rate of Esplanade provided greater than 50% medusahead control at the Adin site and better than 70% control at the Willow Creek site. Generally, medusahead was still controlled within the center of the plots, with medusahead encroaching on the edges of the plots (Photo 9). The long-term activity of Esplanade on medusahead was slightly shorter than the activity shown from other research on cheatgrass (Sebastian et al. 2017). However, Esplanade was much more active than all other herbicide treatments tested in the second and third growing seasons after application.

Table 1: Perennial grass species plants, and the number of pure live seeds planted per acre. Planting rates were taken from *Dryland Pasture Manual* guidelines (Wilson et. al. 2006).

Perennial Grass Species Planted	Native/Introduced	Live Seed/Acre (lbs.)
Sherman big bluegrass (*Poa secunda*)	Native	3
Bluebunch wheatgrass (*Elymus spicatus*)	Native	8
Hycrest crested wheatgrass (*Agropyron cristatum*)	Introduced	5
Great Basin wildrye (*Elymus cinereus*)	Introduced	8
Intermediate wheatgrass (*Elymus hispidus*)	Introduced	12
Russian wildrye (*Psathyrostachys juncea*)	Introduced	6
Squirrel tail (*Elymus elymoides*)	Native	7
Western wheatgrass (*Elymus smithii*)	Native	6

At the time of the trial, it was unknown if seeding perennial grasses into an area that had been treated with Esplanade could be successful. The first seeding occurred in May of 2017, as soon as the field site was dry enough to plant after winter rains. Unfortunately, there was little to no precipitation following planting and very few grass seedlings emerged. As medusahead control continued to be successful into the 2018 growing season, a second planting occurred in April of 2018. Both research sites received precipitation and many of the planted grasses germinated at both sites (Table 2).

Generally, out of the species planted, the best germination and establishment occurred for intermediate wheatgrass and western wheatgrass (*Elymus smithii*) (Table 2). Establishment only occurred in plots where there was effective medusahead control. We observed little to no establishment of the seeded perennial grasses in plots where seedlings had to compete with the invasive annual grasses or other vegetation during the growing season of 2018. The long residual activity of Esplanade provided multiple-year control of the invasive annual grasses and, correspondingly, multiple years of opportunity to successfully seed perennial grasses. However, it is still unknown how soon successful drill seeding can occur after application. Considering that Esplanade inhibits seedling germination, it is speculated that broadcast seeding would not be as effective as drill seeding, as drill seeding may place the seed below the herbicide residue.

During the 2019 growing season, it was clear that intermediate wheatgrass had established the best at both sites compared to other species seeded. Biomass was only harvested in the intermediate wheatgrass strips to demonstrate the best case scenario of shifting the plant community to a perennial species (even if non-native). Intermediate wheatgrass biomass was much higher where medusahead had been controlled with Esplanade at both sites, with

continued next page

Table 2: The number of seedlings counted in each plot for each herbicide treatment, averaged across both sites, for the 2018 growing season.

2018 Number of Seedlings Per Plot Averaged Across Both Sites

Treatment	Hycrest crested wheatgrass	Intermediate wheatgrass	Russian wildrye	Western wheatgrass	Great Basin wildrye	Blue bunch wheatgrass
Accord 16oz	1	3	18	0	0	0
Esplanade 5oz	8	83	7	60	3	32
Esplanade 7oz	1	30	1	18	0	0
Panoramic 12oz	0	11	0	0	0	1
Esplanade 5oz + Method 8oz	7	37	8	57	2	10
Esplanade 7oz + Method 8oz	2	33	10	27	1	16
Untreated	0	1	0	0	0	0

