California
Native
Grasslands
Association

GRASSLANDS

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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've been spending a lot more time than I'd like inside these days, a lot of time thinking. Thinking about friends and colleagues, about what the grasslands I used to visit might look like this year. Thinking about geophytes—plants that resprout from an underground storage organ such as a corm or bulb. Grasslands in California are home to many geophytes: this time of year, it would be blue dicks and ookow (*Dichelostemma capitatum, D. congestum*), fairy lanterns (*Calochortus amabilis* and others), checker lilies (*Fritillaria*) and soap plant (*Chlorogalum*). But they don't always emerge. Sometimes they stay underground for a year or more, waiting for the cue to sprout.

Thinking, too, about purple needlegrass (*Stipa pulchra*). Not just its deep roots and long life, but how as a population they tend to grow some distance from each other, perhaps so they can all survive when moisture is scarce.

And thinking about (just over) 20 years ago, when I was working to incorporate Earth Day 2000 in as many states as possible for the 30th anniversary of Earth Day. Remembering Gaylord Nelson talking about the first Earth Day, about teach-ins and sit-ins and now, this year, the 50th anniversary of Earth Day how once again we are talking about sitting down in solidarity to save—well, if not our planet, each other.

But try as I might, I can't help but think of the things CNGA can't do right now with you: grass identification courses, landscaping workshops, and Field Day at Hedgerow Farms. Things that bring us together in celebration of grasslands and amazing plants and the fun of learning from each other. CNGA hopes this fun is merely postponed, and we are working on ways to stay connected while we're apart (this issue of *Grasslands*, for one). I hope you can join us at one of our rescheduled events if it's safe to do so and help us stay alive "underground" by donating to CNGA during the Big Day of Giving on May 7.

Andrea Williams, President

What though the radiance which was once so bright
Be now for ever taken from my sight,
Though nothing can bring back the hour
Of splendour in the grass, of glory in the flower;
We will grieve not, rather find
Strength in what remains behind

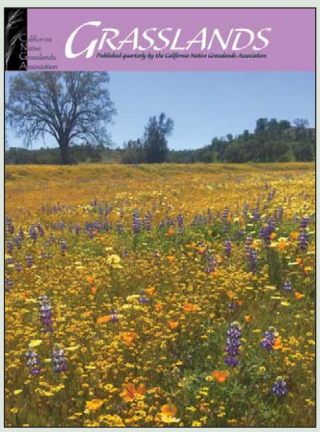
—William Wordsworth, 1770–1850

Upcoming CNGA Workshops & Events

Like all of you, our lives and work at CNGA have been uprooted and we are exploring new ways to adapt our programs and continue working toward CNGA's mission and goals. One of CNGA's great strengths over the years has been our offering of a wide range of training workshops. Our ability to put on workshops has been altered by the recent Coronavirus outbreak and the necessary sheltering and social distancing this new reality demands. Much like newly grazed grass, our growing points are still intact and new ideas are sprouting like tillers. Our Workshop Committee is working out new ways to provide the training and information that serve our members and supporters. We may have been put out to pasture for now, but we will be back in the field—whether in person or in virtual fashion—soon.

Please see page 9 for the latest updates to our schedule.

In this issue



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.

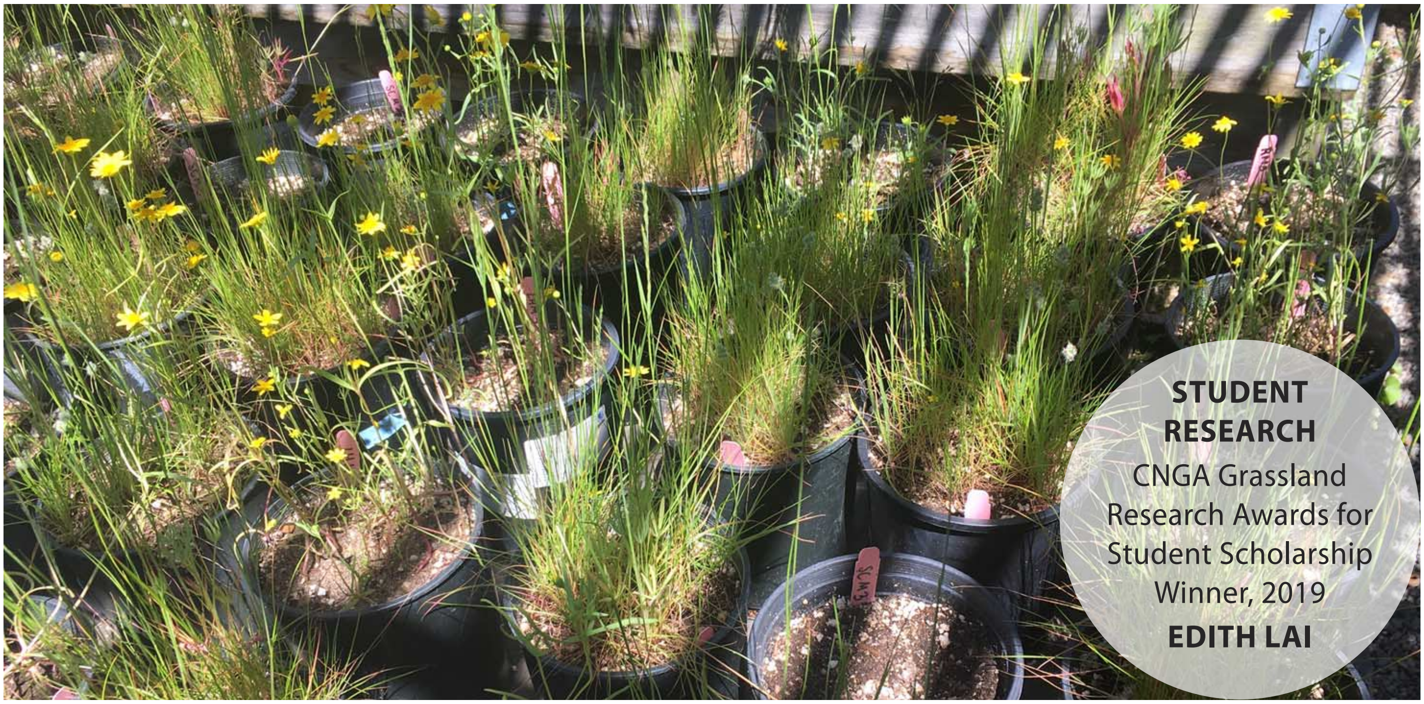
Submission deadlines for articles:

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

When we first used this slogan a couple of years ago, we had no idea how fast the world could change. Now a pandemic has uprooted the economies of the world. Social distancing has disrupted the usual ways we go about things, but it has also provided a time for contemplation. We are confident that we will come through this with new ideas and with a tighter focus on the things that really matter. One thing that will not change is our commitment to our mission. We invite you to invest in long-term ecological resilience and support our mission by donating.

