California Native Grasslands Association

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Special Issue: **Fire in California**

California Native Grasslands Association

Mission Statement

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

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From the President's Keyboard

California's natural history has been shaped by fire. Human-caused fire in particular kept grasslands renewed for thousands of years; only recently has fire suppression combined with introduced species, loss of grazing, and population growth to make native grasslands one of the most endangered systems in the state.

Just within the past decade we have experienced extremes of temperature, precipitation, and winds that have fueled drought and fire. In many instances, our response has been to focus on vegetation as a problem to be solved through its removal. But action without understanding can lead to compounding problems, such as an increase in "flashy" (quick to ignite) fuels and a decrease in soil moisture if native bunchgrasses are overgrazed or low-mown. If we consider fire a natural part of living in California, as we do earthquakes, we can focus our efforts where they are most needed: in building codes and within 100 feet of people's homes, in reintroducing well-managed fire and targeted grazing, in reducing sprawl that creates conditions where human life and property are at risk and also puts at risk the natural beauty of wild places.

Just as drought gave impetus to a shift from thirsty lawns to low-water and native landscaping, fire may let us learn a new way to appreciate our fire- and drought-adapted native species—particularly native bunchgrasses, many of which space themselves in noncontiguous clumps and stay green long after nonnative annual grasses have dried.

In this issue you will see examples of how native landscapes respond to fire, a case study on post-fire invasive plant response and management, information on prescribed burning, and a focus on one of the many fire-dependent species of California's fabulous flora.

Andrea Williams, President

Photo: © Saxon Holt

Coming this Fall:

Establishing Functional California Grasslands, Part 2

Field Practices: Hands-on Restoration Implementation and Maintenance

Grassland restoration and conservation is more important than ever.

Over the past few years, drought and wildfire have highly impacted California forests' ability to store carbon. As the trees burn or die, the carbon stored in their tissues is released to the atmosphere. **Because grasslands store most of their carbon underground, they are predicted to be more reliable at storing carbon than forests in response to climate change**[1]. Please join us in our efforts to work on behalf of conserving and restoring California grassland ecosystems. Your contribution through membership or donation will have a lasting impact!

Join or donate online at **cnga.org** ❊ Call us at **(530) 902-6009** ❊ Email us at **admin@cnga.org**

[1]Pawlok et al. 2018. "Grasslands may be more reliable carbon sinks than forests in California." *Environmental Research Letters*, Volume 13, Number 7. Open access online: **https://iopscience.iop.org/article/10.1088/1748-9326/aacb39/pdf**

Grasslands Submission Guidelines

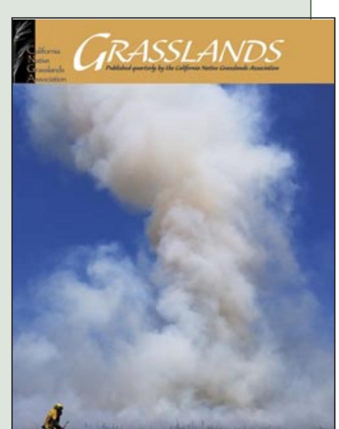
Send written submissions, as email attachments, to **grasslands@cnga.org**. All submissions are reviewed by the *Grasslands* Editorial Committee for suitability for publication. Written submissions include peer-reviewed research reports and non-refereed articles, such as progress reports, observations, 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 2019: 15 Aug 2019 ❊ **Winter 2020**: 15 Nov 2019 ❊ **Spring 2020**: 15 Feb 2020 ❊ **Summer 2019**: 15 May 2020

In this issue



Dr. Billy Krimmel, owner of the Restoration Landscaping Company and CNGA board member, provided an entertaining talk on the evolutionary relationships between native sticky plants and native insects.

CNGA's 12th Annual Field Day at Hedgerow Farms

by Pat Reynolds[1] *Photos courtesy the author*

CNGA's 12th Annual Field Day at Hedgerow Farms was very well attended, and based on the overwhelmingly positive responses in the workshop evaluations, highly successful. It was sold out weeks before the event, the waiting list exceeded 20, and calls requesting admission were pouring in daily in the week leading up to the event. The theme of genetic considerations in plant material selection ("Think Globally, Plant Locally: Restoration and Local Adaption") was well covered by a variety of high-quality speakers, tour guides, field demonstrations, and displays. Participants enjoyed hayrides and walking tours of seed production fields, the extensive demonstration garden, and the experiments currently being conducted at Hedgerow Farms. This year, a greater emphasis was placed on how native seed is produced and how life cycle differences between ecotypes requires adaptation of farming methods to accommodate these variations. Local restoration professionals Chris Rose of the Solano County Resource Conservation District (RCD), Bryan Young of the Sacramento County Sanitation District, Tanya Meyer of the Yolo County RCD, and University of California at Davis's (UCD) JP Marié and Miles DaPrato led the driving tours. They provided participants with information about the history of Hedgerow Farms while sharing their in-depth knowledge of habitat restoration.

Field tours included a detailed examination of seed increase fields with four different speakers providing perspectives on why organizations go to the extraordinary length of setting up seed increase contracts to obtain site-specific seed for their habitat restoration projects. These speakers, all of whom provided a different perspective, included Stacy Jacobsen of the Golden Gate National Parks Conservancy, Erin McDermott of Nomad Ecology, and Michele Ranieri and Michael Maccini of Hedgerow Farms. The tour also included a production field walk with Hedgerow Farms' Farm Manager Jeff Quitter who talked about the intricacies of growing out seed of known genetic origin and the extraordinary measures the Hedgerow Farms implements to provide high quality seed. Included in this talk were samples of different ecotypes of the same species so participants could see how plant characteristics such as color, height, seed shatter, and many others, vary substantially between ecotypes.

Pete Martin and many volunteers from the California Hawking Club had several raptors on display during breaks. This gave attendees an

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[1]Pat Reynolds is the General Manager at Hedgerow Farms and is a CNGA board member.

Left: Emily Allen, independent consultant and CNGA board member, speaks to field day participants on the use of native species in landscaping. Right: UC Davis researchers provided an overview of the pollinator habitat research currently being conducted at Hedgerow Farms to field day participants. Inset: Hedgerow Farms seed production field of coastal tidy tips (*Layia platyglossa*) in full flower during field day.

CNGA's 12th Annual Field Day at Hedgerow Farms *continued*

opportunity to get up close and personal with several different birds of prey as well as opportunities to ask questions about raptor ecology.

The walking tours were led by Pat Reynolds (Hedgerow Farms and CNGA board), Emily Allen (ecological consultant and CNGA board), Andrea Williams (Marin Municipal Water District and CNGA president), and Andrew Fulks (UCD) all of whom discussed how native grasses and forbs are used in habitat restoration projects. Hedgerow Farms' demonstration garden, featuring the 110 + species grown at Hedgerow Farms and the various seed mixes that it sells, was particularly popular with participants. The walking tour also included presentations by Dr. Neal Williams and several students from his lab at UCD on the pollinator habitat experiments currently being conducted at Hedgerow Farms.

Several excellent and informative lunchtime presentations were included in Field Day. Dr. Jessica Wright, U.S. Forest Service (USFS) geneticist, described the long history of ecotype considerations in USFS Tree Seed Zones and how these Seed Zones are currently being updated to take into consideration how global climate change is influencing the distribution of tree species now and in the future. Dr. Billy Krimmel, owner of the Restoration Landscaping Company, gave an entertaining talk about the evolutionary relationship between insects and native plant species. Joe Silveira from the U.S. Fish and Wildlife Service described how the Sacramento River National Wildlife Refuge carefully incorporates ecotype considerations into their restoration planning and described his observations of how soil types between ecotypes influences long-term establishment of vegetation at restoration sites. Dr. Elizabeth Leger, associate professor from the University of Nevada Reno, talked about her research on how ecotype variations influence plant establishment and the common garden techniques that she has developed to answer some of these questions. Dr. Valerie Eviner, associate professor of plant science at UCD, provided an update on her research including the importance of early colonization of forbs after fires. Rachael Long, a Farm Advisor with the UC Cooperative Extension, shared the results of her most recent research on the benefits and cost-effectiveness of incorporating hedgerows into agricultural landscapes.

Overall, Field Day at Hedgerow Farms was once again an outstanding success. Hedgerow Farms and CNGA are already starting to plan for next year's field day and hope you can be a part of it.

Controlled grassland fire at the optimal June timing when weed seed has not yet shattered to the ground, but forage is dry enough to carry a fire.

Location and Seeding Affect the Outcomes of Controlled Burning of California Annual Rangeland

by Josh Davy[1], Lenya Quinn-Davidson[2], and Jeff Stackhouse[3] *Photos courtesy Josh Davy*

Burning has been demonstrated as a successful tool for controlling medusahead (*Elymus caput-medusae* (L.) Nevski) (Murphy and Lusk, 1961; McKell et al., 1962), a weed that displaces native plants and decreases the value of grazing on annual rangelands. Spring burning, once forages have dried but prior to targeted weed seed shatter, provides optimal timing for controlling medusahead with fire.

