



California
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Grasslands
Association

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Mission Statement

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

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From the President's Keyboard

I hope this note finds you well and safe during the Coronavirus pandemic.

Following the orders and recommendations of health organizations, we are moving most of our events to an online platform. A positive outcome of the pandemic is that online workshops and events are accessible to a larger group of people. Those who cannot attend in person, whether because they live too far or don't have the time or funding to travel, can still participate. In the post-pandemic future, we hope to incorporate online components or live feeds to our events.

Like many others, the economic crisis has touched our organization as well, so if you can donate, we would greatly appreciate any donation so we can keep offering quality workshops.

I hope you had opportunities to explore some of California's unique ecosystems over the Spring. Share your pictures if you have them!

Changes to the Executive Committee of CNGA:

The Board of Directors of the CNGA would like to extend our recognition and appreciation to Andrea Williams for her years of service. Effective June 1, 2020, Andrea resigned from her position as Board President due to professional commitments. Starting as a Director in 2014 through 2015, Andrea then joined the Executive Board as Vice President in 2016–2017 and served as President from 2018 to June 1, 2020.

Over the past years, Andrea taught our Grass ID and Apps & Snaps workshops and led walking tours at CNGA's Field Day at Hedgerow Farms. Andrea is an inspirational advocate for California's native grasslands, and we are truly grateful for her service on the CNGA Board and her continued membership and leadership in our Association. We're sure you will join us in expressing our gratitude for her contributions to CNGA.

continued next page

"Grass is what holds the earth together."

— Pamela M. Henson

Historian, Institutional History Division, Office of Smithsonian Institution Archives [in *Forward to Agnes Chase's First Book of Grasses*, Fourth Edition, 1996, by Lynn G. Clark and Richard W. Pohl.]

**Don't miss the articles by CNGA GRASS*
recipients on pages 3 & 8.**

***Grassland Research Awards for Student Scholarship**
Inspiring the Next Generation of Grassland Researchers



Andrea Williams (second from left) and botanical team identifying grassland plants at SoulaJule Reservoir in Marin County, May 2010. Photo by Jim Coleman

From the President's Keyboard *continued*

As your past-President and current Vice President, I have accepted the position of President of CNGA. Andrea's passion for botany and native ecosystems, her dedication to CNGA and her friendly personality made her a valuable asset to our organization, and we are sorry to see her go but know that she is staying close in our hearts — *J.P. Marié*

Andrea is a technically excellent botanist who is dedicated to her craft. She worked tirelessly for CNGA and helped to improve it in many ways. Her high-quality work and keen sense of humor will be sorely missed on the CNGA board. — *Pat Reynolds, Board of Directors*

I first met Andrea in 2010 when she graciously assisted a small team of botanists I was working with to identify and map coastal prairie vegetation in Sonoma and Marin Counties (see photo). Her botanical knowledge seems endless, and she peppers her instruction with a good dose of humor, both of which she displays in the [12-part blog series on grasses](#) she wrote for Marin Municipal Water District. It has been a pleasure working with her then and at CNGA. — *Diana Jeffery, Administrative Director*

Stay healthy. Stay safe.

JP Marié & the entire Board of CNGA

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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:

Fall 2020: 15 Aug 2020 * **Winter 2021:**
15 Nov 2020 * **Spring 2021:** 15 Feb 2021
* **Summer 2021:** 15 May 2021

STUDENT RESEARCH

CNGA Grassland
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Winner, 2019
MADDIE NOLAN

The Impact of Drought and Pocket Gophers on Restored Native Perennial Bunchgrasses in California

by Madeline Nolan¹ and Travis Stoakley²

Abstract

Interactions between native animals and plants are likely to have large impacts on the success of restoration projects, however, interactions are understudied. For example, *Thomomys bottae* (valley pocket gopher) is a native rodent that is commonly found in grassland ecosystems in California and is known to have a large impact on the structure of these communities. To improve future restoration success, it is important to understand how valley pocket gophers impact restored grassland plants. Extreme droughts that are predicted to

increase in the future may also affect valley gopher activity. We sought to explore the interactive impacts of valley pocket gophers and drought on restored *Stipa pulchra* (purple needlegrass) by comparing how gopher activity and different watering treatments impacted the growth and reproduction of purple needlegrass in a field experiment. We found that valley pocket gophers have a significant negative impact on the growth and reproduction of purple needlegrass, especially during dry years. This suggests that valley pocket gopher activity will be a larger problem for restoration during dry years, and during these years, damage could be minimized by caging sensitive plants or watering seedlings. Our results highlight the importance of including animal effects into restoration planning to improve plant establishment rates and increase the overall success of restoration efforts.

¹Madeline Nolan is a doctoral candidate at UC Santa Barbara in the Department of Ecology, Evolution, and Marine Biology (EEMB). ²Travis Stoakley is an undergraduate student at UC Santa Barbara, also in the EEMB department.

Introduction

Grasslands cover approximately 17% of California with most of this area dominated by exotic annual grasses (Huenneke 1989). Many native species that were once widespread are now typically found in isolated pockets and thinly scattered among dense exotic annual grasses (D'Antonio *et al.* 2007). These exotic-dominated grasslands also tend to persist rather than convert back to perennial communities (D'Antonio and Vitousek 1992, Stromberg and Griffin 1996, Seabloom *et al.* 2003), suggesting that active restoration is needed to reestablish native grassland communities. The state grass of California, purple needlegrass, is one of the most commonly targeted species in restoration. Purple needlegrass, and some other perennial grasses, have been the focus in grassland restoration for two main reasons. First, individuals can survive for hundreds of years (Hamilton *et al.* 2002), which makes them more likely to be persistent and stable through time compared to annual species. Second, perennial grasses form the structural basis for native grassland communities (Stromberg *et al.* 2007, Molinari and D'Antonio 2013). Therefore, it is important to explore what ecological factors can promote or impede the establishment, growth, and reproduction of this important grassland species. Interactions between native animals and restored plant communities are likely to have large impacts on the success of restoration projects; however, interactions between the two have been historically understudied in restoration ecology. Animals are also often excluded from restoration planning because it is assumed that by restoring the structure of the plant communities, the restored community will be recolonized or be more amenable to recolonization by native fauna (i.e. field of dreams hypothesis

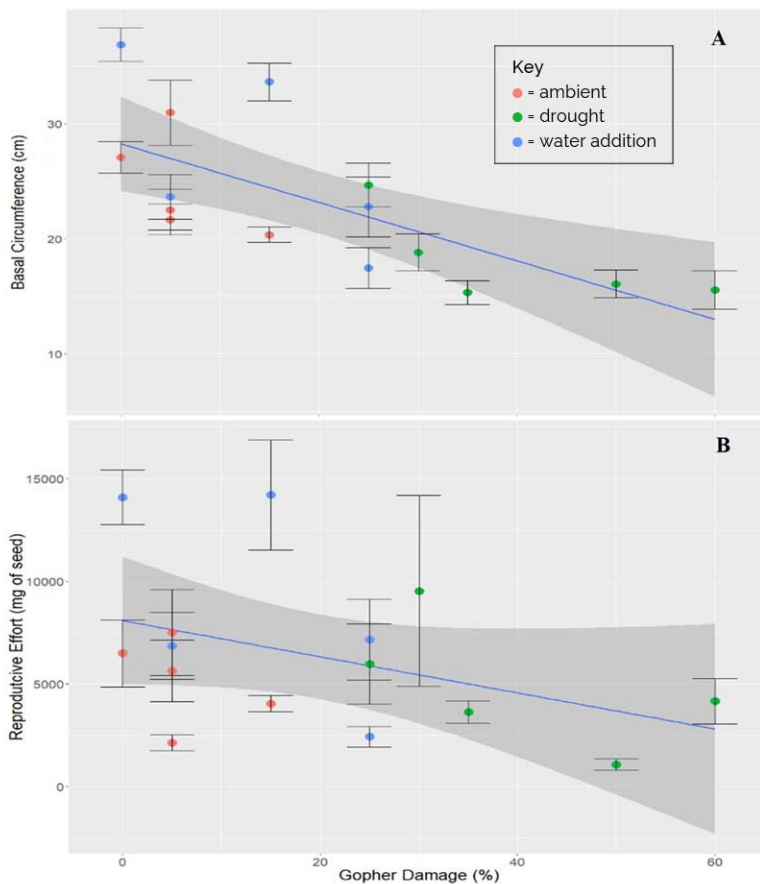


Figure 1. The impact of gopher disturbance on the basal circumference (A) and reproductive effort (B) of *S. pulchra*. Basal circumference was measured at the base of each bunch and the reproductive effort was the total seed mass produced by each plant. The line represents a multiple linear regression including watering treatment and the grey shaded area is the 95% confidence interval.

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Impact of Drought and Pocket Gophers on Restored Native Perennial Bunchgrasses

continued

Hilderbrand *et al.* 2005, Hale and Swearer 2017). While there has been a steady uptick in published work on animals in restoration since the 1970s (Majer 1990), often the focus is on monitoring animals as opposed to exploring how they impact and affect ecosystem functions (Majer 2009). Relationships between animals and plant communities in California grasslands could be especially helpful in shedding light on why grassland restoration efforts often fail to successfully establish native plants.

The valley pocket gopher is an herbivorous rodent native to California with a range that extends from the southern Cascades mountains to northern Mexico (Álvarez-Castañeda 2010). Valley pocket gophers live in grassland ecosystems that were historically composed of perennial grasses such as purple needlegrass, but now tend to be dominated by exotic European annual grasses (Stromberg and Griffin 1996). Most of the year, the diet of valley pocket gophers is composed of up to 70% plant shoots (Burton and Black 1978). The removal of plants by gophers, in turn, can have a large impact on the survival of newly planted grass seedlings in a restoration project. Previous exclosure studies have shown that valley pocket gophers limit both forb abundance and community biodiversity in grassland ecosystems (Cox and Hunt 1992). Pocket gophers tend to favor feeding locations with the greatest floral biomass, reducing vegetation by over one-third in areas located above active burrows (Reichman and Smith 1985). This is particularly concerning for ecosystem restoration because if pocket gophers decrease the survival of plants that have been planted during a restoration project, this could negatively impact the long-term outlook for projects that are near large populations of gophers.