Three ways to make your gift:

1. **Online** — www.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 information



Overview of experimental setup, each pot contains one needle goldfield population and one biodiversity treatment.

Biodiversity Loss and Phenology in California Grasslands

by Edith Lai[1] and Rachel Olliff Yang, M.S.[2]

Background

A major consequence of climate change on plant communities is its effect on phenology - the seasonal timing of life events such as germination, flowering, and fruiting. The main factors influencing plant phenology are temperature, photoperiod, and precipitation, but the effects can be compounded by additional factors (Parmesan and Yohe 2003, Franks 2011). Studies have concluded that the general phenological response to global warming is a shift toward earlier flowering seasons as a result of warmer temperatures during winter (Parmesan and Yohe 2003, Cleland *et al.* 2006 and 2007, Menzel *et al.* 2006). This shift is significant because seasonal synchronicity between plants and pollinators or between plants and consumers may be disrupted, potentially causing complex and adverse bottom-up effects in higher trophic levels (Franks 2015). A recent study demonstrated that declining biodiversity also affects flowering in California grasslands through direct manipulation of species composition in grassland reserve plots over the course of four years. Multiple species flowered significantly earlier in response to reductions in diversity, suggesting a stronger role of biotic factors in phenology (Wolf, Zavaleta, and Selmants 2017). The advance in flowering caused by biodiversity loss is comparable to the advance caused by changing physical conditions attributed to global warming. In addition, biodiversity is positively associated with ecosystem productivity and stability over extended periods of time (Tilman, Reich, and Knops 2006, Craven *et al.* 2018). With downstream effects of climate change leading to invasive species introduction and habitat destruction, declining biodiversity is a significant threat to many ecosystems (Butchart, Walpole, and Collen n.d., Dukes 2002). The combined effects of increasing temperature, precipitation change, and biodiversity loss will have severe effects on California grasslands; therefore, further study on the relationship between biodiversity and phenology is integral to informing the land management and conservation of this valuable ecosystem.

This study is framed around needle goldfields (*Lasthenia gracilis*), an annual herb found throughout California grasslands. This species was chosen because of its widespread distribution and environmental tolerance. In addition, high trait variation and high fixation index — the genetic distance between populations — indicate significant population level differences (Montalvo, Riordan, and Beyers 2017). Within the *Lasthenia* genus and multiple other genera, populations found in decreasing latitudes correlate with earlier flowering time (Hall *et al.* 2007, Olsson and Ågren 2002,Olliff Yang unpublished data). In regions closer to the equator, limited water availability due to dry summers prompts populations to flower earlier, a response called

[1]Edith Lai is a fourth-year undergraduate student at UC Berkeley studying Molecular Environmental Biology and Public Health. This project was conducted through the Undergraduate Research Apprenticeship Program (URAP). [2]Rachael Olliff Yang is a PhD Candidate from the Ackerly Lab in the Department of Integrative Biology at UC Berkeley. She served as the URAP research mentor.

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A monoculture pot of Lost Hills population flower.

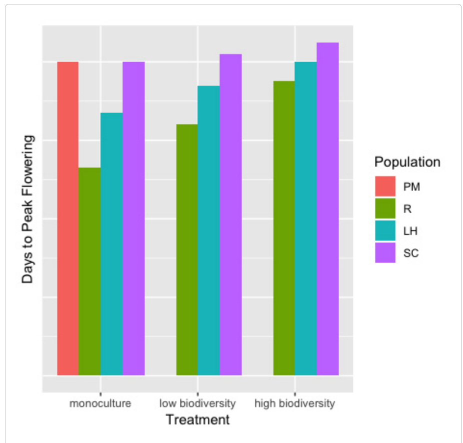

Figure 1. Hypothesized trends in peak flowering date in relation to biodiversity.

Figure 2. Latitudes of needle goldfield populations included in study.

Biodiversity Loss and Phenology in California Grasslands *continued*

drought escape (Franks 2011, Shavrukov *et al.* 2017). In Central Valley and coastal regions of California, where grasslands are located, average annual precipitation decreases as latitude decreases (California Department of Water Resources). Lower latitude plants benefit from early flowering by being able to complete their life cycles early while water is still plentiful. A study on phenotypic plasticity found that among sagebrush, lower latitude populations display greater plasticity in flowering time than higher latitude populations in response to photoperiod and temperature (Richardson *et al.* 2017). Flowering time plasticity, which is the variance in the timing of flowering expressed in response to differential conditions, can be a beneficial adaptation in changing environments. This experimental study seeks to determine if a relationship exists between the latitudinal gradient of populations within a single species and the phenological response to biodiversity loss. Given that lower latitude plants have adapted to flowering earlier to maximize water availability and the phenological plasticity involved in drought escape response, lower latitude populations may exhibit greater phenological plasticity in response to declining biodiversity. To test this, populations of needle goldfields chosen from three latitudes of California grasslands were grown in environments with decreasing levels of biodiversity. We hypothesized that declining biodiversity would correlate with greater phenological shifts for needle goldfield populations originally from lower latitudes than needle goldfield populations originally from higher latitudes in California. The expected results are displayed in Figure 1, with R, LH, and SC representing populations of increasing latitude and PM representing a monoculture mixture of the three populations. In addition, we hypothesized that flowering season lengths for populations would decrease in response to declining biodiversity due to the positive relationship between biodiversity and ecosystem productivity.

Methods

Setup

This experiment took place within a lath house at the University of California, Berkeley, Oxford Tract facilities. Lath houses allow for the use of natural climate and precipitation while protecting the experiment from extreme disturbance. Needle goldfield seeds provided by Pacific Coast Seed originated from Santa Clara, Lost Hills, and Riverside counties to represent populations of high, medium, and low latitudes, respectively (Fig. 2).