Though research has determined the proper timing of burning for weed control, there appears to still be varied success in controlling grass weeds with fire tools. It may be that this has to do with site characteristics. Kyser et al. (2008) hypothesized that site production may impact burning's ability to suppress medusahead seed production by providing enough fuel to ensure seed mortality. In their trials, the higher producing sites were more successful in controlling medusahead. The Kyser trial included multiple foothill annual rangeland sites that successfully controlled medusahead with fire, while their less productive high elevation site was not successful. Similarly, Young et al. (1972) did not successfully control medusahead with controlled burning in the high elevation intermountain area of California. It is not fully understood if differences in production of fire fuel cause variances in successful weed control, or if there is an alternative characteristic in intermountain and valley foothill rangelands that influences the success of fire as a weed suppressor.

Another trial followed a productive foothill annual rangeland site through time to identify how quickly medusahead could reinvade following a control burn. Like previous trials on foothill rangelands, medusahead control was very successful the year following a burn, but after three years of drought, the benefit was no longer apparent (Davy and Dykier 2017). It may be that a beneficial practice such as seeding burned rangelands could assist in preventing medusahead reinvasion as seen by Davy et al. (2017).

This research helps to answer these questions by comparing low production foothill annual rangeland and high production coastal rangeland controlled burning sites. In addition to controlled burning, additional annual ryegrass seeding treatments were included to determine if seeding could assist in weed control in both burned and non-burned sites.

Methods

One site was located in Eastern Tehama County on low production soils underlain with volcanic rock (Vina). The second site was on a highly productive interior coastal rangeland site in Eastern Humboldt County (Bridgeville). The intention of these site selections was to determine if biomass was a factor in successful weed control through controlled burning. The two sites provided drastically differing

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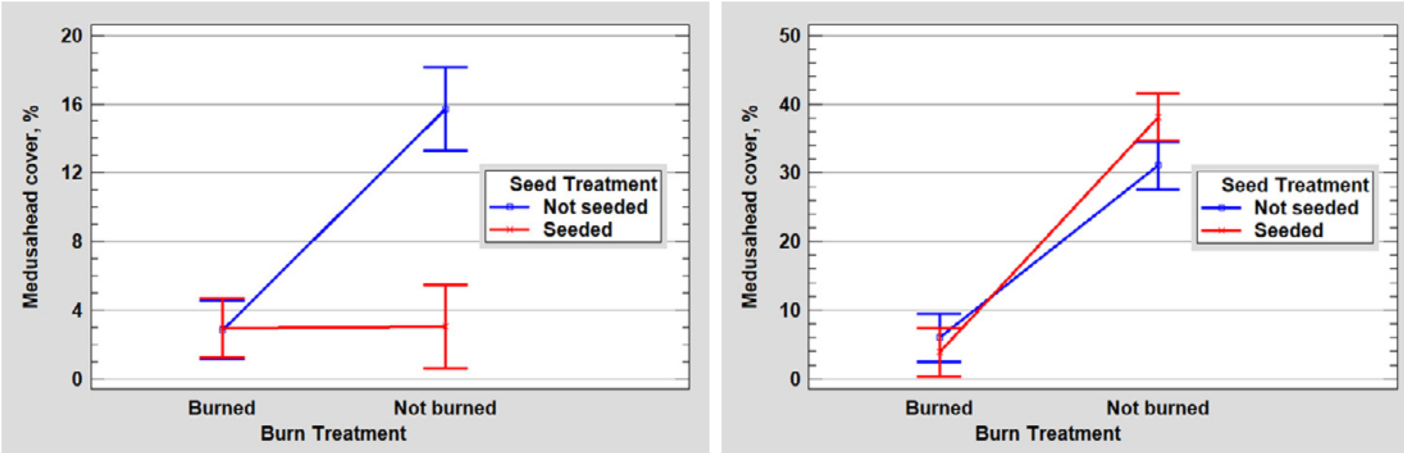
[1]UC Livestock and Range Advisor, Tehama, Glenn, and Colusa Counties. [2]UC Fire Science Advisor, Humboldt, Siskiyou, Trinity, and Mendocino Counties. [3]UC Livestock and Range Advisor, Humboldt and Del Norte Counties.



Interaction between burning and seeding treatments on medusahead cover (Least square means) in Tehema County (left) and Humboldt County (right).

Location and Seeding Affect the Outcomes of Controlled Burning *continued*

production for comparing the efficacy of controlled burning based on production differences. Both control burns were completed in June allowing forage to dry and carry fire, but prior to medusahead seed shatter to ensure seed would be exposed to heat while still on the plant rather than the soil surface.

Three transects were established at each site. Two were in burned areas and one was located in an adjacent non-burned area (control.) Each transect was 400 feet long. Half of all transects (200 feet) were seeded the fall after burning. The design allowed for treatments of a true control (no seeding or burning), seeding without burning, burning with seeding, and burning without seeding. Gulf annual ryegrass (*Festuca perennis*) was broadcast planted at 15 lbs/acre at both sites immediately prior to rain.

Monitoring was done one full calendar year after the burn at peak standing crop. Grazing pressure was light and alloyed ample standing residual forage for plant identification. Full basal species composition readings were taken at 10 foot intervals using a one-meter square frame. Within the larger frame, a smaller one square foot frame was used to measure standing forage using the comparative yield method (George et al., 2009).

Statistics were run in Statgraphics (StatPoint 2009) using a multiple analysis of variance for variables burn, seeding, and site. All two- and three-way interactions were included. Individual models were run for each of the dominant plant species that were found at both sites. Mean separation was done using Fisher's Least Significant Difference test.

Medusahead

Overall, burning lessened medusahead cover at both sites ($P<0.01$; LSM (least square mean) burned = 4%, LSM non-burned = 22%). It appears that burning even in low production (low fire fuel) valley foothill annual rangeland does successfully lessen medusahead populations.

It is unclear why previous work in the intermountain area of California has not shown successful weed control with burning. Our research makes it apparent that fire fuel is not the only factor. Variable control of medusahead between intermountain and foothill rangelands is not unique to burning as a practice. Control of medusahead with herbicide techniques also varies. The use of imazapic has been successful in the intermountain area (Sheeley et al., 2009), where much less success was seen in foothill low elevation rangelands (Kyser et al., 2012).

Although burning worked equally well at lessening medusahead at both sites, seeding did not. Figure 1 depicts the interaction of burning and seeding at the Tehama County site. In this low-production site, the mean control medusahead cover was approximately 16%, while all other treatments dropped medusahead levels below 4%. At this site seeding ryegrass reduced medusahead similarly to burning and both seeding and burning combined (Figure 1).

Seeding was less successful in reducing medusahead at the Humboldt County site (Figure 2). In fact, the level of medusahead in the seeded-only site was equal to the control that was neither burned nor seeded. In this high production area, it would not be expected that solely broadcast seeding annual ryegrass without other forms of weed control will lessen medusahead cover.

Residual dry matter

The seeding treatment ($P=0.02$) and site ($P<0.01$) both affected residual dry matter (RDM; standing biomass), with the seeding treatment yielding 17% less biomass post-grazing than the non-seeded treatment. Ryegrass is a highly palatable species and it would be expected that cattle would readily seek this forage out, causing consumption of the seeded area to be higher. Heavy spring grazing as medusahead plants are beginning to mature has been shown to lessen medusahead seed production if the defoliating impact is at a high level at the correct time (Brownsey et al., 2016). The decrease in biomass may help to speak to the difference in effectiveness in medusahead

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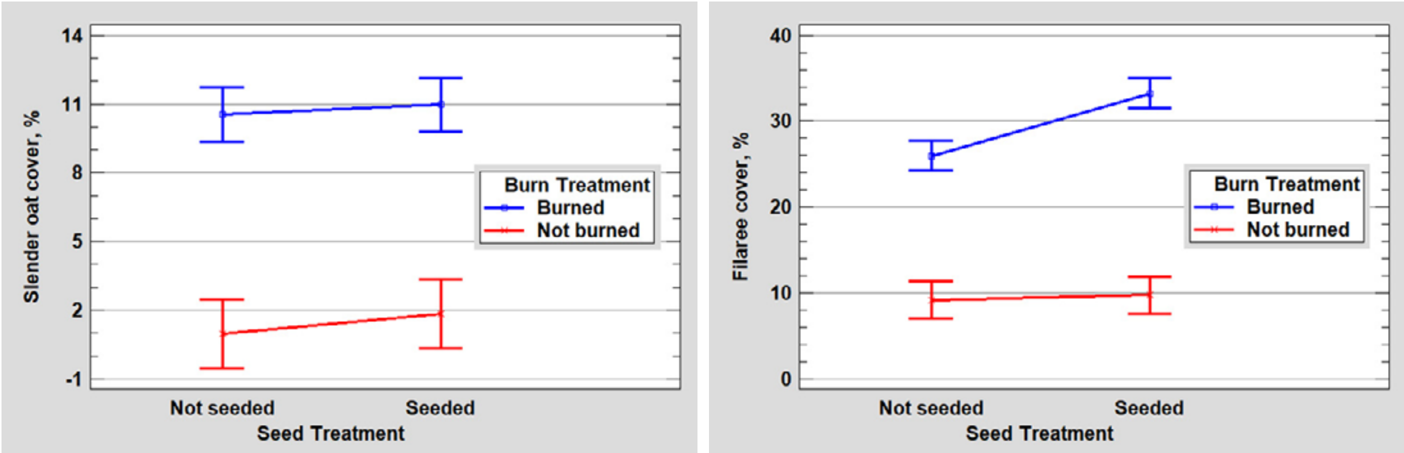

Interaction between burning and seeding treatments on slender oat cover (left) and filaree cover (right) (Least square means) at both sites.

control of seeding between sites. While a reduction in biomass through grazing at the lower producing Tehama site (mean RDM 426 lbs/acre) could cause enough impact to lessen medusahead, the impact would not be high enough at the Humboldt site (mean RDM 2,615 lbs/acre) to adequately impact medusahead and keep it from producing seed. At this site it appears that targeted grazing through the use of an attractant such as ryegrass is not sufficient and could likely require other methods such as fencing to adequately concentrate cattle on the target site.