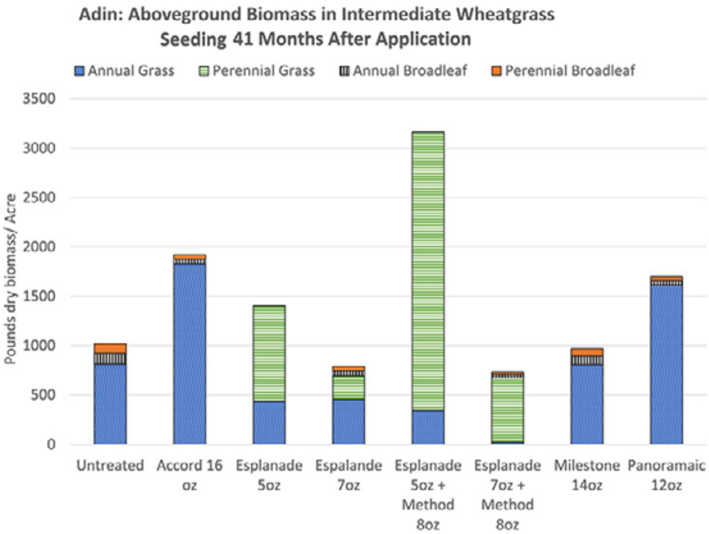


Figure 3: Adin — Pounds of dry biomass per acre, for annual broadleafs (vertical black stripes), perennial broadleafs (orange solid), annual grasses (blue and white dots), and perennial grasses (horizontal green stripes) 41 months after treatment in the intermediate wheatgrass seeding.

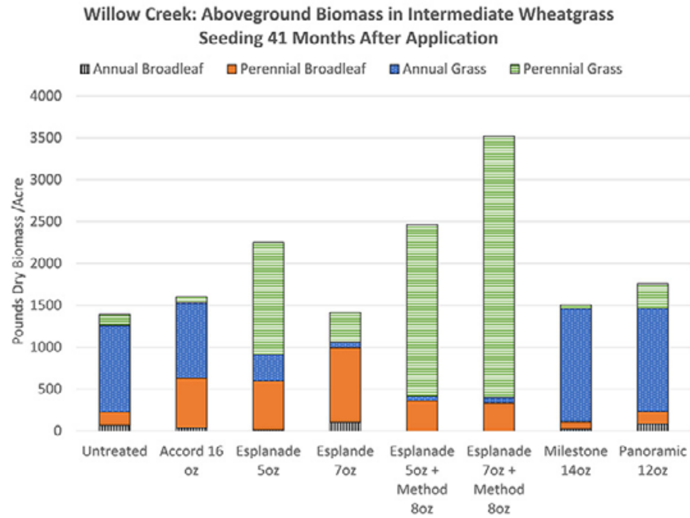


Figure 4: Willow Creek — Pounds of dry biomass per acre, for annual broadleafs (vertical black stripes), perennial broadleafs (orange solid), annual grasses (blue and white dots), and perennial grasses (horizontal green stripes) 41 months after treatment in the intermediate wheatgrass seeding.

Multiple-Year Control of Medusahead on the Modoc Plateau *continued*

little establishment in other treatments where medusahead continued to dominate the site (Figures 3 and 4). However, the success of intermediate wheatgrass establishment was variable between the Esplanade treatments, although it was always more successful than the untreated control and other herbicide treatments.

Variability in intermediate wheatgrass establishment and corresponding biomass could have been negatively influenced by other annual broadleaf species, which had invaded parts of the plots after the medusahead was controlled (Photo 5). Additionally, at the Willow Creek site, there were two perennial broadleaf species, field bindweed (*Convolvulus arvensis*) and poverty weed (*Iva axillaris*), that were released from annual grass competition in two of the replications of the trial, which may have influenced perennial grass establishment. Generally, established perennial species are tolerant to the seedling germination inhibitor Esplanade (Sebastian et al. 2017) and either desirable or undesirable perennial species may be released from annual grass competition after application (Photo 7).

We included introduced perennial grasses in this trial as they are often establishing more successfully than native species, but still provide the functional benefit of a perennial grass ecosystem. In this trial, intermediate wheatgrass was the most successful and robust species planted. The native species, western wheatgrass and blue bunch wheatgrass, also established initially but were less robust. Ideally, medusahead would be replaced with native grasses, but any competitive perennial grass is more desirable than the invasive winter annual. Perennial grasses provide forage for wildlife and livestock, and they stay green much later into the season, reducing the risk of wildfire. Considering the lack of consistent success with dryland plantings and the associated cost, we wanted to evaluate both native and non-native species, as any perennial grass could be more beneficial than medusahead.

From this trial, we found Esplanade provided better long-term control of medusahead than other herbicides tested, with up to 70% control at one site 39 months after application. The ability to offer multiple years of annual grass suppression creates the potential for drill seeding desirable species over multiple growing seasons. This is a large benefit as dryland seedings often fail if adequate precipitation does not occur. However, it is still unknown how soon seeding may occur through herbicide residue without injury to the desirable grasses seeded. While

continued next page

Photo 11: Some strips of perennial grasses were able to establish in the plots where Esplanade provided suppression. This picture is 38 months after herbicide applications.