The other species used to represent a California grassland community were annual lupine (*Lupinus bicolor*), small fescue (*Festuca microstachys*), dotseed plantain (*Plantago erecta*), and annual hairgrass (*Deschampsia danthonioides*). These species were chosen from a larger pool of common grasses and annual herbs. Each population of needle goldfields received three biodiversity treatments: monoculture, low biodiversity, and high biodiversity in a fully crossed design. The masses of seeds in each pot were standardized to control for density dependent effects. In monoculture treatment, 170 mg of needle goldfield seeds were planted in a single pot. In low biodiversity treatment, 56.7 mg each of needle goldfields, annual lupine, and small fescue seeds were planted together in the same pot. In high biodiversity treatment, 34 mg each of seeds of all five species were planted in the same pot. An additional treatment group of mixed populations contained equal amounts of needle goldfield seeds from each of the three populations to compare the phenological effects of population level genetic diversity with community level species biodiversity. Each population and treatment were grown in six-inch diameter pots with high drainage soil. There were five replications of each population and treatment, totalling to 50 pots of five mixed monoculture populations and 15 pots of each needle goldfield population and biodiversity treatment.

Data Collection

Seeds were planted in pots in early February and regularly watered throughout the spring season. After observing the first emergence, we counted the number of emerged needle goldfield seedlings in each pot biweekly to determine the peak emergence dates for each treatment.

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After emergence, we collected data on needle goldfield flowering by counting the number of buds and open inflorescences. Data collection concluded in late June, following the conclusion of the typical needle goldfield bloom period and the senescence of all plants.

Phenology measurements included peak emergence date, first flowering date, peak flowering date, and flowering season length. First flowering is the date in which the first flower opened within a pot, while peak flowering date and flowering season length were determined by counting active reproductive structures — both buds and inflorescences. The flowering season was defined as the number of days between the first and last flower openings.

Analysis

To test our hypothesis, we had to determine if a trend existed between biodiversity and 1) first flowering date, 2) peak flowering date, 3) or season length. We then compared the direction and strength of the trends between populations. The first analysis compared days to peak flowering of monoculture populations using an ANOVA test to confirm the relationship between latitude and flowering. We then determined if changes in days to peak flowering, days to peak flowering, and season length for each population were positive or negative in relation to biodiversity loss.

Results

Data from the Santa Clara flowers, which represents the highest latitude population, were excluded from this first test due to low emergence rates, so only Riverside, Lost Hills, and mixed populations were compared. ANOVA results ($F = 9.17$, $p = 0.0038$) confirm that the peak flowering dates of the monoculture pots are statistically different (Fig. 3). The Riverside monoculture pots reached peak flowering earliest, then Lost Hills, and finally the mixed monocultures.

Figure 3 displays days to peak flowering while Figure 4 displays days to first flowering. Starting with the lowest latitude population, Riverside, days to peak flowering decreased as biodiversity increased and there was no discernible trend between biodiversity and days to first flowering. For the middle population, Lost Hills, days to peak flowering increased as biodiversity increased, while days to first flowering remained constant in relation to biodiversity. For the highest latitude population, Santa Clara, both days to peak flowering and days to first flowering decreased with biodiversity increase. However, this result is less reliable since the sample size was much smaller than other populations and no observations were made in the high biodiversity treatment. An interesting observation about days to first flowering was that the Lost Hills population flowered earlier than Riverside and Santa Clara flowers at every treatment level. Due to the lack of a consistent

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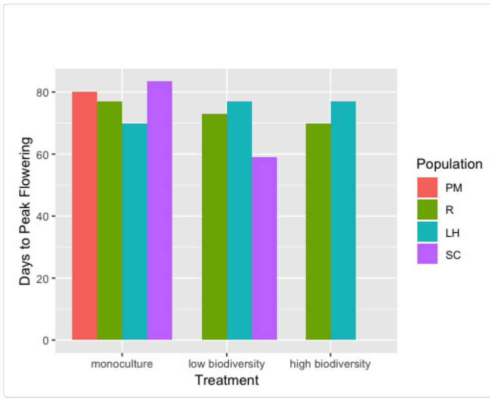

Figure 3. Mean number of days to peak flowering in response to biodiversity levels.

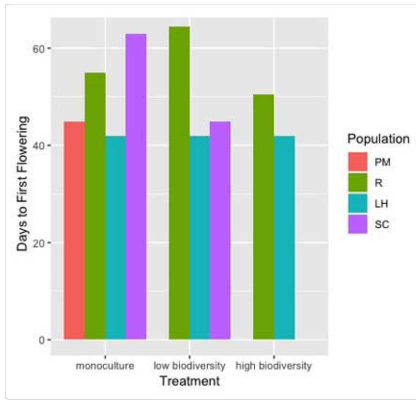

Figure 4. Mean number of days to first flowering in response to biodiversity levels.

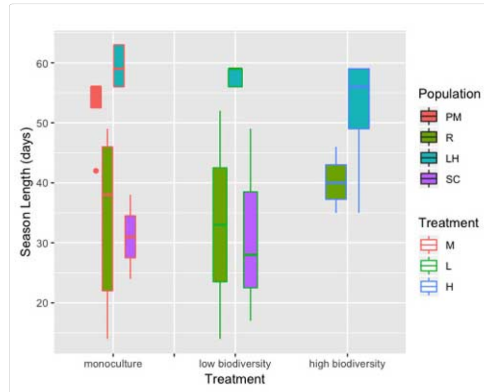

Figure 5. Flowering season length in relation to biodiversity levels.

relationship between flowering and biodiversity, the trends observed within each population could not be compared to each other, and results of the mixed population treatment could not be compared to the other treatments.

Figure 5 displays the range of flowering season lengths for each population and treatment, measured by the average difference between the last and first flowering dates of each pot. The relationship between flowering season length and biodiversity is also inconsistent across populations. For Riverside, there is a slight positive relationship between season length and biodiversity. On the contrary, there is a negative relationship between season length and biodiversity in Lost Hills. There is an unclear flowering season length trend for Santa Clara. Additionally, the Lost Hills population and mixed population treatment group had much longer flowering seasons than either Riverside or Santa Clara. For all three measures, days to peak flowering, days to first flower, and flowering season length, there is no consistent pattern between population and response to biodiversity treatment.