The burning treatment did not affect forage biomass (P=0.33). Another study in Western Tehama County (Davy et al. 2017) showed forage production cut by roughly 50% in the year following a control burn. The biggest difference in this study was the extremes in sites. The Humboldt County site proved resilient in forage production, likely due to good soils and adequate rainfall. The Tehama site is not a largely productive site, thus frequently leaving little residual dry matter. Therefore, when the burn removed what little RDM would have been present, the effects were not as high as those seen in other studies. It would appear that the effect of fire on biomass production can be on a site by site basis, and should be considered when targeting prescribed burn sites.

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Other species and bare ground cover affected by treatment

Slender oat (*Avena barbata* Pott ex Link) cover was not affected by the seed treatment (P=0.50), but was by the burning treatment and site (P<0.01). Slender oat levels increased from nearly zero in the non-burned areas to over 10% basal cover where burned (Figure 3). Filaree (*Erodium* spp.) cover was significantly affected by all treatments (P<0.01; Figure 4). As seen in other trials, the burn treatment significantly increased filaree cover with or without seeding, but seeding only increased filaree cover in the burned areas. It was surprising to see markedly higher filaree levels while not seeing a difference in residual dry matter levels between burned and non-burned areas. Bare ground was affected by the seeding treatment (P=0.01; LSM seeded 11%, LSM not seeded 8%) and to the same degree by the burn treatments (P<0.01; LSM burned 11%, LSM not burned 8%), but not by site (P=0.07). Soft brome (*Bromus hordeaceus* L.) was not affected by either the burn or seeding treatments (P=0.99 and P=0.64, respectively).

Conclusion

This trial points out site differences in prescribed burning. At both foothill rangeland sites medusahead was severely lessened the year following a controlled burn conducted in the spring. Further monitoring will help determine the longevity of this treatment on species composition. The surprising factor in this research was the lack of impact on subsequent year forage biomass following a burn at each

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Control non-burned area on the left and treatment burned area on the right post fire.

Location and Seeding Affect the Outcomes of Controlled Burning *continued*

site. Previous research had shown that productive soils in foothill annual rangeland produced significantly less biomass following a burn. In this case a high rainfall coastal inland site was resilient in production even after a burn, and a foothill valley site in shallow soils produced such a low quantity of forage that burning did not further decrease biomass.

Seeding annual ryegrass did improve cattle utilization of the seeded area, showing 17% less biomass across both sites than the non-seeded area. While this had an impact on medusahead in the low biomass producing site, it did not affect medusahead in the high producing site because the area was not defoliated to a necessary level to suppress medusahead seed production.

This trial demonstrates that site selection is important for rangeland management practices including seeding and prescribed burning. In highly productive coastal-influenced sites, burning is a viable weed control option without compromising production the following year. In shallow soiled foothill annual rangelands, both seeding and controlled burning are viable options for weed management.

Acknowledgements

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SPECIES SPOTLIGHT: *by Tatiana Manzanillo* *Photos courtesy Ron Vanderhoff*

Fire Poppy *(Papaver californicum)*

Poppies hold a special place in the hearts of Californians. The California poppy (*Eschscholzia californica*) received its common name long before it officially became the state flower in 1903. Early Spanish settlers referred to the California coast as the "land of fire" because of the prominent display of poppies on coastal hills.

The fire poppy (*Papaver californicum*) is another native California wildflower, also in the *Papaveraceae* family, that is much more dependent on fire and other disturbances. An annual herb endemic only to California, this species grows in chaparral and oak woodland communities within coastal ranges from Napa County to San Diego County. Fire poppies can vary in height from 30 to 60 centimeters tall, nodding as they bud, then standing erect as they bloom. Its bright inflorescence typically consists of four red-orange petals that are green at the base, with yellow filaments and anthers, and a green pistil, a stark contrast to the charred environments they are adapted to. Fire poppies are obligate fire followers—they rely on fire or some other disturbance to germinate.

Findings of fire poppy, from top: In Black Mountain Open Space Park in San Diego, CA. From the Holy Fire in Cleveland National Forest in Santa Ysabel, CA.

I had the rare opportunity to survey Pepperwood Preserve in Sonoma County for any fire-followers, species that occur after a fire event, after the Tubbs Fire in October 2017. Rachel Kesel, the One Tam Conservation Management Specialist, had invited me to join her on a survey around Devil's Kitchen. Since fire poppies tend to grow in chaparral habitats and usually occur after a fire event, taking a cue from the smoke to germinate, there was a chance we would come across them as the conditions and habitat type were favorable. In chaparral habitat, fire poppies tend to bloom abundantly where they have an established seed bank. This species' seeds can remain viable in the soil for several decades before a fire event causes them to germinate. Despite their long dormancy, individual flowers may only bloom for a couple days. Fire poppies may continue to appear a couple years after a fire until the chaparral species return to shade out the annuals. While conducting our survey with the thought of finding fire poppies in the backs of our minds, we came across other species of interest such as redwood lilies (*Lilium rubescens*) in the burnt forest understory, as well as Brewer's redmaids (*Calindrinia breweri*) and Jepson's leptosiphon (*Leptosiphon jepsonii*) in the chaparral and grassland habitats. Ultimately, our search did not uncover any fire poppies in the regrowth.

Although we did not come across any fire poppies, this does not mean they were absent. In that same year, fire poppies were found blooming on Mount George in Napa County, an occurrence which had not been seen in over 50 years. With its seeds' long potential for dormancy, the fire poppy shows an ability to survive in an ever-changing environment. Fire is a natural part of California's landscape and many endemic species have coevolved with infrequent yet intense burns. While fire is a necessary part of the fire poppy life cycle, improper burning regimes may affect this species — too frequent fires may enable proliferation of non-native annuals, while fire suppression may leave the seeds with no way to germinate. Like many endemic species, the resilience of fire poppies depends on proper land management and human involvement in California's fire regime.

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Invasive Weed Management Post-Wildfire: Closer Look at Camp Fire Invasive Weeds in Right-of-ways

by Tracy Schohr[1], Ryan Tompkins[1], Tom Getts[1], Kate Wilkin[1], and Jen Wiley[2]

Post-wildfire landscapes pose many challenges for property owners and natural resource managers including a diverse array of issues including, but not limited to, safety hazard mitigation, economic recovery, water quality, and soil stability. Another emerging 21st century concern is the establishment and spread of invasive weeds in recently burned areas (Sheley 2002). Invasive weeds are plant species whose introduction or spread is "likely to cause economic or environmental harm or harm to human health" (Beck et al. 2006).

Invasive weeds are often classified as "pioneer" or ruderal species, adapted to colonizing sites soon after a disturbance, such as fire, road construction, or other activities that clear vegetation (Juana et al. 2015). These disturbances create conditions characterized by bare mineral soil, abundant resources such as sunlight, water, and nutrients, and very little other competing vegetation — perfect for invasive weeds to quickly establish and spread (Parendes and Jones 2000).

The three phases of weed invasion include introduction, establishment, and spread (USDA Forest Service 2005). During the introduction phase, seeds or propagules from an existing infestation are transferred to a new, uninvaded location — this may occur passively through wind, wate, and animal seed dispersal, or through management actions which move soil or plant parts from one location to another. Once a seed or propagule is introduced to a favorable site, new individuals may quickly become established. When the invasive weeds reach reproductive maturity, often the spread of many new individuals occurs, thereby expanding populations (Hobbs and Humphries 1995). Prevention of weed introduction and treatment of weeds during the establishment phase are most critical for land managers as invasive weed species are more difficult and expensive to control during the spread phase (USDA Forest Service 2005).

After wildfires, burned landscapes may be vulnerable to invasive weeds depending on the fire severity, the recovery of vegetation, and the extent of invasive weed populations prior to the fire that can colonize disturbed habitats (Zouhar et al. 2008). Areas of high burn severity have exposed soils, increased nutrient pulses, and decreased shade and competition from native plant species — factors which are favorable for the establishment and spread of invasive weeds (Sheley 2002). Invasive species are well-adapted to these conditions. They can even benefit from fire or other disturbances by increasing seed production (Jacobs and Sheley 2003) or reproductive capacity (e.g. root sprouting) (Turner et al 1997).