Sebastian et al. (2017) found desirable perennial species were released by Esplanade applications, at one site in this study undesirable perennial species were released (Photo 7). It is important to know what other species, aside from the targeted weeds, are on-site to predict species shifts in areas where Esplanade applications may be made. In areas with little desirable perennial vegetation, seeding may be needed to shift the plant community to a desirable state, and it may be important to budget for multiple seeding attempts in a dryland site. This trial showed the ability to control medusahead in plots treated with Esplanade, creating bare ground which was essential for perennial grass establishment. However, there are many potential environmental consequences (erosion, degradation, etc.) when creating bare ground for multiple years if desirable vegetation is not established quickly. Esplanade should be used cautiously in areas without established perennial vegetation because of these risks. There may be a good fit for using Esplanade to create firebreaks, in strips on the landscape, or where desirable perennial species are already established. Over the coming years, there is ample opportunity for further research and optimization of this tool for medusahead control.

Bibliography

Balch, J., B. Bradley, C., D'Antonio, and J. Gómez Dans. (2013). Introduced annual grass increases regional fire activity across the arid western USA (1980–2009). *Global Change Biology* 19:173–183

Bovey, R., D. Le Tourneau, and L. Erickson. (1961). The chemical composition of medusahead and downy brome. *Weeds* 9(2):307–311. **https://doi.org/10.2307/4040420**

Brandt, C.A., and W.H. Rickard. (1994). Alien taxa in the North American shrub-steppe four decades after cessation of livestock grazing and cultivation agriculture. *Biological Conservation* 68:95–105

DELTA BLUEGRASS CO.
DBC
EST. 1978

Clark, S., D. Sebastian, S. Nissen, and J. Sebastian. (2019). Effect of indaziflam on native species in natural areas and rangeland. *Invasive Plant Science and Management* 12(1):60–67. **https://doi.org/10.1017/inp.2019.4**

Duncan, C., J. Jachetta, M. Brown, V. Carrithers, J. Clark, J. DiTomaso, R. Lym, K. McDaniel, M. Renz, and P. Rice. (2004). Assessing the economic, environmental, and societal losses from invasive plants on rangeland and wildlands. Weed Technology, 18(sup 1):1411–1416.

Fryer, J.L. (2017). Ventenata dubia. *In:* Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Missoula Fire Sciences Laboratory (Producer). Available at: **https://www.fs.fed.us/database/feis/plants/graminoid/vendub/all.html**

Howell, T.J. (1903). A Flora of Northwest America. Self-published. Portland, Oregon.

Johnson, D., and K. Davies. (2012). Medusahead management in sagebrush–steppe rangelands: Prevention, control, and revegetation. *Rangelands* 34(1):32–38.

Kyser, G., J. DiTomaso, K. Davies, J. Davy, and B. Smith. (2014). Medusahead management guide for the western states. University of California, Weed Research and Information Center, Davis. 68 p. Available at: **https://wric.ucdavis.edu/publications/MedusaheadManagementGuide_pub_2014.pdf**

Mealor, B., B. Fowers, and L. Sander. (2019). Medusahead and ventenata in the northern Great Plains ecoregion: Invasion history and management efforts. *Techline News.* Available at: **https://update-techline.squarespace.com/resources/2018/medusahead-and-ventenata-in-the-northern-great-plains-ecoregion-invasion-history-and-management-efforts**

Sebastian, D., S. Nissen, and J. De Souza Rodrigues. (2016). Pre-emergence control of six invasive winter annual grasses with imazapic and indaziflam. *Invasive Plant Science and Management* 9(4):308–316. **https://doi.org/10.1614/IPSM-D-16-00045.1**

Sebastian, D., M. Fleming, E. Patterson, J. Sebastian, and S. Nissen. (2017). Indaziflam: A new cellulose biosynthesis inhibiting herbicide provides long-term control of invasive winter annual grasses. *Pest Management Science* 73(10):2149–2162. **https://doi.org/10.1002/ps.4594**

Sheley R., and J. James. (2010). Resistance of native plant functional groups to invasion by medusahead (*Taeniatherum caput-medusae*). *Invasive Plant Science and Management* 3(4):294–300.

Swenson, C., D. Tourneau, and C. Lambert. (1964). Silica in medusahead. *Weeds* 12(1):16–18.