Discussion

The results of this study are inconclusive. Based on the collected data, declining biodiversity does not correlate with a consistent pattern in phenological response across the three needle goldfield populations. For all three measures, days to peak flowering, days to first flower, and flowering season length, there were both positive and negative relationships between biodiversity and phenological shift. With regards to the hypothesis, the expected direction of phenological shift in response to biodiversity loss occurred in only one of the three populations, Lost Hills, in which the days to peak flowering decreased as biodiversity decreased. However, the observed flowering season length in this population increased in relation to decreasing biodiversity, which is opposite to the expected direction of change and contradicts assumptions of the diversity-stability hypothesis. These two patterns occurred as predicted within the Riverside population: days to peak flowering increased and season length decreased in relation to biodiversity loss. Because of the conflicting results, the original hypothesis cannot be confirmed or refuted, as there is no latitudinal trend connecting the opposing patterns observed. These results also suggest that the relationship between biodiversity and phenology, if any, may be more variable and complex within a species than previously thought.

While outside the scope of this study, inflorescence size differences were observed in relation to biodiversity levels. In general, inflorescences found in monoculture pots were larger in diameter (produced more flowers) than their counterparts grown in higher biodiversity environments. This trend could be indicative of excess competition. Although the total mass of seeds in each pot was standardized to minimize confounding effects of competition, the two grasses used to model California grasslands had such high germination rates compared to the needle goldfields that the low and high biodiversity pots were significantly more crowded than the monoculture pots. This seemed to result in increased competition, for nutrients, water, or sunlight, in biodiverse treatment pots. An area of further study would be determining whether a trade-off exists between inflorescence size and number in the presence of competition, as this would better inform ecosystem modelling.

The main limitations to this study are the small sample sizes both of needle goldfield populations and of replications. For one of the three populations, Santa Clara, germination rates were too low to comprehensively analyse flowering data across treatment groups. Many of the pots contained only one or zero needle goldfield plants. Due to a limited number of replications within each population, there was not enough data collected at each treatment level to run more statistical tests. Because Santa Clara was the only representative for high latitude populations, the lack of data also limited the ability to determine latitudinal trends. Future studies would benefit from more populations found along California's latitudes in order to account for differential emergence rates among populations and germination trials prior to experimental setup can reveal differences across populations. Alternatively, in studies with fewer sample areas available, replications

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should be increased to capture more germination successes. Although the results of this study are inconclusive, the complex relationship between biodiversity and phenology should continue to be studied, especially in communities facing threats of biodiversity loss. The different patterns observed here pose a lot of questions regarding flowering patterns of needle goldfields, which will be informative to the conservation efforts in California grasslands.

Acknowledgements

Thank you to the California Native Grasslands Association Grassland Research Award for Student Scholarship for generously funding this project. We would also like to thank the Ackerly Lab at UC Berkeley for mentorship and guidance, as well as Pooja Butani and Emily Cox for support running the experiment

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MEET A GRASSLAND RESEARCHER **Sarah Gaffney** sagaffney@ucdavis.edu

Graduate Group in Ecology, Eviner Lab, Department of Plant Sciences, University of California, Davis

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

My research is part of a larger long-term field experimental grassland site in Davis, CA, initiated by Drs. Valerie Eviner and Carolyn Malmstrom in 2007. In this experiment, mixes of the three main plant groups of Central Valley grasslands—native perennial grasses (*Stipa pulchra, Elymus glaucus, E. triticoides*), naturalized exotic annuals (*Avena barbata, Bromus hordeaceus, B. diandrus, Festuca perennis, Trifolium subterraneum*), and the noxious weeds medusahead and goatgrass (*E. caput-medusae, Aegilops triuncialis*)—were seeded into separate replicated plots and allowed to be naturally invaded by species from other, adjacent mixes over the course of the 12-year experiment.

My research utilizes these long-term plots to better understand how grassland plant communities change over time and what factors influence these trajectories. My main research goal is to explore the importance of priority effects in community development — essentially, how important is species' identity at the start in defining a community's future composition? In relation to native grassland restoration, my research has two main components:

1) Is there a time limit to native restoration before the site becomes invaded again? And if so, can we predict whether the naturalized exotic species or noxious weeds will invade and when? I am particularly interested in the potential influence of the recent extreme climatic variation of the 2011–2014 drought that was followed by a historic wet year in 2017. Hopefully our findings can be applied to improve restoration success, especially as many restoration projects lack the funds to monitor post-implementation to determine level of success.

2) Does the initial identity of species in the community affect future composition by changing the soil and creating plant-soil feedbacks? Native restoration largely takes place on previously invaded soil, but recent work has shown that exotic grasses can change the soil's biological, physical, or chemical properties. Thus, my second research goal is to identify any potential soil changes induced by long-term exotic grass dominance and determine how native grass establishment and performance might be affected. If native grasses are negatively affected, weed control alone may not be enough for successful native restoration.

Who is your audience?

My audience consists of grassland restoration practitioners and managers, as the main goal of my work is to improve restoration efforts by identifying factors that influence community change over time. I also hope traditional community ecologists who are intrigued in unraveling assembly theory will gain some insight by my work, as it explores community assembly in a uniquely stable, annual-dominated system.

Who has inspired you, including your mentors?

First and foremost, I have been most inspired by my mother, a woman who is constantly fascinated and intrigued by the world around her. She always knows the names of the local trees, wildflowers, and birds, and I loved asking her about them as a child. Her love of learning has been a guiding force in the development of my scientific mindset — she taught me to be curious about my environment and always ask questions.

My two college advisors also inspired my current track. I was lucky to work with Dr. Virginia Hayssen, a mammologist, who taught me the fundamentals of the research process and Dr. Jesse Bellemare, whose love and enthusiasm for plants was infectious.

Another of my major influences was Dana Hawkins, my boss at Aztec Ruins National Monument, whom I helped in her program to restore native diversity to the monument. She taught me about the many challenges faced by practitioners and encouraged me to think critically about solutions, always valuing my opinion. Dana was an invaluable mentor, and my experience with her strongly influenced my decision to go to graduate school and study restoration ecology. I still remember and admire her tenacity and resiliency when challenges arose and am grateful I had a strong female mentor who believed in me.

On the note of strong female mentors, I have been inspired for the last four years by my graduate research advisor, Dr. Valerie Eviner. Her knowledge of California grasslands knows no bounds, and she has been an amazing guide in helping an East Coaster like myself through the complexities of California's grassland ecosystems. I am thankful

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Upcoming CNGA Workshops & Events

Planned events and status:

CNGA's 13th Annual Field Day at Hedgerow Farms — Rescheduled to June 12, 2020. We are discussing alternate ways to offer this safely if social distancing is prohibitive to a live event.

Landscaping with Nature Workshop — Will be rescheduled as an in-person or virtual event with presentations and panel discussion.