[1]University of California Cooperative Extension. [2]Plumas-Sierra County Agricultural Commissioner's Office.

Fire suppression features and post-wildfire recovery activities such as bulldozer lines, skid trails, and restoration activities, include ground disturbance which creates suitable habitat for invasive weeds. These activities can disperse weed seeds or propagules through equipment movement and ground disturbance, contributing to the inadvertent spread of invasive weed populations (Trombulak and Frissell 2000).

Land managers dealing with post-fire environments should recognize potential impacts from invasive weeds and mitigate introduction, establishment, and spread by utilizing an integrated weed management approach that emphasizes prevention, early detection, treatment, and monitoring.

Prevention. Prevention is the first step and most cost-effective measure in invasive weed management (USDA Forest Service 2001). Prevention limits, manages, or alters activities that create ground disturbance or serve as a weed establishment vector which increases the risk of invasive weed spread. This may include requiring vehicles and equipment to be cleaned of all attached mud, dirt, and plant parts, or requiring gravel, fill, mulches, and/or seed sources to be weed-free. Use of onsite materials helps prevent introduction of new weed populations. Vehicles, equipment, and/or materials should not be staged in areas with noxious weeds. Vehicles, equipment, and/or materials that have been in areas with known noxious weed sites should not be allowed to travel to other areas without first being cleaned or treated.

Detection. Early detection through surveys, particularly along known vectors such as access roads and trails, right-of ways, and equipment parking/staging areas, is critical in managing invasive weeds after wildfires. These surveys help build an inventory of noxious weed locations and population sizes across the landscape and provide the necessary data to determine fire equipment staging areas, access points, and areas that may be vulnerable to noxious weed invasion. This data is also important for determining treatment effectiveness and risk of spread.

Treatment. Noxious weed infestations should be treated with an integrated approach using the best available information to select effective treatment methods including manual, cultural, herbicide, and biological controls. Treatments should be prioritized by site-specific attributes including invasive weed species, population size, reproductive capacity, and proximity of suitable habitat. Treatment goals may include population eradication, control, containment, or tolerance. Primary treatment goals typically revolve around

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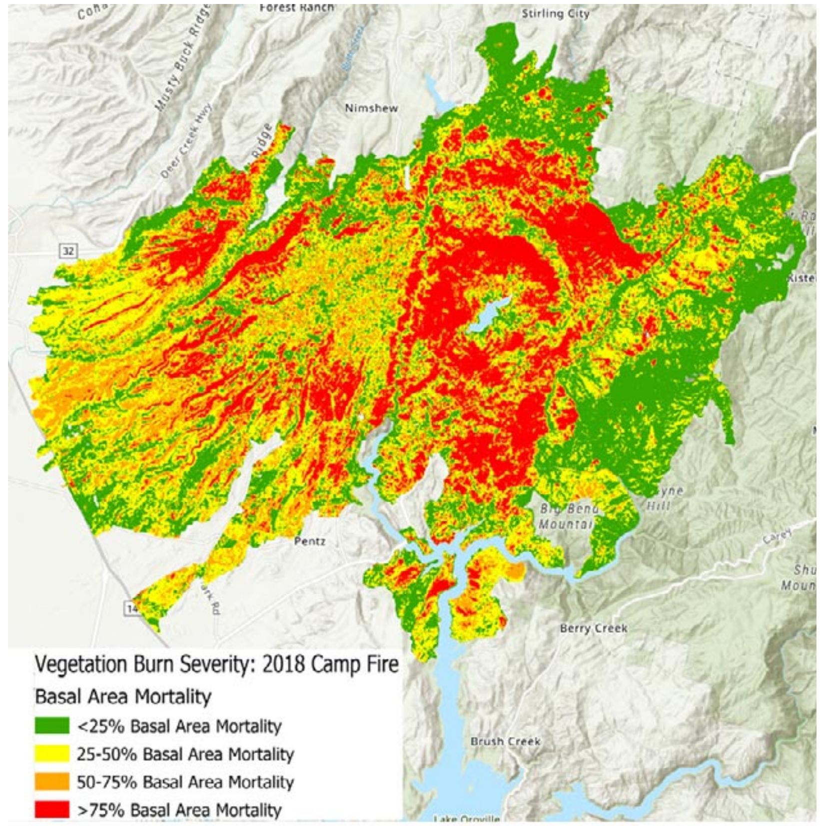
Invasive Weed Management Post-Wildfire *continued*

eradication of weed infestations, but where eradication is not possible, control or containment of infestations may be appropriate. Prompt treatment of small or new infestations is critical and should be prioritized. Treatment effectiveness should be monitored, and follow-up treatments should be prescribed to prevent weed re-establishment or regeneration of a latent seed bed.

Monitoring. Pre- and post-treatment monitoring of noxious weed populations is critical to adaptive treatments and assessing the effectiveness of any invasive weed management strategy. Pre-treatment surveys build an inventory which is essential to prioritizing treatments. Following implementation, post-treatment monitoring typically focuses on the efficacy of treatments. Longer term monitoring is still required to check for subsequent regeneration from a latent seedbank or perennial plant structures.



Camp Fire Burn Severity Map (USFS, 2018)

Case Study: Camp Fire early detection of Yellow starthistle (YST) through right-of-way surveys

The 2018 Camp Fire provides a unique opportunity to examine how pre- and post-fire weed treatments may interact and inform larger post-fire invasive weed strategies and recommendations for landowners. On November 8, 2018 the Camp Fire broke out in the hills above Chico, California, devastating the town of Paradise and nearby communities of Concow, Magalia, and Pulga. The fire burned through forest, range, and community settings as well as along Highway 70. In the Feather River Canyon along Highway 70, various right-of-way weed populations had ongoing treatment and monitoring prior to the burn. This first year after the fire presents a timely opportunity to assess post-fire weed populations and potential habitat, initiate early detection establish treatment methods, and develop an adaptive management strategy.

Yellow starthistle (*Centaurea solstitialis*) (YST) is a well known and problematic invasive species in California (DiTomaso et al. 2007).

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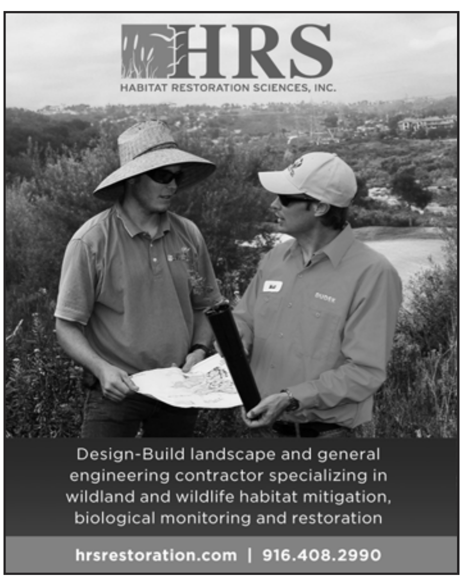
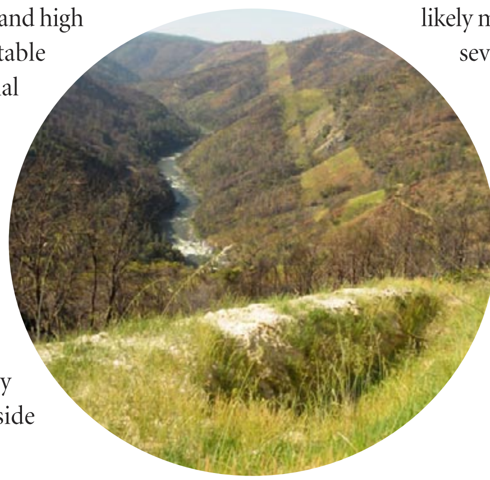




Site 1, from left: 1a) Pre-fire treatment of blackberries. 1b) After Camp Fire November 2018. 1c) Post-fire Spring 2019 with grass establishment.

Invasive Weed Management Post-Wildfire *continued*

There were established populations of YST along highway right-of-ways within the Camp Fire perimeter. Prior to the fire, Caltrans worked in partnership with the local Plumas-Sierra Agricultural Commissioner's Office to control the spread of invasive weeds, including YST, along roadsides and turnouts on Highway 70. Sites along Highway 70 burned with moderate and high fire severity which provides additional suitable habitat for invasive weed spread. The potential impacts of high-severity fire and post-fire activities on invasive species populations along the highway were evident six months following the fire. Below are four site examples of the challenges with invasive species management after a wildfire.



Case Study, Site 1. At Highway 70 mile marker R37.04, YST and Himalayan blackberry *(Rubus armeniacus)* had invaded the roadside drainage area (image 1a). The YST and blackberry vegetation were treated with a foliar application of Milestone® (active ingredient aminopyralid) in May of 2018. Image 1c illustrates the effectiveness of control; a variety of grasses are growing in the spring following the fire with no observations of YST. This pre-fire treatment may likely minimize weed spread during moderate- to high-severity fire events.