It is also important to understand how native animals impact restoration projects because these interactions are likely to interact with the effects of climate change. Precipitation is expected to be the largest driver of change in California grassland communities in the future (Dukes and Shaw 2007, Carter and Blair 2012, Harrison *et al.* 2015), becoming more variable with a greater likelihood of severe weather events such as droughts (AghaKouchak *et al.* 2014). Prior studies have found surface access-tunnel production by gophers to be uncorrelated with temperature or precipitation (Cox and Hunt 1992), but we have seen evidence of increased activity during dry years in previous experiments (D'Antonio unpublished). In addition, research on valley pocket gophers in California grasslands has demonstrated that gophers can promote exotic annual species (Seabloom and Richards 2003) and decrease the growth of native perennial bunchgrasses through their foraging activity (Stromberg and Griffin 1996, Watts 2010). However, it is unclear how these impacts on exotic and native plants will be affected by drought. Our goals

were to understand how water availability impacted gopher activity and how both affect restored purple needlegrass communities. We were specifically interested in understanding how drought and gophers affected purple needlegrass seedlings that had been transplanted into the field, as opposed to populations started from seed. To accomplish this, we manipulated water availability for adjacent restored grassland plots over three years. We measured individual basal circumference and total seed weight of purple needlegrass as proxies for biomass and reproductive output, respectively. After three years, we recorded the amount of gopher disturbance in each plot as a function of total coverage. This field experiment was conducted to answer (1) how water availability in a restored grassland affected gopher activity, and (2) how gopher activity impacts the growth and reproductive output of purple needlegrass that have been transplanted into the field. These metrics are vital for creating a more accurate model for restoration planning in grassland ecosystems, thereby helping to inform

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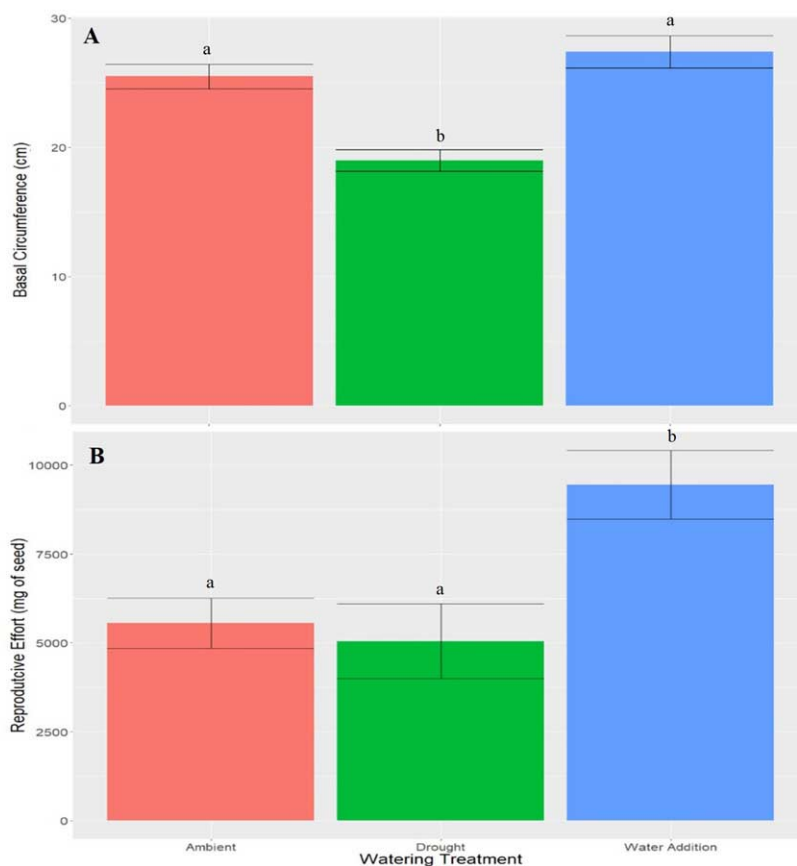


Figure 2. The impact of watering treatment on the basal circumference (A) and reproductive effort (B) of *S. pulchra*. The ambient treatment was the control, the drought treatment received a 50% reduction in precipitation, and the water addition treatment received an additional 4 weeks of water at the end of the growing season. Error bars indicate \pm SE with letters indicating significant differences as measured by an Analysis of Variance.

Impact of Drought and Pocket Gophers on Restored Native Perennial Bunchgrasses

continued

restoration planners on strategies to mitigate potential losses to pocket gopher damage in future projects.

Experimental Design

Study Area

Our work was conducted in the Santa Ynez Valley at the Sedgwick Reserve, a 2,358-hectare reserve managed by the University of California (<https://sedgwick.nrs.ucsb.edu/>). The Santa Ynez Valley is located 35 miles NE of Santa Barbara between the Santa Ynez and San Rafael mountain ranges. The region has a Mediterranean climate with hot, dry summers and cool, wet winters. The majority of the mean annual precipitation (400 mm) falls between October and April, with the rest of the year periodically experiencing seasonal summer fog with little to no rainfall.

Valley Pocket Gopher

The valley pocket gopher is an herbivorous rodent native to California (Álvarez-Castañeda 2010) and tends to live in grassland ecosystems. The diet of pocket gophers is composed primarily of plant shoots (Burton and Black 1978), and they time their reproductive activity to when forb and grass shoots are most available in the spring (Hunt 1992). Pocket gophers prefer to feed on plants from underground tunnels by pulling down the entire plant into the burrow, but individuals also feed on plants outside of their burrows. Pocket gophers are known for their claw-driven burrowing habits, with the overlying vegetation of active burrows reduced by up to two-thirds of the original coverage (Reichman and Smith 1985).

Experimental Plots

Our experimental plots were located in an exotic grassland dominated by wild oat (*Avena fatua*) and Ripgut brome (*Bromus diandrus*), with

native grassland species composing less than 0.01% of total biomass and plot coverage (D'Antonio unpublished). Prior to initiating watering treatments, all plots received an identical restoration treatment that consisted of exotic species removal, the addition of native grass seedlings, and maintenance weeding throughout the experiment. In 2017, we cleared all exotic biomass from fifteen 4x4m plots and scraped the top 5 cm of soil off to remove the seed bank which was dominated by wild oat seeds. Each plot had a 0.5m buffer with a 3x3m core that contained the experiment. On January 21, 2017, 12 purple needlegrass seedlings were transplanted into each plot. At the time of planting, all seedlings were approximately 4 months old and had been germinated and grown in the biology greenhouses at the University of California, Santa Barbara. After the seedlings had been transplanted, all plots were watered that day and one week later. After this initial watering, the amount of water received by the seedlings was dictated by their watering treatment. We randomly assigned one of three different watering treatments to each plot. The watering treatments were 1) a drought treatment, 2) a water addition treatment that had an extended growing season, and 3) a control treatment that received ambient rainfall. To implement the drought treatment, we erected rainout shelters that passively reduced precipitation events by 50%. Each shelter was built according to the specifications laid out by the international drought experiment (<https://wp.natsci.colostate.edu/droughtnet/>). Plots were also trenched down to 50 cm and a plastic shield installed to prevent lateral subsurface flow into the plots. For the water addition treatment, plots were watered biweekly (starting 4/17 in 2019, 4/11 in 2018 and 4/23 in 2019) at a rate of 6.7 L/m² until the end of May (ending 5/29 in 2017, 5/23 in 2018, and 5/23 in 2019). Water was not manipulated in ambient plots. Each watering treatment was replicated 5 times. Exotic species were continuously weeded from the 4x4m plots during the

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Impact of Drought and Pocket Gophers on Restored Native Perennial Bunchgrasses

continued

winter months in the 2016/2017 and 2018/2019 growing seasons. Exotic species were only weeded once in the 2018/2019 growing season.

Response Metrics and Analysis

In May of each year, we surveyed the planted purple needlegrass individuals. In all three growing seasons, we measured the basal circumference and the number of flowering culms. Beginning in 2018, we collected 3 flowering culms and 10 seeds from each plant when available. In 2019, we also harvested the above-ground biomass for each plant. During this annual survey, we also surveyed each plot for gopher disturbance. Here we are only presenting data for the 2018/2019 season. The data consisted of random, independent samples that were normally distributed, so parametric models were used for analysis. Specifically, an Analysis of Variance (ANOVA) was used to compare the growth and reproduction of purple needlegrass in the three watering treatments during the 2018/2019 growing season followed by a Tukey HSD (honestly significant difference) means separation test. An ANOVA and Tukey HSD were also used to compare the amount of gopher disturbance in each of the watering treatments. Since gopher activity was not manipulated we were unable to compare the independent effects of watering treatment and gopher activity. However, we used multiple linear regression to investigate the relationship between gopher damage and the basal circumference and reproductive output of purple needlegrass while accounting for the effect of watering treatment as a covariate.

Results

We found that gopher activity negatively impacted purple needlegrass regardless of watering treatment (Figure 1). As gopher damage increased, both average basal circumference ($F=19.61$, $R^2=0.2941$, $p<0.0001$; Figure 1A) and reproductive output ($F=6.867$, $R^2=0.1226$, $p<0.0001$; Figure 1B) declined.

There was also a significant impact of watering treatment on the basal circumference ($F=11.79$, $p<0.0001$; Figure 2A) and reproductive effort ($F=5.203$, $p=0.007$; Figure 2B) of purple needlegrass. Individuals in the droughted treatment were significantly smaller than individuals in the ambient ($p=0.001$) and water addition treatments ($p<0.0001$) with no difference between ambient and water addition plants ($p=0.47$). Reproductive output, on the other hand, was greatest in the water addition treatment, compared to drought ($p=0.02$) and ambient ($p=0.02$), with no difference in reproductive output between ambient and water addition plants ($p=0.95$).

Finally, we also found that gopher damage differed significantly between the three watering treatments ($F=12.72$, $p=0.00108$; Figure 3), with the drought treatment having significantly more damage than the ambient and water addition treatments ($p=0.001$

and $p=0.008$ respectively). There was no significant difference in gopher damage between the ambient and water addition treatments ($p=0.512$).