SERCAL Conference, Carmel Valley — Rescheduled for September 16–18, 2020. CNGA is hosting the grasslands-focused technical session, *Grassland Ecosystems: Management Perspectives & Local Adaptations.*

In planning stages, several to be offered as online workshops:

Identifying and Appreciating the Native and Naturalized Grasses of California

Apps and Snaps: Smartphone, Camera, and Online Technology for Grassland Plant Mapping, Tracking, and Identification

Grassland Vegetation Monitoring, Methods, and Techniques

Introduction to Grasslands Soils

Planned Grazing: How to Grow Soil, Grassland Health, & Profit

We will send out announcements when registration opens for 2020 events, or you can check for updates at www.cnga.org.

MEET A GRASSLAND RESEARCHER

continued

for her perspective on restoration, mentorship, and the constant support she has offered me over the years.

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"?

Our grasslands are incredibly valuable yet are tricky ecosystems to study and challenging to manage. Successful restoration depends upon an understanding of the underlying ecology, and I believe my research will build upon that ecological foundation. My research will hopefully contribute another set of tools to the restoration practitioner's toolbox by providing insight on how a restored native community may develop over the first ten years and whether soil amelioration may be a necessary part of the restoration process.

Why do you love grasslands?

I am always amazed by the diversity that can be found in California grasslands! I was helping a colleague with botanical surveys last year and was amazed to find 20 species in a single 0.25 x 0.25-m square plot. Granted, a lot of them were exotic, but it's still incredible. I love going out to places and searching for as many species that I can find, and grasslands are essentially a giant treasure hunt in that regard (check out my personal hobby, wildflower identification, on Instagram @wild.flower.hunter, I would love ID help!).

Biodiversity Loss and Phenology in California Grasslands *continued from page 7*

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Italian thistle (*Carduus pycnocephalus*) responds well to bare soil, or chronic rest, or manure spreading.

A VIEW FROM THE FIELD:

Invasive Annual Weeds — Problems or Symptoms? Part 4

by Richard King[1] *Photos courtesy Bob McClure, rancher*

This is the fourth part in a series focusing on California's invasive annual weeds, examining if they are indeed a significant "problem" or merely a symptom of other factors well within our control. The first article emphasized the four major ecosystem processes occurring in grasslands and that adversely affecting any of them can simplify the living community (King 2018a). Increasing bare soil can greatly simplify a community by adversely affecting all of the ecosystem processes and provide a broad niche for opportunists to establish. Part 2 in this series described how excessive rest ("over-rest") can also simplify the community, promoting invasive plant growth (King 2018b). Part 3 emphasized that overgrazing from the plant's point of view is grazing regrowth before the plant fully recovers its vigor and root mass from the first grazing; overgrazing of plants can directly simplify the community dynamics (King 2019). This part of the five-part series looks at excessive nutrient loading ("over-fertilization") as a factor directly affecting the invasiveness of some annuals.

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

Manure

Grassland soils need macronutrients for plant growth such as N, P, K, S, Ca & Mg or micronutrients such as Cu, Zn, Se, B, & Co. One nutrient in particular stimulates the greatest increase in productivity if soil moisture isn't limiting—nitrogen. When livestock spend considerable time congregating in the same bedding grounds, feeding areas, under favorite shade trees, or near their water source, they repeatedly deposit urine and/or feces day after day. Very high levels of plant-available soil nitrogen in the form of ammonia or nitrate can occur.

Some plant species are nitrophilous, meaning they are capable of tremendous nitrogen intake and growth when available, whereas other species can be much less responsive or even harmed by excessive nitrogen fertilization. Nitrogen-loving plant species prefer highly fertile soil. Dairies that spread animal waste from storage ponds to fertilize their fields often experience a flush of new thistle or mustard growth as well as annual ryegrass (*Festuca perennis; Lolium multiflorum*). All are nitrophilous. It is common for some thistles, such as milk thistle (*Silybum marianum*), to become tall dense stands in response to the new fertility. The patches can even become forest-like

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monocultures where they grow quickly and shade out the other grass and forbs (King County 2018). Other kinds of livestock or poultry manure can also result in dense thistle patches wherever the soil nitrogen available for plant uptake becomes abundant.

Synthetic N

While animal waste can provide high amounts of nitrogen in the form of nitrates or ammonia, use of synthetic nitrogen fertilizer can similarly cause nitrogen-loving invasives to thrive. Bags of urea, ammonium sulfate or ammonium nitrate are commonly used to increase grassland vigor and productivity. Not only will many species of thistle respond, invasive mustards and annual ryegrass can quickly respond to high levels of soil nitrogen and similarly form tall dense patches. Fertilizing native grasslands can benefit nitrophilous invasive plant species more than native species. Natives can be swamped by the tall growth of exotic species, which excessively shade them. The green leaves and stems of native plants can turn yellow and die from lack of sunlight.

Other Nitrogen Sources

Nitrophilous invasive plant species respond quickly to any additional N. Although perennial grasslands can suppress the invasiveness of exotic annuals (Chambers *et al.* 2007, Davies *et al.* 2011, Eviner and Malmstrom 2018), research indicates that conversion of native perennial grassland to exotic annuals may be increasing available nitrogen levels in the soil (Parker and Schimel 2010). Perennials more efficiently cycle N because of their longer growing season and greater root mass. Society is inadvertently increasing nitrogen deposition on grasslands through fossil fuel consumption and wildfires. Research done in the grassland hills adjacent to Silicon Valley show that our own consumption of fossil fuels for transportation can elevate the amount of atmospheric nitrogen being added to adjacent grasslands (Weiss 1999). Fires too can create a short-term pulse of soil nitrogen available for plant growth (Neary *et al.* 2005 rev. 2008) or stimulate nitrogen-fixing plant growth. However, while most invasive annuals respond to the increased nitrogen they may help create, a rapid dramatic shift to invasive monocultures of nitrophilous species pales in comparison to excessive fertilization from manure or synthetic fertilizer.

Multiple Factors

Although increasing soil nitrogen can turn some invasive thistles into dense forest-like patches of stickers, often it is a combination of factors (i.e., think more bare ground or over-grazing plants and simplifying the community) or even a lack of disturbance (i.e., think chronic rest from grazing or trampling) along with high nitrogen levels in the soil that best explain why some invasive species have taken over a site. Any of these factors could create more simplified communities. If high N fertilization occurs and nitrophilous plant seed is present in the seed bank, those species will quickly and sometimes dramatically appear and dominate the site.