Whisenant, S.G. (1990). Changing fire frequencies on Idaho's Snake River plains: Ecological and management implications. Pgs 4–10 *In:* Proceedings: Symposium on Cheatgrass Invasion, Shrub Die Off, and Other Aspects of Shrub Biology and Management, E.D. McArthur, E.M. Romney, S.D. Smith, and P.T. Tueller (eds.). General Technical Report INT 276. Ogden, UT: US Department of Agriculture, Forest Service Intermountain Research Station.

Wilson, R., D. Lile, D. Drake, S. Orloff, D. Lancaster, H. George, R. Delmas, and A. Bower. (2006). Dryland pastures: Establishment and management in the intermountain region of Northern California. University of California Division of Agriculture and Natural Resources, Publication 8163.

Young, J.A. (1992). Ecology and management of medusahead (*Taeniatherum caput-medusae* ssp. *asperum* [Simk.] Melderis). *Great Basin Naturalist* 52(3):245–252.

MEET A GRASSLAND RESEARCHER **Roxanne Hulme Foss**

Senior Ecologist with Vollmar Natural Lands Consulting roxanne@vollmarconsulting.com

What is your study system?

I have had the opportunity to work in diverse grasslands throughout California as a researcher, land manager, and consultant. The majority of my work has focused on the relationship between California grassland plant communities and land management practices, particularly grazing. The relationship is often complex, political, and nuanced. Each field site I've had the chance to study adds a layer to my understanding of and appreciation for this complexity: from cattle roaming the expansive Tejon Ranch to targeted goat grazing of pocket vernal pool preserves within cities. I am currently collaborating with UC researchers to study the relationship between residual grassland biomass and fire behavior in the central Coast Range, north Coast Range, and the central Sierra Nevada foothills.

What are your primary research goals?

In general, I seek to utilize the best available scientific approaches to answer specific questions that engaged land managers have asked. The questions often revolve around removing, protecting, or promoting a specific species or community. I try to answer these questions by utilizing existing environmental spatial data to characterize a site, conducting field surveys to fill knowledge gaps, and applying analysis and modeling approaches tailored to the question at hand. In an example of this approach, I developed a predictive model to identify grasslands with high native grass and forb diversity based on field survey results and associated environmental parameters. My current research focuses on addressing a critical data gap in grassland fire science: "What level of biomass effectively reduces wildfire risk?"

Who is your audience?

The goal of my current research endeavor is to provide land managers and livestock operators with a biomass target for areas with high fire risk, such as lands in the wildland-urban interface or adjacent to utility lines. I believe partnerships between scientists, land managers, resource specialists, and livestock producers are critical to addressing land conservation, sensitive species management, and fire hazard reduction in California.

Who has inspired you, including your mentors?

I have been fortunate to have many mentors and inspirational colleagues that have helped me hone and direct my interests. I would be remiss to discount the foundation that my parents provided for me: my father, a park ranger with ranching roots, identifying plants on everyday walks; and my mother, a landscaper and water conservation coordinator, timing my showers and designing water-wise gardens. My interest in grasslands grew during my first years working for Vollmar Natural Lands Consulting (VNLC) when I surveyed ranches with operators whose families had tended lands teeming with native and rare species for many generations. I was also fortunate enough to work under Dr. Bartolome at UC Berkeley and deeply appreciate his ongoing commitment to answering so many questions and sparking new ones.

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"?

I hope that my current research into the relationship between grassland biomass and fire behavior will allow land managers to target grazing in key areas to reduce wildfire hazards while reducing impacts to larger swaths of rangelands that provide a diverse suite of ecosystem services. I also plan to further develop my initial work on a native grassland predictive model to better identify these communities, promote their protection, and support the restoration of areas that may have higher success based on underlying environmental factors.

Why do you love grasslands?

I love that grasslands require commitment from their fans: keying graminoids is not for the faint of heart and locating the full suite of species in a grassland requires crawling on hands and knees, or better yet, sliding on your belly. I also love the seasonal mood changes of California grasslands: the exuberant spring with a rotating cast of showy forbs, the languid summer spent waiting for rain, the anxious fall of germination, and the optimistic green of winter.

JOIN ❊ RENEW ❊ DONATE

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.

For 30 years, the California Native Grasslands Association has represented people concerned with the continued loss and degradation of California's grasslands, the most threatened ecosystem in California. Our dedicated Board of Directors volunteer their valuable time to educate and promote awareness of the beauty and importance of healthy grassland ecosystems.