Discussion

We found that valley pocket gophers have a significant negative impact on the growth and reproduction of purple needlegrass (Figure 1), especially when water is reduced (Figure 3). This suggests that gopher activity could potentially be a larger problem for restoration during dry years due to the additional stress on the plants. Since gopher activity was higher in the drought plots, and we had no drought treatments without gopher activity, it is not possible to tease apart the independent effects of drought and gophers with this experiment. However, our results suggest that gopher activity is likely to have a particularly negative impact on reproductive success as drought alone did not decrease reproduction (Figure 2) but increasing gopher activity did (Figure 1B). While our experiment was not able to separate the effect of drought and gophers on reproduction, previous research has also found that drought does not reduce reproduction output. For example, Fitch *et al.* (2019) found that while increasing water led to greater culm production, plants in the lowest watering treatment produced the same number of culms as those in the control treatment. Therefore, we believe that the decrease in reproductive output was either directly due to increased gopher activity or due to a synergetic effect between gophers and drought. Our results highlight the importance of incorporating animals into restoration planning,

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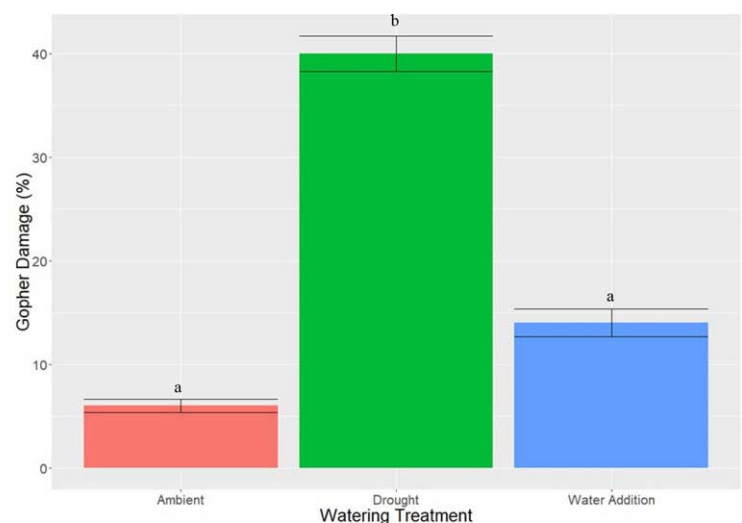


Figure 3. The average gopher damage within each watering treatment. The ambient treatment was the control, the drought treatment received a 50% reduction in precipitation, and the water addition treatment received an additional 4 weeks of water at the end of the growing season. Error bars indicate \pm SE with letters indicating significant differences as measured by an Analysis of Variance.

Impact of Drought and Pocket Gophers on Restored Native Perennial Bunchgrasses

continued

especially when considering how climate change will impact future restoration success.

With droughts expected to become more common in California grasslands in the future (AghaKouchak *et al.* 2014), it is important to understand what factors are going to impact the survival of native species that are commonly targeted for restoration. Knowing how to approach restoration efforts during drought years is critical for practitioners to adjust restoration plans to maximize the likelihood of plant establishment and survival. Understanding impacts on perennial bunchgrasses, like purple needlegrass, is particularly important as these species are often the primary focus in restoration efforts (Stromberg *et al.* 2007). Our results suggest that gophers are likely to amplify the negative effect of gophers on native perennial grasses (Stromberg and Griffin 1996, Watts 2010) during dry years and should be considered when starting or maintaining grassland restoration sites during a drought.

Traditionally, restoration efforts tend to disregard the potential negative impacts of wildlife, focusing more on floral community success (Keesing and Wratten 1998). Ignoring the effects of animals, however, could lead to declines in plant survival and ultimately to restoration failure. We are not advocating for the removal of native animals from grassland restoration sites, as these species are an integral part of the community and native to these ecosystems. For example, valley pocket gophers provide valuable ecosystem services such as nutrient cycling, and promoting native species that rely on disturbance for dispersal (Reichman and Seabloom 2002). Thus, attempts to remove gophers from the system could negatively impact the ecosystem as a whole despite benefiting purple needlegrass. However, our results do suggest that during a drought, gopher activity could be minimized by caging sensitive plants or watering seedlings to reduce the increase in damage during already stressful dry years. As frequent

and prolonged droughts increase throughout California in the coming decades, practitioners need to adapt and change management plans during dry years to account for their unique challenges. Also, as we move forward with restoration ecology, animals and animal behavior need to be further integrated into restoration planning to successfully restore native ecosystems (Halle *et al.* 2004, Lindell 2008). Only when we start thinking about the relationships between native animals and plants, and how to facilitate positive interactions between these species, will we be able to successfully restore resilient, self-sustaining communities in the future.

Acknowledgements

This project was generously funded by the University of California Santa Barbara Coastal Fund and the Schmidt Family Foundation. We would also like to thank two anonymous reviewers for feedback on an early version of this paper.



References

- AghaKouchak, A., L. Cheng, O. Mazdiyasni, and A. Farahmand. 2014. Global warming and changes in risk of concurrent climate extremes: Insights from the 2014 California drought. *Geophysical Research Letters* 41:8847–8852.
- Álvarez-Castañeda, S.T. 2010. Phylogenetic structure of the *Thomomys bottae-umbrinus* complex in North America. *Molecular Phylogenetics and Evolution* 54:671–679.
- Burton, D.H., and H.C. Black. 1978. Feeding habits of Mazama pocket gophers in south-central Oregon. *Journal of Wildlife Management*:383–390.
- Carter, D.L., and J.M. Blair. 2012. High richness and dense seeding enhance grassland restoration establishment but have little effect on drought response. *Ecological Applications* 22:1308–1319.

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MEET A GRASSLAND RESEARCHER **Justin Luong** jluong4@ucsc.edu

PhD Candidate in the Environmental Studies Department at UC Santa Cruz and Research Affiliate at the Cheadle Center for Biodiversity and Ecological Restoration at UC Santa Barbara

What is your study system? What are your primary research goals?

My dissertation research focuses on the ecological restoration of California coastal prairies and grasslands. More specifically, I am interested in the long-term success of restoration projects that use planting and/or seeding as a primary method and how climate change may affect the success of these practices. Financial investment in restoration is large and only continuing to grow. Despite the growing investment and community engagement, investments are still dispersed, providing bare-minimum funds for scattered restoration projects. This low, project-specific, funding can cause a heavier focus on implementation, and less on tracking restoration outcomes. As a result, few restoration projects are tracked beyond the first few years post-implementation. In order to address this, I am undertaking a regional-scale assessment of restored coastal grasslands that have actively reintroduced native plants. My 32 sites range from Santa Barbara to Humboldt counties, are up to 31 years post-implementation, and range from 1 to 30 acres in size. In conjunction with ecological field surveys, I also collected project documents and will interview restoration practitioners to determine the sustainability of coastal grassland restoration and major barriers to its success. I also have an experimental design at Younger Lagoon Reserve in Santa Cruz, where I am exploring the effects of extreme drought on planting success. My goal with this project is to determine if there are predictive measures that can be used during plant selection to improve planting survival and restoration success.

STUDENT RESEARCH

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

Who is your audience?

My work is geared towards restoration practitioners and ecologists. My personal beliefs and work on restoration implementation have led me to especially promote communications between researchers and land managers to make sure that research addresses on-the-ground needs. I hope to connect ecological theory with applied on-the-ground environmental issues because ecological theory can provide a framework in which we view restoration outcomes and help make ecological restoration more predictive.

Who has inspired you, including your mentors?

Years of spending time in the chaparral of Santa Barbara is what first led me to ecology. After discovering my affinity for the natural

environment, I sought out various sources of mentorship. I first came across the Cheadle Center for Biodiversity and Ecological Restoration, which led me down my future path in restoration ecology. I was inspired by supervisors and coworkers every day through the depth of localized natural history knowledge they showed and the passion that motivated their work. I eventually connected with Carla D'Antonio, and I worked as an undergrad research assistant in her lab. I began to build a strong research foundation and steadily found my passion. I currently am doing research at UC Santa Cruz with my advisers Dr. Michael Loik and Dr. Karen Holl. Both have been a tremendous inspiration to me and have supported me along every step. Michael has inspired me to take a closer look at plant physiology and help climatic change with plant responses, whereas Karen has helped me interpret how restoration communities come together and how to facilitate researcher-practitioner collaborations.



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”?

The main objectives of my research are to help improve restoration methods of

California coastal grassland. My project seeks to understand how restoration will respond to drought, but also what practitioners perceive as the greatest barriers to success. My research aspires to help connect private, public, and non-profit agencies and their management practices to improve restoration planning and knowledge transfer.

Why do you love grasslands?

I love grasslands because they are beautiful, underappreciated, and overlooked. Grasslands contain a large suite of diversity and host a large proportion of endangered and sensitive species. Grasslands have spectacular wildflower blooms, and even though blooms are amazing, the grasses themselves are ignored. Grasses also have flowers, which is only common knowledge to few, but if we really take the time to look at them, we can see how beautiful they can be.