Some nitrophilous invasive species can also exhibit allelopathic effects that reduce the germination and establishment of other herbaceous species. Indeed, some of these species may be creating an environment in which only they can thrive in the presence of elevated ammonia or nitrates until the excessive nitrogen declines from volatilization, incorporation in organic matter, or is transported away in water.

Summary

Over-fertilization of nitrogen in grasslands using livestock/poultry manure or synthetic nitrogen fertilizers can create an explosion of growth by nitrophilous invasive plant species due to high levels of ammonia and/or nitrate in the soil. Bare soil, overgrazing of plants,

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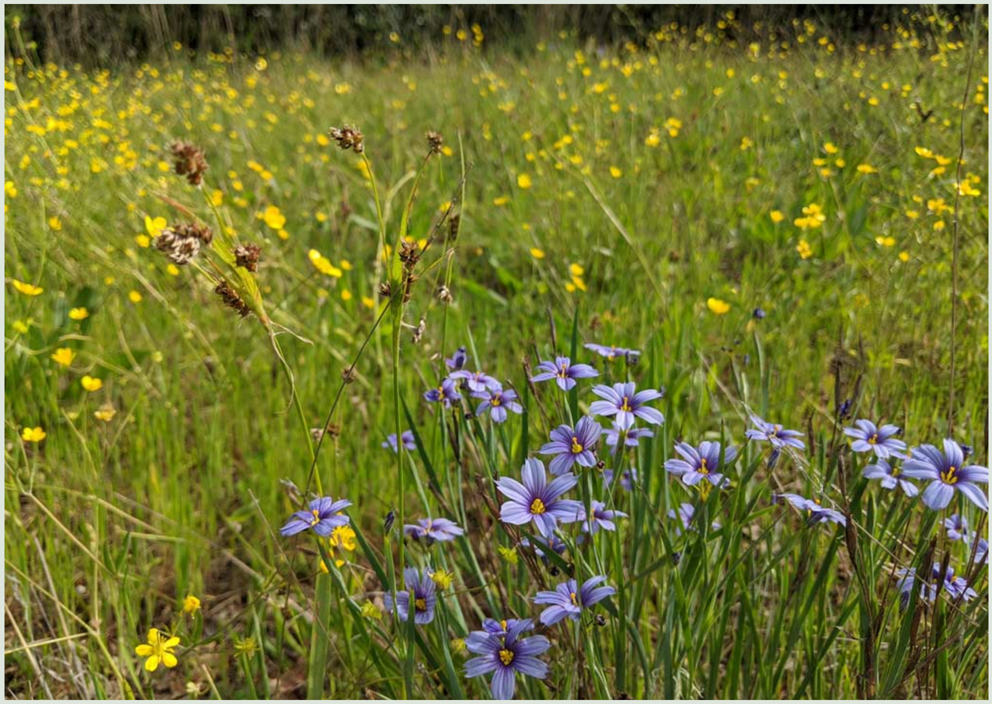

Left: *Luzula comosa* flowers and the soft hairs on the edge of the leaf margin and hairy culm, March 30, 2018. Right: *Luzula comosa* with *Sisyrinchium bellum* and *Ranunculus occidentalis* along a roadside, April 17, 2020.

SPECIES SPOTLIGHT: *by Emily Allen*[1] *Photos courtesy of the author*

Hairy Wood Rush (*Luzula comosa*)

I was out hiking with a local botany group in early February a few years ago when someone pointed at a small, dark green, clumping, grass-like plant and asked if I knew what it was. At first glance, the dark brown flowers made me think it was a *Juncus* species, but looking closer, I saw long hairs on the leaf and culm. This confused me made me wonder if it was, in fact, a grass. I asked Andrea Williams, CNGA's president, for help, and she excitedly told me it was a wood rush! She said she often gets this question in early spring and that in general, when there is a graminoid (grass-like plant) that doesn't quite look like a sedge, rush, or grass and has a visibly hairy culm and leaf edges, it is a wood rush (*Luzula* sp.).

The rush family, Juncaceae, has two genera: the well-known *Juncus* genus and the lesser-known *Luzula*. The key in the Jepson Manual distinguishing the two genera includes the following features: *Juncus* species have noticeably smooth (glabrous) leaves with an open sheath, and their fruits have many seeds, while *Luzula* leaves have hairy margins and a closed sheath and their fruits contain only three seeds each (Baldwin *et al.* 2012). The genus *Luzula* may be derived from the Italian word *lucciola*, which means firefly or glowworm, a good description for how the light shines through dew drops that cling to the leaf hairs, while *comosa* means "tufted, furnished with a tuft of some kind" (Calflora.net 2020). Keep an eye out this spring for these charming early-blooming plants. There are several species of wood rush native to California, however there is currently opportunity for further differentiation of species and varieties (Baldwin *et al.* 2012). As recently as 2015, Zika *et. al.* proposed two new species of wood rush in California, with potential for further reclassifications.

Hairy wood rush (*Luzula comosa*) is the most common wood rush species in California, and like all the wood rush species in California, it is a perennial. This bunch-forming (cespitose) graminoid can have short rhizomes (Baldwin *et al.* 2012) but usually grows in clumps in wetter areas with partial shade (Calscape 2020). Hairy wood rush can be found in a variety of habitats including meadows, forests, and woodlands throughout much of the state, although it is noticeably absent from the Great Central Valley and most of the lower deserts and Modoc Plateau. The *Jepson Manual* lists the flowering period as June through July, where Calflora.org has the boom period as March through June. I have observed it blooming in several locations in February, so it doesn't hurt to keep an eye out for it at the end of winter. The easiest time to spot this fascinating species is early spring while their flowers are showy and visible, and before the other colorful flowers have begun to bloom.

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Hairy Wood Rush *continued*

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Milk thistle can respond dramatically when animal waste is spread on pasture or silage fields; some landowners mow or spray it.

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and prolonged rest can exacerbate their establishment and vigor. Patches of thistles growing as virtual monocultures are a widespread example. Although many other factors may be increasing nitrogen levels in grasslands, bare soil, over-resting, overgrazing, and over-fertilization are the most powerful factors that create the abundance and dominance of the invasive annuals we love to hate. Yet these four factors can all be managed differently to improve the four ecosystem processes and shift toward more complex living communities. Does that mean how we manage our grasslands is the real culprit leading to large areas of grassland now dominated by invasive annuals? The next and final article will explore that question in order to finally answer the overarching question of this series—'Invasive annuals: problems or symptoms?'