Case Study, Site 2. At Highway 70-mile marker R37.68, YST had invaded a drainage ravine (image 2a). The YST was treated with a foliar application of Milestone® in May 2018. Image 2b shows the burnback from treatment in July 2018. Image 2c illustrates the effectiveness of YST control; a variety of grasses are growing in the spring following the fire with no observations of YST. Although this

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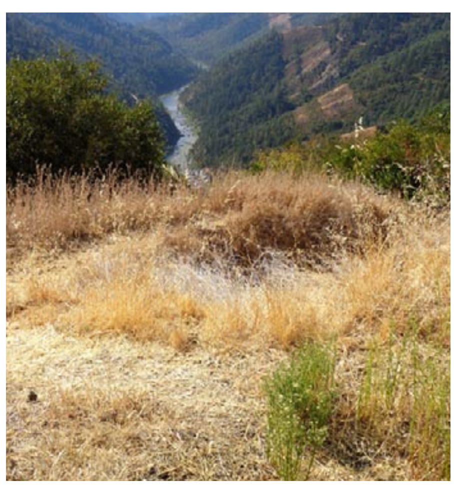


Site 2, from left: 2a) Pre-fire treatment of yellow starthistle, May 2018. 2b) Treatment control, August 2018. 2c) After Camp Fire, November 2018. Inset: 2d) Post-fire Spring 2019 with grass establishment.

Site 3, from left: 3a) Pre-fire treatment of yellow starthistle berm. 3b) After Camp Fire November 2018. 3c) Post-Fire Spring 2019 closeup of historic manzanita bush roots and emergent yellow starthistle.

Invasive Weed Management Post-Wildfire *continued*

site burned at high severity, pre-fire treatment of YST likely reduced potential for spread, though additional post-fire monitoring is recommended.

Case Study, Site 3. Along Highway 70-mile marker R37.68, there is evidence of post-fire YST establishment. Pre-fire YST growing on the berm along the turnout had been treated with a foliar application of Milestone® in May 2018. Native vegetation (the circled manzanita bush (*Arctostaphylos manzanita*)) was avoided in this pre-fire treatment. This site burned with moderate to high fire severity during the Camp Fire and post Camp Fire activities called for the removal of the manzanita bush skeleton in image 3c. Emergent YST plants have now established after the fire and post-fire activities.

Case Study, Site 4. At Highway 70-mile marker R39.11, post-fire disturbance by restoration crews created opportunity for YST establishment when moving a rock. A pre-fire population of YST had been treated with a foliar application of Milestone® in May 2018. Following the fire, crews moved rock for armoring drainage features, thereby disturbing soil and exposing ground to establishment by YST.

Management Implications

The right-of-way case studies above create insight into broader implications and challenges for land managers to control invasive weeds after a fire. An active management program for invasive weeds prior to disturbance may serve to better control invasive weed populations after moderate and high severity fire (case studies one and two). However, where a refuge population of invasive weeds was left uncontrolled to protect desirable vegetation prior to the disturbance (case study three), the disturbance created an opening for the reinvasion of the site. Left uncontrolled with limited management, this weed population has the potential to spread, as other desirable vegetation may not capture resources as effectively as the ruderal invasive weed YST. As demonstrated by case study four, fire is not the only disturbance invasive weeds can take advantage of. Even with prior

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Site 4, from left: 4a) Pre-fire treatment of yellow starthistle turnout May 2018. b) After Camp Fire November 2018. 4c) Post-Fire Spring 2019 closeup of yellow starthistle where rock was historically located.

Invasive Weed Management Post-Wildfire *continued*

treatment of the weed population, disturbance of the rock during post-fire management activities resulted in re-establishment of YST to the site from the seedbank.

Across the broader landscape impacted by fire, private foresters, ranchers, and public agencies have multiple challenges that are illustrated by the case studies above. Two key examples include: 1) Disturbances create opportunities for invasive weeds to flourish with limited competition after a fire. These disturbances can occur directly from the impact of the burn, or through secondary disturbances of anthropogenic management action. Examples are, soil/rock movement as in case study four, and within the larger landscape movement of soils along dozer lines used as fire control, or other soil-disturbing activities. 2) Open habitats created after a fire can be a place for invasive weeds to emerge as shown in case study three. When the initial patch of YST was treated, treatment around the manzanita was deemed unnecessary, as the shrub was desirable, and competition from the shrub was suppressing the YST. Moderate-to high-severity fire and post-fire activities can drastically reduce cover of native vegetation and create open habitat for weed establishment. This sets up a quandary in weed management decisions in the uncertainty of disturbance occurring. The soil historically covered by the manzanita served as refuge for YST seeds left unsuppressed by residual herbicide control. Case study one shows the power of residual herbicide control, where the blackberries were sprayed and the treatment controlled the weed seedbank, allowing grasses to emerge in the spring following the Camp Fire.

Populations of invasive weeds which were present prior to the fire and may not have been under active management, have great potential to expand after fire disturbance. This may be more likely in high severity burn areas, where desirable vegetation may not be as quick to recover as ruderal invasive weeds are to expand their populations. Burn severity maps in conjunction with known populations of invasive weed species may help create priority areas for initial invasive weed management. Post-fire vegetation burn severity maps, developed by the US Forest Service, geographically display burned areas with higher levels of vegetation mortality and exposed soil disturbance. These mapping tools can help land managers identify areas of concern for post-fire invasive weed spread.

Invasive weeds are a significant concern after fires, regardless of the size and severity of the fire. Active management of invasive weeds though the utilization of the various tools available for land managers (e.g., grazing, herbicide, mowing) is an important component to post-fire restoration. Any information land managers have available on pre-fire weed infestations, management actions, will help inform appropriate post-fire efforts.

UC Cooperative Extension has local field-based specialists throughout California that can be an essential resource for information on controlling invasive weeds and promoting native grasses.

Authors' Note

Any mention of pesticide is not a recommendation or endorsement of use by the University of California or the authors. Pesticides are mentioned by trade names for informational purposes only. Read and follow the label when using a pesticide.

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Links to invasive weed and fire severity resources:

https://www.cal-ipc.org/

https://www.fs.fed.us/projects/four-threats/#species

https://fsapps.nwcg.gov/ravg/

MEET A GRASSLAND RESEARCHER **Sasha Berleman**

Fire Forward Program Director, Audubon Canyon Ranch

What is your study system?

These days I primarily work with a team to restore fire as an ecosystem process to California's fire-adapted landscapes around the greater Bay Area. My main work in this field is with the non-profit Audubon Canyon Ranch directing the Fire Forward program, but I also do some consulting in the field. Most often, our work of planning fuels treatments and ecological prescribed burns is focused in systems of annual grassland, coastal prairie, oak savannah, oak woodland, or mixed evergreen forest. We aim to always pair these fuels treatments and prescribed burns with monitoring techniques so that we may quantifiably understand the impacts of our efforts, employ adaptive management strategies, and share treatment results with land managers and researchers across the region.

What are your primary research goals?

Our research goals are centered around management and determining the effects of fuels treatments and prescribed fire on biodiversity, ecological balance, system health, pathogens, and as a tool for restoration. In grasslands and oak savannahs we gather native grass and forb seeds immediately prior to burning so they may be dispersed the following fall. We are looking to see whether we can increase native grass and forb abundance through this method. In oak woodlands and mixed evergreen forests we are monitoring to determine whether our treatments successfully reduce fuel loading, how long it takes the systems to become fuel-impacted again, and whether these treatments successfully tip scales in favor of large, healthy, and resilient trees. We also intend to indirectly study pathogen response to prescribed fire through study of tree health. We have designed our monitoring efforts in oak woodlands and evergreen forests to be modular so that a manager can implement any subset of the monitoring effort on their land, and so that the monitoring protocol could be paired with any other number of research questions.

Who is your audience?

Our audience is land managers and landowners who are interested in stewarding their land for resilience, longevity, biodiversity, and ecosystem services in a fire-adapted landscape with a rapidly changing future.

Who has inspired you, including your mentors?

I have been fortunate to have been mentored and inspired by so many people over the years. My PhD advisors, Dr. Scott Stephens and Dr. Katie Suding, and my direct mentor in the lab, Danny Fry, absolutely had immense influence over me and are wonderful mentors who always challenged my critical thinking and pushed me further than I knew I could go to deepen my understanding of the natural world and to question everything. I'm also so often inspired by the land managers I work with who, through their dedication to the land, develop profound knowledge of the systems at play and always impress me with their ground-truthed wisdom and insights. One of those people is Jeff Wilcox at Sonoma Mountain Ranch Preservation Foundation, with whom I pursued one of my PhD chapters. I continue to work with Jeff in a professional capacity today.

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"?

Prescribed fire is an ecosystem process that has managed California grasslands, oak savannahs, woodlands, and forests for millennia. In California today, these systems face a suite of novel challenges including but of course not limited to: negative impacts of disturbance exclusion (both fire and grazing), invasion of non-native grasses and forbs, and climate change. We aim to use our management efforts and associated monitoring of that work to share practical methods for using ecosystem processes to promote native diversity and abundance and system health.

Why do you love grasslands?

I love grasslands for the tranquility they offer. Few spaces are more serene. The experience of sitting in an intact native bunchgrass meadow speckled by the brilliant colors of diverse wildflowers watching the grasses sway in the breeze with the sunlight captured and glimmering on each seed, listening to pollinators buzzing around you is quintessentially a California dream.