Impact of Drought and Pocket Gophers on Restored Native Perennial Bunchgrasses

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- Cox, G.W., and J. Hunt. 1992. Relation of seasonal activity patterns of valley pocket gophers to temperature, rainfall, and food availability. *Journal of Mammalogy* 73:123–134.
- D’Antonio, C.M., and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. *Annual Review of Ecology and Systematics* 23:63–87.
- D’Antonio, C.M., C. Malmstrom, S.A. Reynolds, and J. Gerlach. 2007. Ecology of invasive non-native species in California grassland. Pages 67–83. In: *California Grasslands: Ecology and Management*. University of California Press, Berkeley, California.
- Dukes, J.S., and M.R. Shaw. 2007. Influences of climate and atmospheric change on production and composition of California grassland: Implications for restoration. Ecological Society of America Annual Meeting Abstracts.
- Fitch, R.L., E.J. Questad, and E.G. Bobich. 2019. Soil resource availability and its effect on the ecophysiology and establishment of *Stipa pulchra*. *Journal of Plant Ecology* 12:603–614.
- Hale, R., and S.E. Swearer. 2017. When good animals love bad restored habitats: How maladaptive habitat selection can constrain restoration. *Journal of Applied Ecology* 54:1478–1486.
- Halle, S., M. Fattorini, V. Temperton, R. Hobbs, and T. Nuttle. 2004. Advances in restoration ecology: Insights from aquatic and terrestrial ecosystems. Pages 10–33 In: *Assembly Rules and Restoration Ecology: Bridging the Gap between Theory and Practice*.
- Hamilton, J.G., J.R. Griffin, and M.R. Stromberg. 2002. Long-term population dynamics of native *Nassella* (Poaceae) bunchgrasses in Central California. *Madroño* 274–284.
- Harrison, S.P., E.S. Gornish, and S. Copeland. 2015. Climate-driven diversity loss in a grassland community. *Proceedings of the National Academy of Sciences of the United States of America* 112:8672–8677.
- Hilderbrand, R.H., A.C. Watts, and A.M. Randle. 2005. The myths of restoration ecology. *Ecology and Society* 10(1):19.
- Huenneke, L.F. 1989. Distribution and regional patterns of Californian grasslands. Pages 1–2. In: *Grassland Structure and Function*. Springer.
- Hunt, J. 1992. Feeding ecology of valley pocket gophers (*Thomomys bottae sanctidiegi*) on a California coastal grassland. *American Midland Naturalist* 127:41–51.
- Keesing, V., and S.D. Wratten. 1998. Indigenous invertebrate components in ecological restoration in agricultural landscapes. *New Zealand Journal of Ecology* 99–104.
- Lindell, C.A. 2008. The value of animal behavior in evaluations of restoration success. *Restoration Ecology* 16:197–203.
- Majer, J. 1990. Rehabilitation of disturbed land: long-term prospects for the recolonisation of fauna. *Proceedings of the Ecological Society of Australia* 16:509–17.
- Majer, J.D. 2009. Animals in the restoration process—progressing the trends. *Restoration Ecology* 17:315–319.
- Molinari, N.A., and C.M. D’Antonio. 2013. Data from: Structural, compositional and trait differences between native and non-native dominated grassland patches. *Functional Ecology* 28:745–754 [doi:10.1111/1365-2435.12206](https://doi.org/10.1111/1365-2435.12206)
- Reichman, O., and E.W. Seabloom. 2002. The role of pocket gophers as subterranean ecosystem engineers. *Trends in Ecology & Evolution* 17:44–49.
- Reichman, O., and S.C. Smith. 1985. Impact of pocket gopher burrows on overlying vegetation. *Journal of Mammalogy* 66:720–725.
- Seabloom, E.W., W.S. Harpole, O.J. Reichman, and D. Tilman. 2003. Invasion, competitive dominance, and resource use by exotic and native California grassland species. *Proceedings of the National Academy of Sciences* 100:13384–13389.
- Seabloom, E.W., and S.A. Richards. 2003. Multiple stable equilibria in grasslands mediated by herbivore population dynamics and foraging behavior. *Ecology* 84:2891–2904.
- Stromberg, M.R., J.D. Crobin, and C.M. D’Antonio., editors. 2007. *California Grasslands: Ecology and Management*. University of California Press, Berkeley.
- Stromberg, M.R., and J.R. Griffin. 1996. Long-term patterns in coastal California grasslands in relation to cultivation, gophers, and grazing. *Ecological Applications* 6:1189–1211.
- Watts, S.M. 2010. Pocket gophers and the invasion and restoration of native bunchgrass communities. *Restoration Ecology* 18:34–40.





Figure 1. Aerial image of experimental site at the U.C. Davis Russell Ranch Sustainable Agriculture Facility (38°32'21.6"N 121°52'11.5"W) near Davis, California, USA (Google 2020). Outlines: largest outermost box = burned area (fire occurred September 6, 2013); smaller inner box = experimental watering treatment and control plot locations; small separate box = unburned sampling area.

Can a Summer Burn Following Watering to Flush the Exotic Annual Grass Seedbank Confer an Advantage to Native Perennial Grasses in Restored Grasslands?

by Kristina Wolf¹

Introduction

Over 9.2 million hectares of native plants in California's prairies and grasslands have largely been replaced by exotic plants (Seabloom *et al.* 2003), mainly annual Mediterranean grasses and forbs (Mooney and Drake 1986), which are well-adapted to California's climate (Stromberg *et al.* 2007). Recently disturbed restoration sites are particularly susceptible to invasion by exotic annuals that can delay, reduce, or prevent success of planted native perennial grasses (Munson and Lauenroth 2012). Native grassland restoration could benefit from a shift in the competitive balance away from exotics, and in favor of desired plants, both before and after planting.

Exotic annual grasses (hereafter, "exotic[s]") may rapidly deplete available resources—particularly water—at the start of the growing

season before perennial grasses become active (Lowe *et al.* 2003). The ability of exotics to take early advantage of resources, known as a "seasonal priority advantage", may reduce native plant success (Reynolds *et al.* 2001, Wainwright *et al.* 2012). Manipulating this seasonal priority advantage to reduce competition from exotics is a frequent practice among land managers. Farmers and restoration practitioners commonly apply water at large scales to induce artificial "flushing" (i.e., germination and emergence) of weeds, followed by lethal post-flushing interventions, such as tillage and herbicide application. Additional methods for altering the seasonal priority advantage of exotics include manipulating the timing of planting (Palmer *et al.* 1997, Vaughn and Young 2015); planting in patches to reduce competition between species with different phenology (Porensky *et al.* 2011); weed control methods that reduce competitive pressure from undesirable plants for a short period to give desirable species a competitive advantage (Funk *et al.* 2008, Wainwright *et al.*

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2012); and manipulations of water, nutrient availability, and biotic interactions with other trophic levels (Funk *et al.* 2008, 2015). These options are useful for promoting success of desirable plants in annual croplands and initial restoration settings — where managers start with a relatively ‘blank slate’ — but options are much more limited in post-restoration settings.

In California’s Mediterranean climate, supplemental water during the summer may create circumstances early in the season that favor native perennial grasses, while reducing competition from exotic annuals later in the growing season by allowing for native growth during the usually dormant season and storage of carbohydrates, creating an increased competitive edge for native perennials in the following growing season (Clary *et al.* 2004). Surveys of annual and perennial grass cover in Spain and California revealed a positive correlation between perennial grass cover and warm season rainfall (Clary 2007), or proximity to the cool, moist coast (Clary 2012). At the same time, summer watering may negatively impact exotics, causing them to ‘flush’ and then die prior to the start of ambient rainfall and before setting seed, theoretically reducing the exotic seedbank, and theoretically, competition with native perennial grasses (hereafter “native[s]”) in the fall. Indeed, Wainwright *et al.* (2012) found summer watering to be effective in reducing exotic cover in invaded southern California coastal sage scrub, at least in the short-term, but exotic cover was not monitored after January (midway through the growing season).

I tested this in a 2012 study in which I applied five replicated watering treatments ranging 10–20 L per day in 1-m² plots in late summer: once



Figure 2. Image of the burned grassland at the UC Davis Russell Ranch Sustainable Agriculture Facility (38°32′21.6″N 121°52′11.5″W) two days post-fire, on September 8, 2013

daily, ranging from four to sixteen days of watering, or twice daily for four days. Only the once-daily watering treatments spanning sixteen days, and the twice-daily watering treatments for four days, had significant flushing effects for exotics. Moreover, keeping the soil moist between watering was apparently critical to inducing the strongest flushing response: watering twice daily for four days produced a larger peak flushing response than watering once daily for 16 days. Although both treatments conferred a short-term reduction in annual grass emergence at the start of the subsequent rainy season, they did not reduce total exotic cover in the following growing season, or provide a longer-term advantage to native perennial grasses (Wolf and Young 2016).

I subsequently carried out this follow-up experiment to investigate whether increasing the number of watering events per day, or applying those watering treatments later in the summer (September versus August), could produce longer-lasting results in terms of reducing exotic grass cover and/or increasing native perennial grass cover. In this experiment I aimed to test whether these fine-tuned methods for summer watering in a restored grassland could: 1) cause substantial

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Table 1. Experimental summer watering treatments.

| Treatment (n) | Dates of Watering | Total Days of Watering | Frequency (times per day) | Times Watered (total) | Total H ₂ O Applied per Plot (cm ¹ / L) | Equivalent Water per Acre (L / Gallons) |
|----------------------|---------------------|------------------------|---------------------------|-----------------------|---|---|
| Control (6) | n/a | 0 | 0 | 0 | 0 / 0 | 0 / 0 |
| 1-2 (6) | 8/21/2013 | 1 | 2 | 2 | 2.2 / 22 | 89,030 / 23,519 |
| 2-2 (6) | 8/21/2013–8/22/2013 | 2 | 2 | 4 | 4.4 / 44 | 178,062 / 47,039 |
| 4-2 (6) | 8/21/2013–8/24/2013 | 4 | 2 | 8 | 8.8 / 88 | 356,124 / 94,078 |
| 4-3 (6) | 8/21/2013–8/24/2013 | 4 | 3 | 12 | 13.2 / 132 | 534,186 / 141,117 |
| 4-4 (6) | 8/21/2013–8/24/2013 | 4 | 4 | 16 | 17.6 / 176 | 712,247 / 188,156 |
| Unburned Control (8) | n/a | 0 | 0 | 0 | 0 / 0 | 0 / 0 |

Notes: Control and treatment plots burned on 9/6/2013, approximately 2 weeks post-treatment.

¹Approximately 1.1 cm of water was applied in each 1-m² plot (~11 Liters, or ~3 gallons) at each watering time.

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exotic emergence in the summer; 2) reduce exotic cover in the following growing season; and 3) increase native cover over the longer term (i.e., one year later). However, an accidental burn cut the experiment short and limited the experiment to August watering treatments. Thus, I took advantage of this fire to investigate the ability of summer watering to flush exotic annuals followed by a summer burn on exotic annual and native perennial grass cover in a restored California grassland.

Methods

Study Site

This experiment was conducted at the U.C. Davis Russell Ranch Sustainable Agriculture Facility (38°32'21.6"N 121°52'11.5"W) near Davis, California, USA. Davis is located in the Central Valley and has a Mediterranean climate with long, hot, dry summers and wet, cool winters. Mean annual precipitation is 44 cm, falling almost entirely between October and April. Average summer (dry season) maximum temperature is 32° C, and average winter (wet season) minimum temperature is 7° C. Germinating rains generally begin in the late fall in October or November (Menne *et al.* 2015). Soils are classified as Yolo silt loams (NRCS 2019).