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Left: Large-flowered fiddleneck plants have their reproductive parts arranged in one of two ways. This photo shows a thrum morph, with prominent anthers; the pin morph has a prominent stigma and style. *Photo by author.* Right: Habitat at the most successful re-introduced populations of large-flowered fiddleneck, located in eastern Alameda County (abovet) and western San Joaquin County. Participation of cooperating landowners has been essential for the success of reintroduction efforts. *Photo by Rebecca Wang*

Large-flowered Fiddleneck Recovery Implementation Team *by Jeb Bjerke*[1]

Background

Large-flowered fiddleneck (*Amsinckia grandiflora*) is a critically endangered plant that historically ranged from northeastern Contra Costa County to southwestern San Joaquin County. All known natural populations of large-flowered fiddleneck have now disappeared, except for one small population in San Joaquin County. The primary reason for the near extinction of large-flowered fiddleneck is competition with annual grasses from other parts of the world that have invaded and established in the plant's habitat. The Large-Flowered Fiddleneck Recovery Implementation Team was formed by the U.S. Fish and Wildlife Service in 2014 to help recover large-flowered fiddleneck and protect the species from extinction in the wild. The team consists of dedicated and talented scientists, land managers, agency representatives, and other experts.

Species

Large-flowered fiddleneck is an annual plant, which means that it grows from seed, reproduces, and dies within one growing season, typically from November to June. The plant has bright, red-orange, trumpet-shaped flowers that are arranged into a coiled group that resembles the neck of a fiddle, hence the name fiddleneck. Large-flowered fiddleneck only grows on extremely steep, north-facing grassy slopes that are shaded by the surrounding landscape for much of the year.

Reintroduction

Jake Schweitzer of Vollmar Natural Lands Consulting has led an ambitious multi-year project to reintroduce large-flowered fiddleneck into its historical range. The project has been funded by the U.S. Bureau of Reclamation's Central Valley Project Conservation Program. The Large-Flowered Fiddleneck Recovery Implementation Team has helped advise the project and has provided collaborative assistance for many aspects of the project.

Jake and his team began in 2012 by developing a computer habitat model using information from the last remaining natural population and other locations where large-flowered fiddleneck occurred in the past. Field surveys were conducted to collect additional habitat information at known and new locations identified by the computer habitat model. In partnership with cooperating landowners, ten of the most promising sites were selected for large-flowered fiddleneck reintroduction. The University of California Botanical Garden at Berkeley produced tens of thousands of large-flowered fiddleneck seeds and thousands of seedlings for the multi-year effort.

Planting areas were cleared of non-native vegetation at each of the ten sites and monitoring plots were established. Approximately 4,000 large-flowered fiddleneck seeds and 200 seedlings were planted at each of the 10 introduction sites in the winter of 2014–2015, and again in the winter of 2015–2016. Plantings were watered as necessary when rain was not in the forecast, requiring the use of water-filled backpack sprayers on the extremely steep slopes. Hand-weeding and limited use of grass-selective herbicides were necessary at some sites. Fencing was also installed to evaluate the effects of grazing on the introduced

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populations. One thousand additional large-flowered fiddleneck seedlings were planted at each of the four most promising introduction sites in the winter of 2016–2017, and again in the winter of 2018–2019. To date, approximately 12,000 large-flowered fiddleneck seedlings and 80,000 seeds have been planted.

Results

As a result of reintroduction efforts, over 30,000 large-flowered fiddleneck plants were documented at introduced populations in 2019, making 2019 the best year for large-flowered fiddleneck in decades. The outplanting of large-flowered fiddleneck seedlings grown at the University of California Botanical Garden was found to be a crucial aspect of project success, because seedlings were better at establishing and reproducing at outplanting sites than outplanted seed. Although only four of the ten total outplanting sites were successful over the course of the project, the establishment of robust large-flowered fiddleneck populations at these four sites is encouraging for the future of large-flowered fiddleneck. An impressive 3,740 plants were also documented at the last remaining natural population in 2019. The natural population has not been supplemented with any additional plantings and remains an important reference for evaluating the success of reintroduced populations.

In addition, there is now a greater scientific understanding of preferred habitat for large-flowered fiddleneck, the beneficial effects of careful rangeland management for biodiversity conservation, and propagation and planting techniques. Cooperation with private landowners has been instrumental to project success and has been developed by making in-person connections, working with Natural Resources Conservation Service, and through issuance of California Safe Harbor Agreements.

Team

There are several reasons that the Large-Flowered Fiddleneck Recovery Implementation Team has been successful in advancing the goal of species recovery. The team's success has been due to 1) the cooperation of private and public landowners, 2) prioritization by the U.S. Fish and Wildlife Service, 3) funding from the U.S. Bureau of Reclamation's Central Valley Project Conservation Program for reintroduction, 4) the determination of the Fiddleneck Reintroduction Project Lead, 5) partnership with the University of California Botanical Garden at Berkeley, and 6) the support of numerous volunteers. In addition, the experience, expertise, cooperation, and assistance provided by team members from various agencies and disciplines has been invaluable.

Many thanks to members of the Large-Flowered Fiddleneck Recovery Implementation Team: **Dr. Douglas Bell** (Wildlife Program Manager at East Bay Regional Parks District), **Jeb Bjerke** (Senior Environmental Scientist in the California Department of Fish & Wildlife's Native Plant Program), **Dr. Tina Carlsen** (member alumnus), **Jackie Charbonneau** (Ecologist at the U.S. Department of Agriculture Natural Resources Conservation Service), **Holly Forbes** (Curator at the University of California Botanical Garden at Berkeley), **Dr. Vanessa Handley** (Director of Collections and Research at the University of California Botanical Garden at Berkeley), **Jamie LeFevre** (Project Manager at the U.S. Bureau of Reclamation Central Valley Project Conservation Program), **Lisa Patterson** (Biologist at Lawrence Livermore National Laboratory), **Cary Richardson**(Watershed Resources Superintendent at Contra Costa Water District), **Jake Schweitzer** (Senior Ecologist at Vollmar Natural Lands Consulting, and Large-flowered Fiddleneck Reintroduction Project Lead), **Samuel Sosa** (Biologist at U.S. Fish and Wildlife Service), and **Dr. Rosemary Stefani** (member alumnus).

Meet the 2020 Grassland Research Awards for Student Scholarship (GRASS) Recipients

Thanks to the generosity of our donors and supporters, we were able to fund six student researchers this year, the second year of our newest program. The GRASS program offers competitive research funds to promote undergraduate and graduate student research focused on understanding, preserving, and restoring California's native grassland ecosystems in accordance with the CNGA Mission and Goals.