With two units totaling 345 acres, this burn in Humboldt County was the largest NRCS-funded burn in California history. Humboldt County Prescribed Burn Association, Fall 2018.

Burning by the Day: Why cost/acre is not a good metric for prescribed fire

by Lenya Quinn-Davidson[1] and Jeffery Stackhouse[2] Photos courtesy Lenya Quinn-Davidson

As California's fire problem grows, so too does the interest in and social license for prescribed fire. There is now widely shared recognition by federal and state agencies, private landowners, and the public that more prescribed fire is needed to curb severe wildfires and restore and maintain California's diverse fire-adapted habitats, including grasslands and prairies in which prescribed fire can be an effective tool for invasive species control. However, with this interest and support have come important questions about the cost of prescribed fire projects, and how prescribed fire costs compare with other types of treatments. This article summarizes the costs of prescribed fire projects implemented by the Humboldt County Prescribed Burn Association—a landowner-led cooperative in California's North Coast that is forging a new path for prescribed fire on private lands in California. These examples from Humboldt County demonstrate the limited utility of cost/acre as a metric for understanding prescribed fire costs, and point to cost/season and cost/day as more helpful approaches to planning and budgeting for prescribed fire.

University of California Cooperative Extension, 5630 South Broadway, Eureka, CA 95503: [1]Area Fire Advisor, Lenya has a background in fire ecology and restoration, and the bulk of her program is focused on empowering and training landowners and land managers to use prescribed fire. [2]Livestock and Natural Resources Advisor, Jeffery is a wildlife biologist and range ecologist with research experience in a wide variety of habitats, from North Dakota to California. Prescribed fire has become an important part of Jeff's range management toolbox.

Prescribed Fire Costs

The Humboldt County Prescribed Burn Association (HCPBA) officially formed in March 2018 and is modeled after prescribed burn associations in other parts of the country, where community members pool labor, equipment, and expertise to implement burns on private lands (Toledo et al. 2014). Burns in Humboldt County have focused on a variety of objectives, including restoration and maintenance of grasslands through control of invasive species and woody encroachment. Unlike federal- and state-prescribed fire programs,

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Why cost/acre is not a good metric for prescribed fire *continued*

which rely on paid staff and agency resources, PBAs are mostly volunteer and based on a system of mutual benefit and reciprocity—a true neighbors-helping-neighbors approach (Diaz et al. 2016). Costs for PBA burns vary depending on where they are located, but in Humboldt County, the primary costs include air quality permit fees, contractor fees for burn planning and burn bossing, and volunteer fire department stipends, which the HCPBA recommends for in-season burns with permits that necessitate fire department resources. Most of these costs are one-time expenses that relate loosely, if at all, to project size.

Figure 1: Air quality permit fees for prescribed fire in the North Coast Unified Air Quality Management District (Humboldt, Trinity, and Del Norte counties). Note: changes were made to the fee structure in spring 2018, so projects in 2017 were subject to a different fee structure.

Permit	Cost	Lifespan
1-10 acres	$80	1 calendar year, expires Dec. 31
10-100 acres	$250	1 calendar year, expires Dec. 31
100-300 acres	$500	1 calendar year, expires Dec. 31
300+ acres	$1250	1 calendar year, expires Dec. 31
Smoke management plan (SMP) (required for projects larger than 1 acre) from date of execution	$65	2 years
No-burn day permit (one-day variance to burn on a no-burn day; applicants with SMPs may apply)	$65	Day of burn

Air Quality permit fees

In Humboldt County, air quality permits are the one project cost that relate directly to project size. The North Coast Unified Air Quality Management District (NCUAQMD) has a graduated permit fee structure (Figure 1) based on the acreage of the project, plus set fees for smoke management plans and no-burn day permits (i.e., variances). The NCUAQMD is the most expensive air district in northern California (Stackhouse, personal communication, May 1, 2019), with costs ranging from $80 for a project less than 10 acres to $1250 for a project of 300 acres or more, plus $65 for a smoke management plan and an additional $65 for a no-burn day permit (NCUAQMD website 2019). Other northern California air districts have minimal or no permit fees.

Burn planning and burn bossing

For complex or in-season burns, the HCPBA has worked with private contractors to develop burn plans and provide leadership on the day of burn. Burn plans describe project objectives, outline the prescription necessary to meet those objectives, and provide guidance on unit preparation and resources needed to implement the project safely and effectively. Burn plan development generally requires site visits, conversations with the landowner, mapping, and clear synthesis of information in a written plan. Costs for burn planning generally range from $500-$1,000, depending on the complexity of the project.

In California, there are several private burn bosses who can provide leadership on the day of the burn. These private burn bosses typically have decades of fire experience and meet the federal (National Wildfire Coordinating Group) standard as a Type 2 Burn Boss. Private burn bosses usually bring some level of insurance with them, providing an additional buffer for the landowner. During declared fire season, when Cal Fire permits are required, burn bosses lend credibility and

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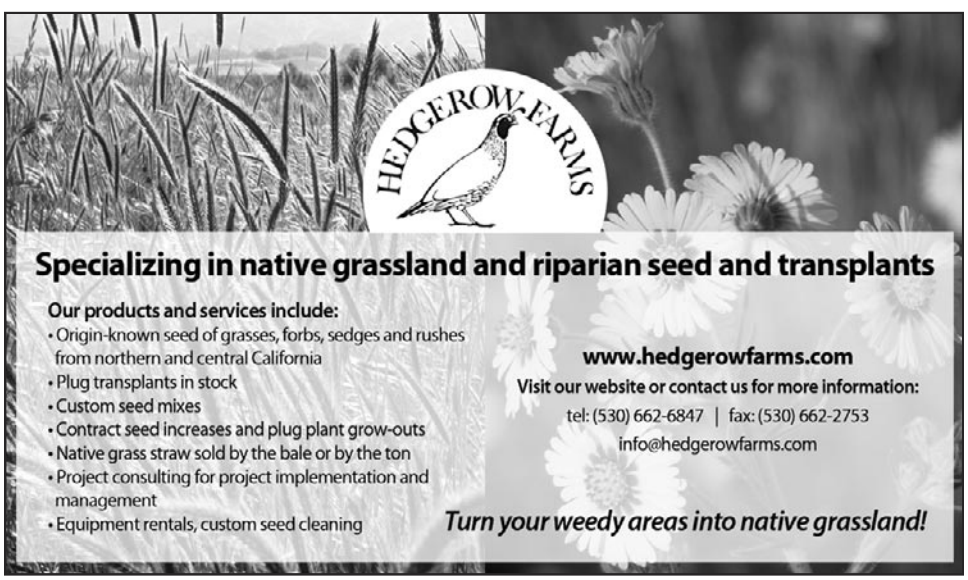

expertise to prescribed fire operations, often easing the permit process. However, private burn bosses are in short supply, and private contractors are hesitant to provide burn boss services unless they have trusting relationships with burn organizers and adequate resources to implement the burn safely. Prescribed fire leadership will continue to be a bottleneck in California in the absence of programs and resources that build new capacity outside of state and federal fire management agencies. Day-of-burn leadership by a private Type 2 Burn Boss typically costs $1,000-$1,500.

Other costs

Burns organized by the HCPBA may include other costs, including volunteer fire department stipends and lunch. Landowners are also encouraged to make a donation to the HCPBA for equipment maintenance and project coordination. The landowner is also expected to prepare units for burning, which can include brush work, tree thinning, and installing firelines. In Humboldt County, those costs have in some cases been offset through landowner contracts with the Natural Resources Conservation Service (NRCS) or with other grant funding secured by the HCPBA.

Comparing Project Costs

As demonstrated in Figure 2, per acre costs have varied substantially on burns implemented by the Humboldt County Prescribed Burn Association. Costs have ranged from $3/acre on a winter oak woodland restoration burn to almost $1,100/acre on an in-season understory fuels reduction burn. Costs are heavily influenced by seasonality, because the HCPBA has contracted private burn bosses for almost all projects that occurred during declared fire season (typically May 1 – late October/early November). Thus, for in-season burns more than an acre in size, costs averaged $2,481 (±$446) per day with project sizes ranging from 3 to 215 acres, whereas out-of-season burns averaged $439 (±$665) per day with project sizes ranging from 2 to 163 acres. On any of those days, a smaller or larger project on the same property would have cost roughly the same amount. During both seasons, the cheapest per acre costs were realized on the largest burns, because costs accrue by day—not by acre. For example, in Humboldt County, the only cost difference between a 20-acre and 200-acre medusahead (*Elymus caput-medusae*) or starthistle (*Centaurea solstitialis*) burn in early summer would be the air quality

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Figure 2: Actual day-of-burn costs of burns conducted by the Humboldt County Prescribed Burn Association, June 2017 – April 2019. Italicized objectives indicate burns that occurred during Cal Fire's declared fire season. Table does not include unit preparation, hospitality costs (e.g., lunch), or donations to the HCPBA. Note: * indicates when an existing burn plan or air quality permit was used, meaning no additional costs were accrued.