A grassland restoration was implemented in the fall of 2004 by drill seeding a mix of three native grass species: *Elymus triticoides*, *E. glaucus*, and *Stipa pulchra*. The site was mowed to 15 cm one week prior to the beginning of the watering experiment in August 2013. Exotic annual grass species had reinvaded the site, primarily *Avena* spp. and *Bromus hordeaceus*. Non-native forb cover was relatively low (<1% cover) and included *Sonchus oleraceus*, *Lactuca serriola*, and *Brassica nigra*, which I hand-pulled weekly from August to November. There were a few native forb species present, but only *Eschscholzia californica* was present at any notable—although still low—cover within plots (also <1% cover).

Experimental Treatments

I established 72 1-m² plots separated by a 1.5-m buffer on all sides, with treatments replicated six times in a strip-plot design, with five watering treatments and one control randomly applied to six each of 36 plots in August, and the same treatments randomly applied to six each of the remaining 36 plots in September. Plots were arranged in a 6x12 grid, with the August and September treatments assigned to all plots in alternating rows. Each of the five watering and control treatments for each month were randomly applied to each of the 36 plots within the appropriate rows for that month until all six replicates of each treatment were assigned.

Watering treatments were applied two to four times per day over a one- to four-day period in 36 plots from August 21–24, 2013. Water was applied from a gravity-fed tank through a hose and water wand, and the amount of water was monitored by flowmeter at a relatively slow rate (3 gallons/min) to prevent runoff. Three gallons of water was applied to each plot assigned to watering at each watering event. Therefore, the amount of water applied at each watering event was the same across all plots receiving water at that event, but the total amount of water applied to a plot over all watering days varied, dependent upon treatment. The total water applied altogether over the course of a treatment was only higher in treatment plots receiving water either more times per day, or for more days (Table 1).

The remaining 36 plots would have received the same water treatments in September to explore the effect of a later versus earlier watering month, but an accidental burn on September 6, 2013, prevented application of the September water treatments, and this became a new focus of the experiment. The fire was started on the adjacent gravel road by a beekeeper, and it quickly burned over the entire study site and 100–250 feet around the outermost experimental plot edges. The

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Can a Summer Burn Following Watering to Flush the Exotic Annual Grass Seedbank Confer an Advantage to Restored Grasslands? *continued*

fire lasted less than one hour, and was extinguished with water from fire trucks by the local fire department (see Figures 1 and 2).

Monitoring

I monitored exotic and native grass aerial cover in the interior 0.5 x 0.5m of each 1-m² plot to reduce edge effects, beginning with a pre-watering baseline (August 14, 2013) monitoring event (first monitoring event = ME 1). I continued to monitor weekly thereafter, within 6 to 8 days of the previous monitoring event to maintain weekly calendar surveys, through December 12, 2013, for 12 additional weekly monitoring events after ME 1 (MEs 2 through 13). I followed with a spring survey on May 5, 2014 (ME 14, the 38th week after treatments were applied), and a fall survey on August 8, 2014 (ME 15, 1 year after treatments were applied). During the spring survey (ME 14), I also monitored 8 additional randomly selected 1-m² plots in an adjacent unburned area, approximately 100 feet from the edge of the outermost burned plots on the eastern side of the larger experimental area (see Figure 1), with the same monitoring method as described above.

Statistical Analyses

All statistical analyses began with data exploration to determine the approximate distribution of the data, investigate relationships between different parameters, and check for homogeneity of variances across the dataset and between treatment groups. I tested the data for normality via a Shapiro-Wilk normality test (R Core Team 2019), and for homogeneity of variances with Levene's Test for Homogeneity of

Variances (Fox and Weisberg 2019). In general, the data at most MEs for exotics and natives were not normally distributed ($W < 0.95$, and $p\text{-value} < 0.05$), but were generally homoscedastic across groups (i.e., treatments; small F-values and large $p\text{-values} > 0.05$), thus allowing for non-parametric models to be applied.

Parametric models (i.e., linear regression) did not adequately model the data, nor were model assumptions met. I applied a non-parametric anova test via the Kruskal-Wallis rank sum test (Hothorn *et al.* 2006, 2008b). To investigate differences between the control and watered treatment plots, I followed with a post-hoc test for multiple comparisons between the watering treatments and control plots with the Dunnnett method for contrasts at a 95% confidence level (mtcp with the multcomp [Hothorn *et al.* 2008a], mvtnorm [Genz *et al.* 2009, Genz *et al.* 2019], and nparcomp [Konietschke *et al.* 2015] packages). The alternative hypothesis was that true differences of relative effects would not be equal to zero. All analyses were conducted in R (R Core Team 2019).

I compared control plots to watered plots to explore the effects of watering treatments on exotics and natives as appropriate at four time points: 1) pre-treatment baseline to explore initial differences in live native cover across the different, randomly applied treatments (at ME 1); 2) initial response of exotics and natives to summer watering (at ME 3); 3) live cover of exotics and natives in the following spring (at ME 14); and 4) live native cover one year post-treatment (at ME 15).


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Can a Summer Burn Following Watering to Flush the Exotic Annual Grass Seedbank Confer an Advantage to Restored Grasslands? *continued*

Results

Pre-treatment Baseline

Pre-watering (ME 1) native cover was very low, with a mean of 0.063% (SE±0.024%) across all treatment plots. There were also no significant differences (chi-squared = 3.33, $p = 0.68$) between treatment plots at ME 1. There were no live exotic plants present in the summer.

Initial Response to Summer Watering Treatments, pre-burn

At the time of ME 3—approximately two weeks after water application and just prior to the accidental burn—native cover had decreased to an average of 0.002% in control plots, down from 0.45% cover three weeks earlier at ME 1, indicating a stress response to the continued heat as the summer progressed. However, in watered treatment plots, both exotic and native cover increased. Treatment had a significant effect on exotic cover (chi-squared = 28.4, p -value < 0.0001), and all treatments receiving water—except the treatment receiving only one day of watering (Treatment 1-2)—were significantly different from the control (p -value < 0.001) (Figure 3a). Compared to the control, exotic cover was significantly higher in the 2-2, 4-2, 4-3, and 4-4 watered treatment plots, with relative differences of 0.57%, 23.2%, 24.8%, and 23.7%, respectively (p -values < 0.001); only the 1-2 treatment was not significantly different from the control, although

exotic cover was still higher than the control (which had no live exotic cover) by an estimated 0.042%, which was not significant ($p = 0.782$).

Watering treatment had a significant effect on native cover (chi-squared = 21.89, $p < 0.0001$), which was significantly higher in the 4-2, 4-3, and 4-4 watered treatment plots by 10.5% ($p < 0.001$), 8.7% ($p = 0.006$), and 7.67% ($p < 0.001$), respectively (Figure 3b). Natives responded to the watering treatments to a lesser degree than exotics, and although the 1-2 and 2-2 treatments were only borderline significantly different from the control, native cover was still higher than in the control by 2.33% ($p = 0.051$) and 3.22% ($p = 0.062$), respectively.

Spring Cover, 8 months post-burn

At the time of ME 14—during peak flowering of exotics in the spring—treatment did not have a significant effect on exotic cover (chi-squared = 12.03, $p = 0.063$; Figure 4a). Treatments receiving water for less than four days had high exotic cover (13.3–14.3%) and were not significantly different from the control (all $p > 0.800$), which had 13.2% exotic cover. Treatments 4-2, 4-3, and 4-4 had lower exotic cover than the control, with 7.83%, 9.17%, and 5.73% average exotic cover (p -values = 0.103, 0.231, and 0.100, respectively), but were also not significantly different from the control.

Watering treatment did not have a significant effect on native cover (chi-squared = 8.21, $p = 0.220$) (Figure 4b). Native cover in burned and unburned control plots was 38.3% and 41.0%, respectively, and the treatments were not significantly different from each other ($p = 0.999$). Native cover in watered treatment plots ranged from 23.7% to 49.2%, and none of the treatments were significantly different from the control plots, burned or unburned (p -values = 0.310–0.999).

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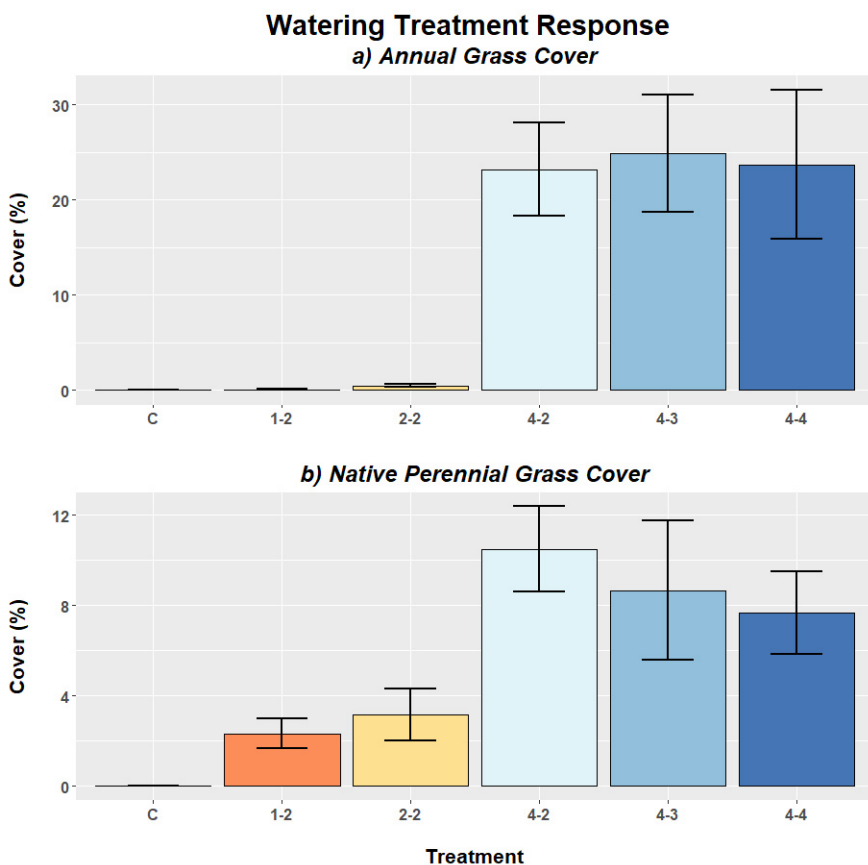


Figure 3. Exotic annual and native perennial grass cover per 1-m² plot (surveyed areas restricted to interior 0.5-m² of each plot and results extrapolated to 1-m²) two weeks post watering treatment, on September 3, 2013. Treatments were applied from August 14–17, 2013. N = 36; error bars are one standard error of the mean.