Three ways to make your gift:

1. **Online** — cnga.org
2. **By Mail** — send your check or credit card information to: CNGA, PO Box 485, Davis CA 95617
3. **By Phone** — call us at (530) 902-6009 with your credit card info

Kamprath Seeds inc.

Wholesale distributor of cover crop mixes, irrigated and dryland pasture mixes, and forage blends in California.

1-800.466.9959

www.kamprathseed.com

Sun City Lincoln Hills Community Association

965 Orchard Creek Lane, Lincoln, CA 95648
916-625-4000; www.suncity-lincolnhills.org

Active adult retirement community

It's more than a place to live. It's a way to live.

We protect and preserve the 500 acres of open space and preserved wetlands, riparian, and oak-woodlands that surround Sun City Lincoln Hills. You can go to HTTP://WILDLIFEHERITAGE.ORG for more information.

HANFORD

Hanford is a licensed general engineering and landscape contractor specializing in ecological restoration and heavy civil construction in environmentally and culturally sensitive areas.

765 BAYWOOD DR, SUITE 237 PETALUMA, CA 94954
707.996.6633 | WWW.HANFORDARC.COM

CNGA's Bunchgrass Circle

A Special *Thank You* to our Bunchgrass Circle Members!

As a nonprofit organization, CNGA depends on the generous support of our Corporate and Associate members. Ads throughout the issue showcase levels of Corporate membership ($1,000, $500, $250). Associate members ($125) are listed below. Visit www.cnga.org for more information on joining at the Corporate or Associate level.

Corporate Members

Muhlenbergia rigens

Delta Bluegrass Company
Hedgerow Farms
S & S Seeds

Stipa pulchra

Dudek
Habitat Restoration Sciences
Hanford Applied Restoration & Conservation
Kamprath Seeds
Pacific Coast Seed

Poa secunda

Deborah Shaw Restoration + Landscaping, Inc.
Ecological Concerns Inc.
Golden Gate National Parks Conservancy
Grassroots Erosion Control
Joni L. Janecki & Associates, Inc.
Marin Municipal Water District
Pacific Restoration Group, Inc.
Precision Seeding
Sun City Lincoln Hills
Westervelt Ecological Services
WRA, Inc.

Associate Members

Carducci Associates
City of Davis
CNPS, Los Angeles Chapter
Djerassi Resident Artists Program
East Bay Regional Park District
Steven Foreman, LSA
Friends of Alhambra Creek, Martinez, CA
Jim Hanson, Landscape Architect/Land Conservation
Irvine Ranch Conservancy
Master Gardener Program, UCCE, Mariposa County
McConnell Foundation
Michael Oguro, Landscape Architect
Miridae — Design/Build Landscaping Services
Oakridge Ranch, Carmel Valley
OC Parks, Orange County, CA
Olofson Environmental, Inc
Orinda Horsemen's Association
Ozark Hills Insurance
Putah Creek Council
Roche + Roche Landscape Architecture
Ronny's Inc. Landscaping
Sacramento Regional County Sanitation District
San Luis National Wildlife Refuge Complex
Saxon Holt Photography
Sequoia Riverlands Trust
Sierra Foothill Conservancy
Solano County Water Agency
Sonoma County Agricultural Preservation & Open Space District
Sonoma Mountain Institute
Sonoma Mountain Ranch Preservation Foundation
Tassajara Veterinary Clinic
The Watershed Nursery
Truax Company, Inc
Yolo County Flood Control and Water Conservation District
Yolo County Resource Conservation District
Zentner and Zentner

California
Native
Grasslands
Association

P.O. Box 485
Davis, CA 95617
www.CNGA.org

NON PROFIT ORG
U.S. POSTAGE
PAID
TUCSON, AZ
PERMIT NO. 3341

FSC
The mark of responsible forestry
10% Post Consumer Waste

Selecting Coastal California Prairie Species for Climate-Smart Grassland Restoration — page 4

Front cover: Fresh snow blankets a dormant grassland on top of Sonoma Mountain in Sonoma County. *Photo: Jeffery T. Wilcox, Managing Ecologist, Sonoma Mountain Ranch Preservation Foundation, Former CNGA Board Member.*

Back cover: Purple needlegrass (*Stipa pulchra*) at the UC Hasting Reserve, January 2020. *Photo: Jesse Miller. Department of Biology, Stanford University.*