Year	Objective	Acres	Burn plan	Burn Boss	VFD stipend	Air quality	Crew size	Total cost	Cost/acre
2017	*Medusahead control/training*	18	$500	$1,500	$600	$100	30	$2,700	$152
2017	*Coyote brush control/training*	140	$500	$1,000	$600	$200	25	$2,300	$17
2017	Oak woodland restoration/training	20	N/A	N/A	$0	$100	12	$100	$6
2017	Oak woodland restoration	15	N/A	N/A	N/A	$100	3	$100	$7
2017	Oak woodland restoration	13	N/A	N/A	N/A	$0 *	6	$0	$0
2018	Blackberry control	5	$500	$1,500	N/A	$145	10	$2,145	$431
2018	*Grasshopper control/medusahead control/training*	6	$0	$1,500	$600	$145	25	$2,245	$378
2018	*Coyote brush control/training*	215	$500	$1,000	$750	$565	35	$2,815	$13
2018	*Coyote brush control/training*	145	$0 *	$1,000	$750	$565	30	$2,315	$16
2018	*Native grass seeding trial*	0.25	N/A	N/A	N/A	$145	3	$145	$592
2018	*Coyote brush control/training*	*130*	*$0 **	*$1,000*	*$750*	*$0 **	*30*	*$1,750*	*$14*
2018	*Understory fuels reduction/training*	3	$1,000	$1,500	$600	$145	25	$3,245	$1,090
2019	Oak woodland restoration	163	N/A	N/A	N/A	$565	2	$565	$3
2019	Oak woodland restoration	22	N/A	N/A	N/A	$315	9	$315	$15
2019	Blackberry control	2	N/A	N/A	N/A	$145	3	$145	$74
2019	Understory fuels reduction/training	5	$0	$0	$0	$145	20	$145	$33

Prescribed fire can be used to halt woody encroachment and maintain grasslands. Humboldt County, CA, just after a Fall 2018 burn (left), and seven months later in Spring 2019 (right).

Why cost/acre is not a good metric for prescribed fire *continued*

permit fee. Either unit would be achievable in one day. The burn plan and burn boss fees would be the same, as would the resource (fire engine, crews, and water) requirements outlined in the Cal Fire permit (and reflected in the VFD stipend). In this example, the landowner could accomplish 180 more acres of invasive plant control for a cost difference of $420 (and some neighboring air districts would have no difference in cost.) Likewise, preparation of the units becomes significantly more efficient as the units grow in size. As a simple example, a square one-acre grassland unit would require 836 ft of perimeter fireline (836 ft/acre of treatment), a five-acre unit would require 1,867 ft of fireline (373 ft/acre of treatment), and a 100-acre unit would require 8,348 ft of fireline (83.5 ft/acre of treatment). These examples show that prescribed fire costs do not have a linear relationship to project size in the same way that other treatments (e.g., mastication, thinning) might.

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Conclusion

This paper demonstrates that cost per acre is not a useful metric for considering prescribed fire implementation costs. Rather, private landowners in California should be considering costs by season and by day. In-season burns are naturally more complex, and will usually require additional resources, crew members, and expertise. For many landowners, those additional costs are justified by their specific burn objectives, which may only be achievable during certain times of year (e.g., medusahead and starthistle control) or may require drier weather. Likewise, some fuel types (e.g., forested areas) may add complexity and require additional resources and post-fire patrolling. For other landowners whose objectives can be met during cooler times of year and with fewer resources, costs will be lower. For all landowners, there is clear incentive to maximize project area when planning prescribed burns, as most implementation costs accrue by the day, and the cost efficiency of preparation, permitting, and implementation greatly increases with project size.

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The Humboldt County PBA has two 55-gallon slip-in units that can be easily lifted by two people and used in the bed of a pick-up. In this case, a PBA member brought both units to a burn in his livestock trailer.

Field Report: Building a burn trailer to support your community's prescribed fire efforts

by Lenya Quinn-Davidson[1] and Jeffery Stackhouse[2] Photos courtesy Lenya Quinn-Davidson

Throughout the West, there is increasing interest in utilizing prescribed fire to reduce fuels, improve and restore habitat, and increase wildfire resilience on private lands. For California grasslands in particular, prescribed fire shows promise as one of the most cost-effective tools for controlling invasive species like medusahead (*Elymus caput-medusae*), starthistle (*Centaurea solstitialis*), and barbed goat grass (*Aegilops triuncialis*), as well as for limiting the spread of woody plants. Although prescribed fire has been an "expert"-driven practice in the West for many decades—used primarily by federal and state land management agencies that staff wildland fire crews—there is a history of community-based burning in the region, and many areas are finding a renewed interest in grassroots prescribed burn associations (PBAs), which they see as the only realistic model for bringing fire back to private lands at a meaningful scale. Prescribed burn associations are common in the Great Plains and have enabled a significant scaling-up of prescribed fire in that region over the last decade (Weir et al. 2015). In 2018, Humboldt County (CA) formed the first prescribed burn association in the West, convening more than 70 local members and 10 volunteer fire departments and burning more than 900 acres on nine different properties in their first two years.

Critical to the efforts of the Humboldt County Prescribed Burn Association (HCPBA) has been their burn trailer, which was funded in 2017 and 2018 by the California Deer Association and includes equipment and tools to support prescribed fire implementation. This document presents a list of recommended burn cache items, and it is intended to inform the efforts of newly forming PBAs and other community-based prescribed fire efforts in the West.

Additional recommendations and lessons learned

Trailer: When the Humboldt County PBA built their burn trailer, they special-ordered a high-clearance trailer that was big enough to fit a UTV, should they someday find grant funds to purchase one. The trailer is roomy and can drive over rough terrain, but it is also very tall

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Building a Burn Trailer *continued*

and too large for anything but a full-size pickup to tow. ***Recommendation:*** *Purchase a burn trailer that is big enough to fit tools and equipment, but it is not necessary to have a high-clearance trailer or a trailer big enough for a UTV.*

Slip-in units: The Humboldt County PBA purchased two 55-gallon Northstar skid sprayers and one 200-gallon Northstar skid sprayer, thinking the 55-gallon units would be suitable for UTVs and the 200-gallon unit would be suitable for a pick-up truck. However, the 55-gallon units were bigger than expected and, in the steep country of California's North Coast, are safer in the bed of a pick-up than in a UTV. The 55-gallon units are easily moved by hand with two or three people, and their water supply lasts longer than expected thanks to an efficient hose and nozzle. The 200-gallon unit is too heavy to move without a tractor or forklift, and it is therefore less user-friendly than expected. ***Recommendation:*** *Unless you have a vehicle available to permanently house the 200-gallon unit, prioritize purchase of the 55-gallon units. Likewise, smaller units (in the 15-25 gallon range) are most appropriate for ATVs and UTVs.*

Personal protective equipment: The Humboldt County PBA requires volunteers to wear the following: natural fiber clothing (no synthetics), long pants and long-sleeved shirts, leather boots, leather gloves, hard hat (for forested units) or cap, and eye protection. The Humboldt County PBA does not require participants to wear Nomex or to carry fire shelters. Requiring Nomex and shelters can be limiting for

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Figure 1. Tools and equipment to include in a burn trailer. Note: The costs outlined in this document are estimates based on purchases made by the Humboldt County PBA and through additional online research. Individual PBAs will need to assess costs and desired numbers as appropriate for their local efforts and needs.

Item	Estimated cost/unit	Recommended number	Total cost
HIGH PRIORITY NEEDS			
Enclosed trailer (7x16)	$6,800	1	$6,800
Spare tire	90	2	180
Tie-downs/straps	250	1	250
Locks/totes/other	200	1	200
Custom tool rack in trailer	400	1	400
Kestrel 5500FW Fire Weather Meter Pro	450	1	450
VHF radio	300	40	12,000
PBA radio frequency (10 year)	600	1	600
Radio chest harness and/or belt clip	40	40	1,600
55-gallon skid-sprayer for pick-up truck	2,000	4	8,000
Drip torch	160	12	1,920
Road sign and stand	160	4	640
Backpack sprayer	180	10	1,800
McLeod	60	15	900
Fire rake	60	10	600
Rogue hoe	60	10	600
First aid kit	150	1	150
Hard hat	20	20	400
Smoke mask (N95 20-pack)	15	10	150
ATV sprayer (15-20 gal)	220	4	880
Ethanol-free fuel/2-stroke oil	160	1	160
MEDIUM PRIORITY NEEDS			
Pulaski	60	5	300
Shovel	60	5	300

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Members of the Humboldt County PBA designed and installed tool racks on the inside wall of the burn trailer.