Treatments:

- C = Control, no water
- 1-2 = watered twice/day for one day
- 2-2 = watered twice/day for two days
- 4-2 = watered twice/day for four days
- 4-3 = watered three times/day for four days
- 4-4 = watered four times/day for four days

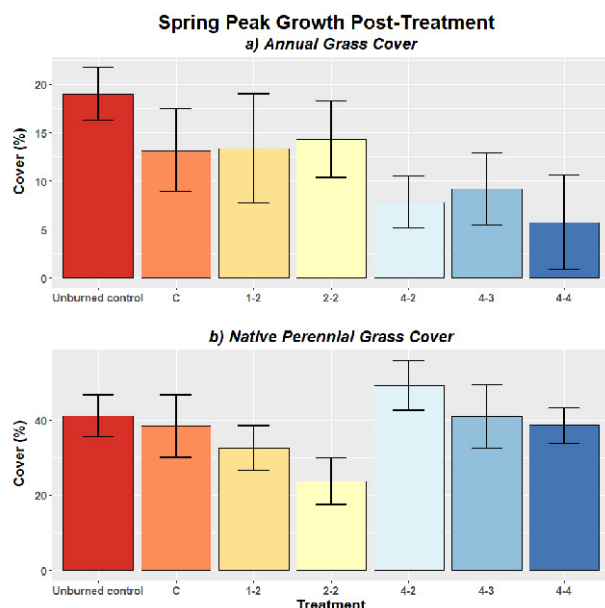


Figure 4. Exotic annual and native perennial grass cover per 1-m² plot (surveyed areas restricted to interior 0.5-m² of each plot and results extrapolated to 1-m²) during peak flowering in the following spring, on May 15, 2014. N = 36; error bars are one standard error of the mean. Eight random 1-m² quadrats were monitored in an adjacent unburned area approximately 100 feet from the burned plots for comparison to the burned control ("C"). For other treatments, see Figure 3 caption.

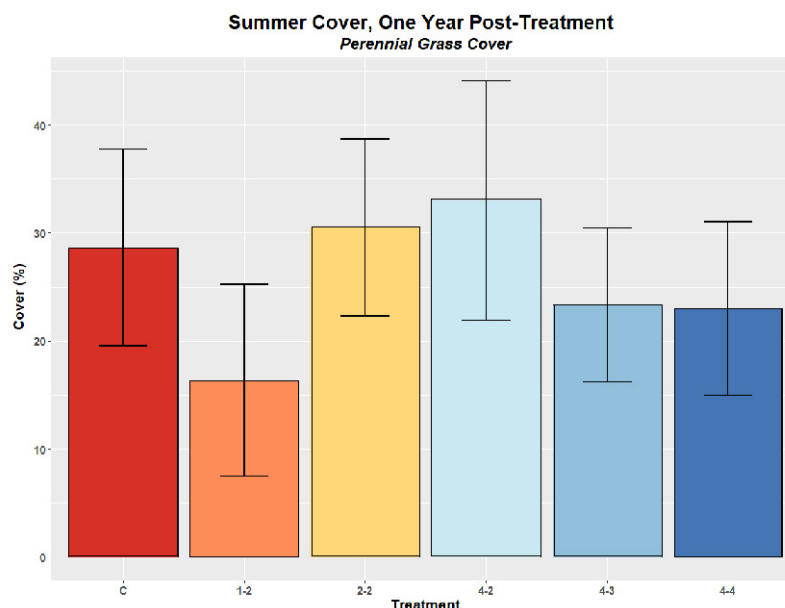


Figure 5. Native perennial grass cover per 1-m² plot (surveyed areas restricted to interior 0.5-m² of each plot and results extrapolated to 1-m²) one year post-watering treatment and burn, August 8, 2014. N = 36; error bars are one standard error of the mean. For explanation of treatments, see Figure 3 caption.

Can a Summer Burn Following Watering to Flush the Exotic Annual Grass Seedbank Confer an Advantage to Restored Grasslands? *continued*

Summer Cover, one year post-watering and post-burn

One year after watering treatments, at ME 15, treatment did not have a significant effect on native cover (chi-squared = 2.99, $p = 0.702$). Average native cover in the control was 25.8%, while average native cover in watered treatments ranged from 16.3% to 33.0% (Figure 5), and none of the treatments were significantly different from the control (p -values = 0.749–0.999).

Discussion

The objective of the experiment changed within three weeks of the baseline monitoring when the site burned. After the burn, I revised my experimental questions, and sought to determine whether increased watering treatments in the summer—followed by a burn that top-kills all live vegetation—would: 1) cause a substantial exotic annual grass flush in the hot, dry California summer; 2) reduce exotic annual grass cover in the following growing season; and 3) increase native perennial grass cover longer term (one year later).

Significant flushing of exotics did occur due to summer watering, but only for the treatments receiving water for at least two days (i.e., the 1-2 treatment did not result in significant flushing). Funk *et al.* (2015) also found that watering in the field once per day in the summer did not have a significant effect on exotic cover, perhaps because the soil

dried too quickly or dried out in between days of watering. They did report substantial germination in a concurrent greenhouse watering study, but this entailed covering the soil to conserve soil moisture. Wainwright *et al.* (2012) observed only a few emerging annual grass seedlings per 2-m² plot in response to both August and September summer watering with 1–3 cm of water in each plot over a 1- to 3-day period in coastal sage invaded by exotic grasses. My results suggest that substantial amounts of water, and at least twice per day for at least two days, are required to create a significant flush of exotic annuals under hot, dry field conditions.

In my previous watering study, only the two most extreme watering treatments stimulated a significant flushing response due to summer watering (3 gallons once per day for 16 days, and 3 gallons twice daily for four days) (Wolf and Young 2016). I observed a similar response to watering treatments in this study, in which water applied more frequently for a greater total volume resulted in significant flushing of exotics. Therefore, the question of whether or not exotics can be artificially flushed to a substantial degree in the summer has now been investigated many times, and the bulk of the evidence shows that the answer is "Yes", but that large amounts of water are required over the course of multiple watering events per day for at least two days, and up to four days. Many natives can also be stimulated to grow—often quite

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Can a Summer Burn Following Watering to Flush the Exotic Annual Grass Seedbank Confer an Advantage to Restored Grasslands? *continued*

robustly—in the middle of summer when they are usually dormant and remain active at least to the onset of ambient rainfall, which could theoretically shift the balance of power to the natives at the start of the growing season, when exotics usually dominate.

The new question then is, “Can the addition of fire after a summer watering flush decrease the exotic seedbank sufficiently to bring about the desired longer-term reduction in exotic cover and increase in native cover?” While the subsequent die-off of flushed germinants in this and the previous study—by desiccation in the previous experiment (Wolf and Young 2016) and by fire in this experiment—is evidence of a reduction in the seedbank, the answer still appears to be “No”. In the previous study, exotic germination at the onset of ambient rainfall was reduced in the two significantly flushed treatments by an average of 50% and 81%, respectively, as compared to control plots (Wolf and Young 2016). However, in both experiments, by the time of peak spring flowering in the following spring, exotic cover was not significantly different in watered treatment plots compared to control plots. The addition of burning after watering treatments had flushed the seedbank would not only ensure death of emerging exotics (guaranteeing they did not survive to the onset of ambient rains, thereby having an even greater head start than they would otherwise have had under natural rainfall conditions), but also would be likely to kill many ungerminated viable exotic seeds on the soil surface. However, burning to further reduce the exotic seedbank was still not sufficient to result in lower exotic cover in the subsequent spring.

It is interesting to note that in the previous study, average exotic cover was 5–10% lower in plots that significantly flushed (Wolf and Young 2016). In this experiment, average exotic cover was up to 7.5% lower in significantly flushed treatments (treatments receiving water for four days) than in the control, but the variance was so high that this difference was not statistically significant. Thus, in both experiments, the most promising treatments did not confer a statistically significant longer-term reduction in exotic cover, or an increase in native perennial grass cover, even with the potentially-increased depletion of the seedbank by burning.

Because the burn was not intentional and not originally incorporated into the experimental design, I did not collect baseline data for the unburned area, so including those data in the statistical analyses is not entirely appropriate. However, the application of statistics as a mathematical practice can be incorporated with common sense, particularly in natural ecosystems where little variation is often not controlled. The adjacent burned and unburned areas were restored at the same time with the same methods, are in a continuous grassland matrix on the same soil type, have similar physical properties, and are only about 100 feet apart, and represent a “natural experiment”. There is no reason to think that the unburned area adjacent to the burned plots would have been significantly different from the experimental

area, which was chosen for convenience of access. It appears reasonably unlikely that there was an initial difference in cover between the two areas, and I proceeded with statistical analysis to compare the experimental plots to sampled plots in the unburned area. None of the watered treatment plots were significantly different from the burned or unburned controls in the spring or fall, and the burned and unburned controls were not significantly different from each other.