Again, many thanks to our members and donors for supporting this next generation of grassland researchers and congratulations to the 2020 award recipients!

Roisin Deák, Cal Poly San Luis Obispo. Advisor: Dr. Nishi Rajakaruna. Project Title: *Meadow vegetation trends in relation to fire.*

Roisin is a first-year graduate student interested in the maintenance of plant diversity and how that diversity scales to ecosystem services. She is investigating the effects of wildfire on meadow composition, which captured her interest while working for the US Forest Service Range Monitoring program. While working, she observed the conversion of a dry, weedy meadow being encroached upon by forest into a veritable wetland after a severe fire swept through the area. She hopes that by examining long-term data from burned meadows, she can discern under what circumstances fire promotes the growth of obligate wetland species. Roisin is interested in obligate wetland species in particular, because they have been shown to contribute to watershed resilience. She intends to share her findings with land managers to refine decisions on control burn tactics or restoration efforts. She has been working as a field botanist for the last seven years and is thrilled to return to the meadows this summer!

Justin Luong, PhD Student, Environmental Studies, University of California, Santa Cruz. Advisors: Karen Holl & Michael Loik. Project Title: *Using management perspectives to improve the ecology of grassland restoration*.

Justin is a third-year PhD Candidate in Environmental Studies at UC Santa Cruz researching how to further improve efficacy in implementing coastal grassland restoration projects. He is particularly interested in understanding long-term trends in planted or seeded grassland restoration projects and whether restoration goals are sustained years after project implementation. He is also interested in understanding the perspective of restoration practitioners and what is perceived to be the best way to improve future success from the implementation perspective. Justin became interested in understanding long-term restoration trajectories after working at the Cheadle Center for Biodiversity and Ecological Restoration after finishing his undergraduate degree, where he worked to restore coastal grasslands and vernal pools. Because of the increasing economic investment in restoration, he wishes to help make restoration as effective as possible. This is Justin's second GRASS award.

Brianne Palmer is a PhD candidate in the joint doctoral program with San Diego State University and University of California, Davis. Supervisors: David Lispon, Valerie Eviner, and Rebecca Hernandez. Project title: *Sources of cyanobacterial inoculum for the recolonization of biological soil crusts in Southern California grasslands*.

Brianne is currently studying how biological soil crusts recover after fire in the grasslands of Southern California. Using field work and DNA sequences of the microbial community, she hopes to understand the resiliency of the crusts and their impact on the post-fire landscape. Read more about Brianne's research interests in *"Getting to Know Grassland Researcher: Brianne Palmer,"* by Emily Allen, *Grasslands*, Fall 2018.

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CNGA 2020 GRASS Award Recipients, from top: Roisin Deák, Justin Luong, and Brianne Palmer.

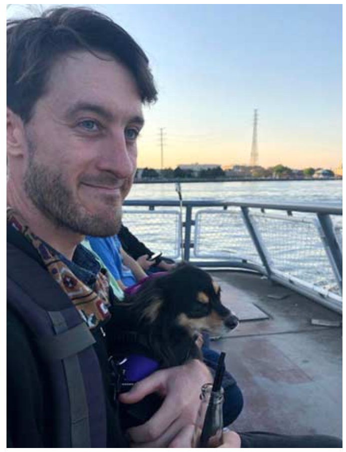
Meet the 2020 Grassland Research Awards for Student Scholarship (GRASS) Recipients *continued*

Seth Small, Harvey and Lois Watson Scholar and MA Candidate in International Environmental Policy: Natural Resource Policy and Management, Middlebury Institute for International Studies, Monterey, CA. Project Supervisor & Institution: Dr. Christy Wyckoff, Director of Conservation Science, Santa Lucia Conservancy. Project Title: *Measuring grassland response to targeted grazing on the Santa Lucia Preserve.*

Seth is a graduate student in Natural Resource Policy and Management at the Middlebury Institute of International Studies at Monterey. After farming in Massachusetts and Oregon, Seth returned to his native California to pursue a career in ecological restoration and agroecology. He currently manages data for the Santa Lucia Conservancy's conservation grazing program and is designing a GIS model to map compost application zones at Marks Ranch in Salinas for Big Sur Land Trust. The model will be applicable to farms and other relevant sites, helping especially those interested to qualify for CDFA's Healthy Soils Program. Seth enjoys field work and has participated in cultural burns led by the North Fork Mono tribe in Mariposa over the past couple years. He hopes to spend the summer learning more about restoration in natural and agricultural areas, and will ideally join a restoration camp in Paradise this fall.

Joanna Tang is a PhD student, University of California, Santa Barbara. Advisor: Carla D'Antonio. Project Title: *Investigating biotic and abiotic interactions in restored grassland vernal pool communities.*

Joanna is researching long-term invasion dynamics in restored urban ecosystems. As a born-and-bred Californian, she is committed to developing innovative restoration techniques that preserve and restore California's unique native communities in the face of widespread exotic invasion.



Daniel Toews, PhD Student, Environmental Systems, University of California, Merced. Advisor: Jason Sexton. Project Title: *The role of soil heterogeneity on adaptation in an endemic vernal pool annual plant* Limnanthes douglasii *ssp.* rosea.

Daniel is advised by Dr. Jason Sexton at UC Merced whose research centers on understanding the vulnerabilities and adaptive responses of plants to a rapidly changing world. Daniel's research interests are conservation oriented and focused on understanding the patterns of plant diversity and plant adaptation across complex environments. He uses a combination of metagenomics (environmental DNA barcoding) and field experimentation to better understand ecological and biogeographical effects that shape plant diversity and local adaptation in vernal pools wetlands. Inbetween extracting plant DNA from environmental samples or measuring vernal pool plant traits, Daniel works as an environmental consultant and has developed somewhat of an obsession with *Neostapfia colusana*. He enjoys spending time with my wife and twin boys, botanizing, and mountain biking. This is Daniel's second GRASS award.

CNGA 2019 GRASS Award Recipients, from top: Seth Small, Joanna Tang, and Daniel Toews.

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Inside: ***Large-Flowered Fiddleneck Recovery Implementation Team successfully protects critically endangered species from extinction.***

Front cover: San Luis Obispo County wildflowers, April 13, 2019. *Photo: Mariga Torossian*

Back cover: Black swallowtail caterpillar at Lassen Volcanic National Park at Dersch Meadows. *Photo: Kendra Moseley, CNGA Board Member*