As in Wolf and Young (2016), there are several potential reasons that even the ‘successful’ watering treatments did not lead to a longer-term reduction in exotic cover or an increase in perennial cover. The number of seeds produced by exotics may be so high that one artificial flushing event was not sufficient to reduce the seedbank enough to significantly reduce exotic cover (DiVittorio *et al.* 2007). Moreover, the watered plots were small relative to the surrounding landscape (including plot buffers), and seeds from neighboring plants just outside the plot area could repopulate the plots. Alternatively, or in addition, flushing might produce a “fertilizer effect”. Under natural rainfall conditions, a large number of seedlings will emerge at the onset of ambient rains, but many of them die by “self-thinning”. These self-thinned seedlings then provide nitrogen to surviving or later germinating seedlings (Eviner and Firestone 2007). It is possible that the large number of seedlings that died after the artificial summer watering—along with nutrients released from the accidental burn—produced such a fertilization effect that this allowed more individual plants to survive than usual, or perhaps surviving individuals grew larger, than would have occurred under natural conditions. Or it may be that the level of plant available nutrients did not change much at all, and that a reduction in the seedbank did result in a lower number of exotics, but that these individuals were still abundant enough to saturate the carrying capacity of adult annuals that survived self-thinning. Even native cover was not significantly different in watered treatment plots when compared to the controls. Compensation by exotics (Seabloom *et al.* 2003, Eviner and Firestone 2007) may have caused this, despite initial differences in response to watering treatments.

Management Implications

Management of exotic annual grasses in restored grasslands is challenging because grass-specific herbicides can harm other desirable grasses, or often cannot be applied (Laude 1953, Voltaire and Norton 2006). Reduction of competitive pressure via flushing of exotics is commonly practiced in croplands and pre-restoration settings (Fitzpatrick 2004, Stromberg and Kephart 1996), when it can be accompanied by simple lethal post-flushing interventions, like tillage or herbicides. I investigated whether or not the additional burn, along with a more logistically feasible watering schedule (adjusted in response to the results of a previous study, Wolf and Young 2016), would reduce the annual grass seedbank enough to effectively reduce

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Can a Summer Burn Following Watering to Flush the Exotic Annual Grass Seedbank Confer an Advantage to Restored Grasslands? *continued*

the challenge of weed management in restored grasslands without harming—or perhaps even helping—native perennial grasses. While all three of the 4-day watering treatments were, in many respects, biologically significant, the results were not always statistically significant. Initial responses of up to 20% exotic cover in watered treatments is associated with the subsequent death of exotic seeds in the seedbank, and growth of natives was vigorous during the summer period, when they would normally have been dormant. The addition of fire may have helped kill more exotic seeds than the watering treatments could have alone. While subsequent results in the following year revealed nothing statistically significant, there is an apparent average difference in plots that were watered and then burned, and it is possible that a second similar treatment in the following year may compound initial results, and statistically significant differences may become detectable.

The average initial reduction in absolute exotic cover of up to 7.5% I observed in the 4-day watering treatments would be welcome to land managers in any year, although the effort required to apply such treatments might not offset this benefit, particularly as the outcome is still subject to high variability and uncertainty. Moreover, this method comes at the cost of large amounts of water, and hauling and applying water is not commonly practiced at large scales, although greater areas could be covered by industrial sprinklers with a lower daily time commitment (as is practiced in many local, large agricultural production systems for much longer durations). Applications of this method at small restoration sites may be more feasible, but additional testing of the long-term implications of increased daily frequency of watering over the course of several years should be investigated. Grazing combined with native grass seeding may also be an effective method for reducing invasive cover, and potentially increasing native

species richness, although native cover may also be reduced (Funk *et al.* 2015). Additional investigations into whether summer watering with or without burning or other treatment methods over a period of consecutive years may produce longer-lasting results and prove to be effective in reducing exotic grass cover, and/or increasing native perennial grass cover, could provide further insight into the long-term management needs and strategies for successfully restoring native perennial grasslands and prairies.



References

- Clary, J. 2007. Rainfall seasonality determines annual/perennial grass balance in vegetation of Mediterranean Iberian. *Plant Ecology* 195:13–20.
- Clary J., R. Savé, C. Biel, F. de Herralde. 2004. Water relations in competitive interactions of Mediterranean grasses and shrubs. *Annals of Applied Biology* 144:149–155.
- Clary, J. 2012. Perennial grass persistence in California grasslands driven by distance from coast. *Plant Ecology* 213:1203–1209.
- DiVittorio, C.T., J.D. Corbin, and C.M. D'Antonio. 2007. Spatial and temporal patterns of seed dispersal: An important determinant of grassland invasion. *Ecological Applications* 17:311–316.
- Eviner, V.T., and M.K. Firestone. 2007. Mechanisms determining patterns of nutrient dynamics. Pages 94–106. In: Stromberg, M.R., J.D. Corbin, and C.M. D'Antonio (eds.) *California grasslands: ecology and management*. University of California Press, Berkeley.
- Fitzpatrick, G.S. 2004. Techniques for restoring native plant communities in upland and wetland prairies in the Midwest and West Coast regions of North America. City of Eugene, Parks and Open Space Division, Eugene, OR. Accessed February 17, 2020.
http://www.cascadiaprairieoak.org/documents/EPA-WhitePaperFinal_001.pdf
- Fox, J., and S. Weisberg. 2019. *An R Companion to Applied Regression, Third Edition*. Sage: Thousand Oaks, CA.

<https://socialsciences.mcmaster.ca/jfox/Books/Companion/>

Funk, J.L., E.E. Cleland, K.M. Suding, and E.S. Zavaleta. 2008. Restoration through reassembly: Plant traits and invasion resistance. *Trends in Ecology & Evolution* 23:695–703.

Funk J.L., M.K. Hoffacker, and V. Matzek. 2015. Summer irrigation, grazing and seed addition differentially influence community composition in an invaded serpentine grassland. *Restoration Ecology* 23:122–130.

Genz, A., F. Bretz, M. Tetsuhisa, X. Mi, F. Leisch, F. Scheipl, and T. Hothorn. 2019. mvtnorm: Multivariate Normal and t Distributions. R package version 1.0-11. <http://CRAN.R-project.org/package=mvtnorm>

Genz, A., and F. Bretz. 2009. *Computation of Multivariate Normal and t Probabilities*. Lecture Notes in Statistics, Vol. 195. Springer-Verlag: Heidelberg, Germany.

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Hairy Orcutt grass (*Orcuttia pilosa*) within mud-cracked bottom of a vernal pool. Photo courtesy of George W. Hartwell



This small native grass thrives in harsh conditions but produces a massive amount of seed (2019). Photo courtesy of Chad Aakre

SPECIES SPOTLIGHT: by Chad Aakre¹

Hairy Orcutt Grass (*Orcuttia pilosa*)

Hairy Orcutt grass (*Orcuttia pilosa*) is a rare grass endemic to vernal pools of the Central Valley and San Joaquin Valley of California, occurring presently within four counties and a handful of known locations. I first became familiar with this species in association with a project specifically targeting hairy Orcutt grass for restoration, enhancement, and management in Madera County. As I researched further into this species and its tribe, I have become increasingly fascinated by its tenacity to adapt and persist in harsh environments.

Hairy Orcutt grass is one of five species within the genus *Orcuttia* to occur in California; all are endemic to the State. All *Orcuttia* species are rare and endemic to California; California Rare Plant Ranking (CRPR) status 1.B.1: Rare, threatened, or endangered in California and elsewhere. Hairy Orcutt grass was likely more prevalent within the vernal pools that covered the Central Valley and San Joaquin Valley of California in the past.

Vernal pools are a type of temporary wetland and are some of the most ecologically important and distinctive areas in California. Vernal pools are depressions in areas where a hard underground layer prevents rainwater from draining downward into the subsoil. When rain fills the pools in the winter and spring, the water collects and remains in the depressions. In the springtime, the water gradually evaporates away, until the pools become completely dry in the summer and fall (CDFW 2013). The spring phase of the vernal pools in California is characterized by a very diverse set of

flora, often with a high number of native species as opposed to the surrounding areas.

Hairy Orcutt grass is currently found in two clusters: one located in Tehama and Glenn Counties, and the other in Madera County. The cluster in Northern California includes populations located at the Vina Plains Preserve, within lands managed by the Sacramento National Wildlife Refuge, and two on private lands under conservation easement. Merced and Stanislaus Counties had previously reported populations, but most are presumed extirpated. One population remains extant outside of Madera County at the Hickman vernal pools; however, its existence is fragile due to habitat conversion to year-round ponded conditions from orchard runoff. Hairy Orcutt grass germinates in saturated habitat and then persists in dry habitat for the remainder of the year. Permanent inundation has resulted in much of the Hickman populations being lost. The populations in Madera County, representing the bulk of the southern cluster, are the location of my project and recent experience.

The genus is named after the botanist who first collected it, C.R. Orcutt; a fervent botanical collector from the early 1900s whose other passion was collecting and cataloging abalone and other crustaceans. His collection of plant specimens proved important to understand the California floristic province, and his devotion to collecting was renowned (Bullard 1994).

All *Orcutt* grasses are endemic to vernal pool habitat and thought to be derived from an ancient lineage that evolved on the margin of a shallow inland sea that covered the length of the Central Valley

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Hairy Orcutt Grass *continued*

and San Joaquin Valley during the early Tertiary Period. All Orcutt grasses are wind-pollinated, though some insect pollination may occur, including by native bees (*Halictidae* sp.), which have been observed visiting plants (Griggs 1976).

Hairy Orcutt grass germinates in standing water after vernal pools have become inundated by late fall and early winter rains. The primary leaves are a submerged basal rosette of five to eight cylindrical leaves. The secondary leaves consist of a submerged lower blade, and a flat, floating upper blade adapted to increase photosynthesis by emerging above water. This blade is crucial for developing grasses because it aids with early root development while the vernal pool is saturated. A third set of leaves develop after the pool dries up, and flowering culms form, often referred to as

terrestrial leaves. If the vernal pool becomes re-inundated with water after the terrestrial leaves have formed, high mortality typically occurs; thus, late-season rainfall events tend to have a detrimental effect on hairy Orcutt grass populations from year to year. The flowering stems become latent with seed in favorable conditions, such as slow pool desiccation and gradual drying of mud. Plants may produce no seed or very little seed in less favorable conditions where drying of the pools occurs rapidly. Favorable conditions for hairy Orcutt grass during the growing season include average, above average, or well-timed rainfall and moderate temperatures during vernal pool dry-down. These conditions present a fragility tested by erratic weather patterns and exacerbated by climate change.

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Can a Summer Burn Following Watering to Flush the Exotic Annual Grass Seedbank Confer an Advantage to Restored Grasslands? *continued*

Google Earth Pro. 2020. 38°32'21.6"N 121°52'11.5"W. Viewed February 18, 2020. <http://www.google.com/earth/index.html>

Hothorn, T., K. Hornik, M.A. van de Wiel, and A. Zeileis. 2006. A Lego system for conditional inference. *The American Statistician* 60(3):257–263. <https://doi.org/10.1198/000313006X118430>

Hothorn, T., F. Bretz, and P. Westfall. 2008a. Simultaneous Inference in General Parametric Models. *Biometrical Journal* 50(3):346–363.

Hothorn T., K. Hornik, M.A. van de Wiel, and A. Zeileis. 2008b. Implementing a class of permutation tests: The coin package. *Journal of Statistical Software* 28:1–23. <https://doi.org/10.18637/jss.v028.i08>

Konietschke, F., M. Placzek, F. Schaarschmidt, and L.A. Hothorn. 2015. nparcomp: An R software package for nonparametric multiple comparisons and simultaneous confidence intervals. *Journal of Statistical Software* 64(9):1–17. <http://www.jstatsoft.org/v64/i09/>

Laude, H.M. 1953. The nature of summer dormancy in perennial grasses. *Botanical Gazette* 114:284–292.

Lowe, P.N., W.K. Lauenroth, and I.C. Burke. 2003. Effects of nitrogen availability on competition between *Bromus tectorum* and *Bouteloua gracilis*. *Plant Ecology* 167:247–254.

Menne M.J., C.N. Williams, and R.S. Vose. 2015. Climate data by year, Site 042294, DAVIS 2 WSW EXP FARM, California. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee. Accessed May 15, 2015. <http://cdiac.ornl.gov/epubs/ndp/ushcn/ushcn.html>

Mooney, H.A., and J.A. Drake, eds. 1986. *Ecology of biological invasions of North America and Hawaii*. Springer-Verlag, New York, NY.

Munson, S.M., and W.K. Lauenroth. 2012. Plant community recovery following restoration in semiarid grasslands. *Restoration Ecology* 20:656–663.

[NRCS] Natural Resources Conservation Service. 2015. Web Soil Survey. United States Department of Agriculture, Washington, DC. Accessed 31 May 2015. <http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx>

Palmer, M.A., R.F. Ambrose, and N.L. Poff. 1997. Ecological Theory and Community Restoration Ecology. *Restoration Ecology* 5:291–300.

Porensky, L.M., K.J. Vaughn, and T.P. Young. 2011. Can initial intraspecific spatial aggregation increase multi-year coexistence by creating temporal priority? *Ecological Applications* 22:927–936.

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://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* 48:230–235.

Seabloom, E.W., W.S. Harpole, O.J. Reichman, and D. Tilman. 2003. Invasion, competitive dominance, and resource use by exotic and native California grassland species. *Proceedings of the National Academy of Sciences* 100:13384–13389.

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

Stromberg, M.R., and P. Kephart. 1996. Restoring native grasses in California old fields. *Ecological Restoration* 14:102–111.

Vaughn, K.J., and T.P. Young. 2015. Short-term priority over invasive exotics increases the establishment and persistence of California native perennial grasses. *Ecological Applications* 25:791–799.

Volaire, F., and M. Norton. 2006. Summer dormancy in perennial temperate grasses. *Annals of Botany* 98:927–933.

Wainwright, C.E., E.M. Wolkovich, and E.E. Cleland. 2012. Seasonal priority effects: Implications for invasion and restoration in a semi-arid system. *Journal of Applied Ecology* 49:234–241.

Wolf, K.M., and T.P. Young. 2016. Summer water in a restored native grassland flushes annual grass seed bank but fails to increase native perennial cover. *Ecosphere* 7(6):e01309.

Hairy Orcutt Grass *continued*

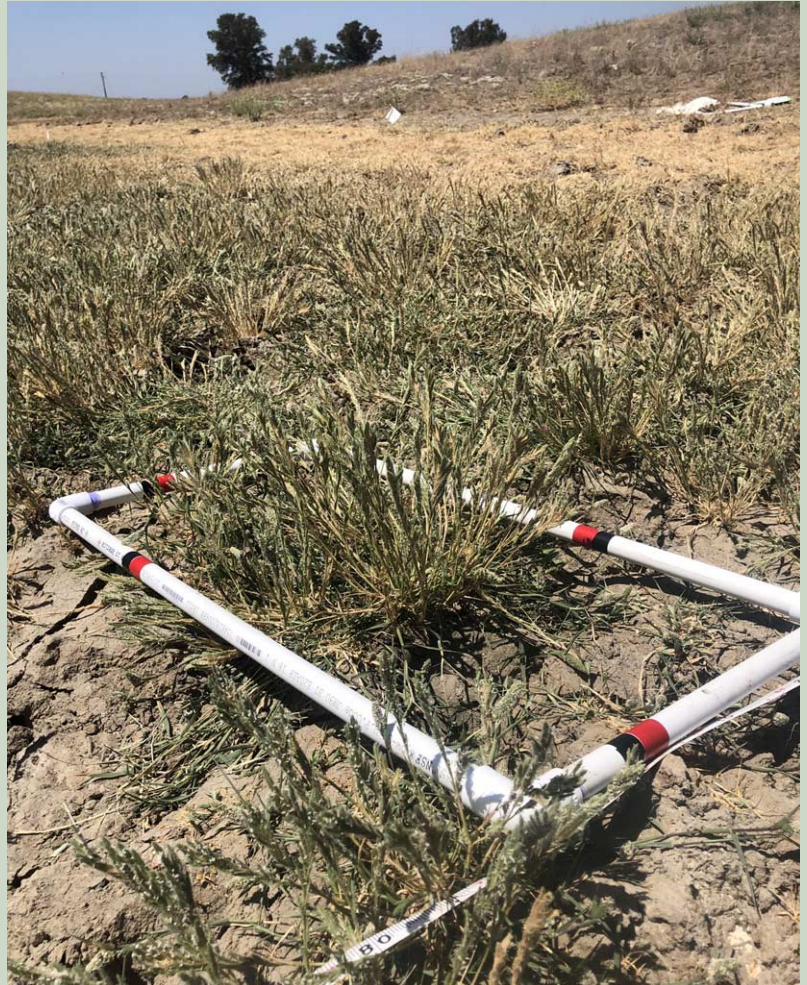
Among other fascinating attributes, Orcutt grass species have a significant relationship with black mold, which aids germination. Research has shown that a black fungus contained within the chaff is necessary for seed germination and so “naked” seeds (i.e. seeds with no chaff) will not germinate (Birker 2018).

Hairy Orcutt grass flowers are protogynous, meaning that female flowering parts become mature and receptive well before male pollen is shed. Vernal pools, at early summer dry-down, present various ranges of age classes between the pool margin and its center. Mature dead plants containing ripe seed may be present at the margin, while the center may contain premature flowering individuals. This variability in age classes within a small area supports the theory that successful pollination occurs with a strong protogynous reproduction strategy.

Hairy Orcutt grass is tough and gritty and several interesting adaptations ensure their survival. Seed production and dispersal is an adaptation that singles out this grass from other species. They do not immediately shed their seed like most grasses. Seeds remain firmly attached to the parent plant, and senesced plants persist late into the dry season and are largely shattered and disbursed by the first heavy rains of the late fall/early winter. It is presumed that seed retention helps prevent seeds from being blown into the surrounding unfavorable upland grasslands adjacent to vernal pools. They also produce an enormous amount of seed — up to 10,000 seeds on a single plant (Griggs 1980). Thus, favorable years likely result in a massive amount of seed production and add to the seed bank in the soil, buffering some of the fragilities of the species, including years of low seed production and high mortality.

Hairy Orcutt grass does not tolerate heavy competition from other plants. It commonly occurs in the deepest portions of vernal pools with a relatively long inundation period and low soil depth (shallow hardpan). This niche suggests that shallow soils and harsh environments play an important role in reducing plants that are competitive with this species. Another interesting adaptation of hairy Orcutt grass and other members of the genus is that they produce a secretion that is extremely acidic and is initially aqueous, becoming viscous and brown as the plant matures. The secretion helps deter predation from grasshoppers, grazing animals, and other herbivores (Griggs 1976).

Like many other rare plants, hairy Orcutt grass thrives on the edge of the world in an extreme habitat with specific conditions. Although habitat conversion and fragmentation has resulted in a significant reduction in this species over time, its unique ecological



Quadrats were used to quantify a huge hairy Orcutt grass stand within a vernal pool (Madera County, 2019). Photo courtesy of Rebekah Bergkoetter

niche and biological characteristics have served to buffer those effects and provide hope for the continued existence of this rare and unique California grass species.



References

- Birker, C. 2018. Seed banking and germination testing of *Orcuttia viscida*. Unpublished report to Carol Witham, Rancho Santa Ana Botanical Garden, Claremont.
- Bullard, A.D. 1994. Charles Russell Orcutt: Pioneer naturalist. *Journal of San Diego History* 42(2).
- CDFW. 2013. California's vernal pools. California Department of Fish and Wildlife. Accessed June 26, 2020. <https://wildlife.ca.gov/Conservation/Plants/Vernal-Pools>
- Griggs, F.T. 1976. Life history strategies of the genus *Orcuttia*. In: *Vernal Pools: Their Ecology and Conservation*. Institute of Ecology Publication No. 9: University of California, Davis.
- Griggs, F.T. 1980. Population studies in the genus *Orcuttia* (Poaceae). Ph.D. dissertation: University of California, Davis.

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**Inside: The surprising secrets of a rare
grass with an ancient lineage that
evolved on the margin of a shallow
inland sea — see article, p. 18.**

Front cover: A beautiful and diverse collection of natives was found on a rural roadside outside of Petaluma. Species found include the pictured *Achillea millefolium* (yarrow) and *Clarkia gracilis* ssp. *sonomensis* (*Sonoma clarkia*). Other species found nearby but not pictured include *Elymus multisetus* (big squirreltail grass), *Stipa pulchra* (purple needlegrass), *Gilia capitata* (gilia), *Eschscholzia California* (California poppy), June 2019.
Photo: Emily Allen, CNGA Board Member

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