Figure 1. *continued*

Item	Estimated cost/unit	Recommended number	Total cost
MEDIUM PRIORITY NEEDS			
Flapper	60	5	300
Fire goggle	45	20	900
Fire shroud	30	20	600
Flo-Fast fuel canister for drip mix	95	6	570
UTV sprayer (20-35 gal)	600	2	1,200
LOW PRIORITY NEEDS			
Solar panel/lights/battery	300	1	300
Logos/wrap	250	1	250
10 gal water jug	2	75	150
Fold-a-tank	1,100	1	1,100
Hose: 1.5″ x 100′	150	15	2,250
Hose: 1″ x 50′	85	10	850
Inline T	75	10	750
1.5″ Y	80	1	80
2.5″ to 1.5″ reducer	45	1	45
Nozzle/bail 1.5″	275	1	275
Nozzle 1″	15	10	150
Hose clamp	65	10	650
Hose pack	175	2	350
Hose coupling 1.5″	5	5	25
Transfer pump	550	1	550
UTV	16,000	1	16,000
String trimmer	190	2	380
Backpack blower	580	1	580
Pole saw	600	1	600
Chainsaw- 18″ bar	350	1	345
Saw chain	12	20	240

Building a Burn Trailer *continued*

community members who can't afford to buy them, and it can also make some community members uncomfortable. ***Recommendation:*** *The Humboldt County PBA has found that participants are most comfortable, agile, and confident when wearing their own clothes, as long as they meet the basic safety requirements outlined above. Carhartt makes nice fire-resistant work clothes, which are also an option.*

Radios: Communication is one of the most important safety considerations on a prescribed burn. ***Recommendation:*** *Prioritize purchase of reliable radios. The Humboldt County PBA also purchased a 10-year county-wide frequency to increase the autonomy and reliability of their radio communications.*

Planning: Project planning is critical for success. The Humboldt County PBA often hires private burn bosses to help develop burn plans, and University of California Cooperative Extension advisors have been a helpful resource for understanding the appropriate timing for burns and monitoring the ecological effectiveness of burning. Local Cal Fire staff are also a good resource for private landowners interested in burning, and they should be looped into project plans as they develop, especially for in-season burns that require Cal Fire permits. ***Recommendation:*** *Resources are available to help with burn planning. Reach out to a private burn boss, your local University of California Cooperative Extension office, the authors of this article, Cal Fire staff, or other prescribed fire experts as plans develop.*

Conclusion:

Private landowners throughout the West are interested in bringing prescribed fire back into the management toolbox. Prescribed fire can be a cost-effective means of achieving a wide variety of management objectives, including the restoration and maintenance of grasslands and woodlands, reduction of hazardous fuels, and the control of invasive species. In the Great Plains and other parts of the country, shared tools and equipment are a cornerstone of community-based prescribed fire efforts, and prescribed burn associations have burn trailers to house and transport shared equipment caches. This article outlines and prioritizes items that could be included in a burn trailer, and it lends additional insights from the perspective of the Humboldt County Prescribed Burn Association—the first PBA in the West. As new PBAs coalesce and start to build capacity, this article is intended to provide ideas, guidance, and inspiration.

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Many grassland plants including *Asclepias speciosa* are both fire resistant and attractive to beneficial insects.

GOING NATIVE Designing for Fire — Homeowner Guidelines and Considerations for Native Planting

by Haven Kiers[1] and Jessica Colvin[2] *Photos courtesy Haven Kiers*

Introduction

California wildfires broke records in 2018, with the Mendocino Complex Fire staking claim as the largest fire in state history and the Camp Fire capturing the title of deadliest, most destructive, and costliest fire on record in the United States (Cal Fire 2018). In fact, the state tops both the list of *Most Wildfire Prone States*, with over 2 million Californian households at high or extreme risk from wildfires (Texas is a distant second with only 700,000 high risk homes), and the *Number of Acres Burned* list, with more than 1.8 million acres burned by wildfire in 2018 (Verisk's Wildfire Risk Analysis 2019). It is clear that California homeowners living in the wildland urban interface (WUI) need to take precautions to protect their homes, and defensible space principles and fire-resistant landscapes provide the best option for home survivability (e.g., Bell et al. 2007, White and Zipperer 2010). However, it is less clear which types of plants and plant palettes should be installed around residential areas in the WUI, where vegetation should be placed to have the most beneficial (and least detrimental) effects, and exactly how the creation of defensible space is best accomplished to combine both functionality and aesthetics.

Given the gravity of these most recent fires, the resulting home insurance premium hikes in fire-prone areas (or the dropping of homeowners entirely from existing insurance policies), and subsequent public service campaigns focused on fire prevention, most homeowners in the WUI understand the necessity to create defensible

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space around their homes. Barriers to widespread adoption of wildfire defenses do not arise from a lack of knowledge about correct fire-scaping practices, but instead from the perception of associated labor and costs, the difficulty in disposing of the resulting brush, and, perhaps most importantly, the lack of specific knowledge on recommended plant materials and landscape designs which provide wildfire defense (Hodgson 1994).

Daunted by the power and scale of recent wildfires and unable to tackle the scope of the problem on their own, state and federal agencies such as California Department of Forestry and Fire Protection (Cal Fire), the U.S. Forest Service (USFS), and the U.S. Bureau of Land Management (BLM) have increasingly focused on preventative measures individual homeowners living in the WUI can take to reduce the risk to their structures during a wildfire event. This article takes the defensible space recommendations developed by Cal Fire as a starting point, incorporates a firewise native plant palette, and proposes a modernized, habitat-focused, aesthetic approach to defensible space design at the neighborhood scale.

Clusters of *Heuchera rosada* and *Iris douglasiana* thrive in shady spots.

Background

The western landscape has evolved with fire, and, as a result, many of its native plants require fire to germinate, establish and/or reproduce. As a regular component of these ecosystems, wildfire historically serves to maintain the health of native fire-adapted species, while also reducing dead biomass and subsequent fuel for more devastating fires. However, because people are increasingly moving into the wildlands, a management strategy of fire suppression has been adopted, leading to the accumulation of fuel loads and the encroachment of non-native, often invasive, species (Syphard 2007).

Although the practice of fire suppression is crucial for the protection of lives and property, it has led to complex management challenges along the WUI. As development continues to expand to areas bordering wilderness, natural resource managers from local, state, and federal agencies are left with little to no choice on how to proceed with fire occurrence at these edges (Miller 2011). Warming temperatures, extreme weather events, and prolonged drought add to fears of wildfires, demanding action and attention. Managers from county planning departments, Cal Fire, and the USFS have realized that asking homeowners to take preventative measures to reduce risks to their structures can effectively help reduce the spread of wildfires.

The Rules of Defensible Space

Creating defensible space is a preventative measure that homeowners can take to minimize the risk of losing their structures to wildfire. Defensible space is defined as "the area surrounding a structure where plants and other landscape elements are maintained to decrease fire hazard and allow firefighters to make a stand; addressing embers and spot fires before they grow" (UCCE Defensible Space Website). Defensible space is typically divided into three zones. Zone 1, or the "Near-Home Noncombustible Zone," starts at the walls of a structure and expands out to 5'. Zone 2, which is also called the "Lean and Clean Zone," stretches from 5-30' away from the structure, and Zone 3, the "Reduced Fuel Zone," spans from 30-100' (or to the property line, if less than 100') (Franz 2018). Vegetation of any type other than regularly irrigated potted plants is discouraged within Zone 1, while low groundcovers (including mown grass, flowers, and vegetables) are allowed within Zone 2. Trees and shrubs are acceptable in Zone 3 as

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This low-growing annual meadow provides flowers in the spring and can be mown in the summer.

Designing for Fire *continued*

long as they are widely spaced and pruned up to avoid a fire ladder effect.

Although it is tempting to focus primarily on plant selection when designing a fire-resistant landscape, the reality is that there are no "fire-proof" plants, and most of the fire-resistant/firewise plant lists available are based on anecdotal, rather than scientific, information. Standardized methods for determining plant flammability or WUI landscape suitability do not currently exist (Bethke 2015). While plant selection does play a significant role in designing a fire-resistant landscape, plant maintenance is even more important. Preventative maintenance is key — a poorly maintained landscape can easily become a fire hazard, even if the majority of its plants are labeled as fire-resistant. Thus, the principles of defensible space require that all vegetation within 100' from the structure is regularly irrigated and routinely checked for dead/dry material. Dead trees or branches, lawn clippings, and any dried-out vegetation must be cut, cleared away, and immediately removed from the property (Readyforwildfire.org 2018).

Cal Fire's publication, "Defensible Space and Hardening Your Home," outlines another key component of firewise landscapes — plant and tree spacing. Plants need to be separated from each other both horizontally and vertically. Trees and shrubs must be pruned up to at

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least 15' above ground level (10' above roof level) and spaced out to prevent canopies from touching. Islands of taller vegetation should be separated from each other with paths, hardscape, or low-growing groundcovers (Cal Fire 2017).

Rethinking the Rules

While it is challenging to align garden design principles of aesthetics, habitat creation, and human comfort with the defensible space principles of cut, clear, and remove, homeowners *can* create fire-resistant landscapes that are both beautiful and attractive to pollinators and wildlife. As developed land increases and population continues to grow, re-establishing habitats in urbanized areas has become crucial for a changing climate. Local pollinators are best adapted to local climate conditions and offer the best chance of enhancing native biodiversity and promoting the success of locally native plant species. Although most California native species have moderate maintenance requirements (pruning or cutting back, regular weeding until the native species have become established, removing dried material/deadheading), those needs align with what is already required by defensible space principles. A simple way to approach the creation of defensible space is by incorporating the "Three R's" developed by the Sierra Club as a model for fire prevention in the East Bay Hills (Sierra Club 2018):

REMOVE fire-dangerous exotic and native vegetation in areas most at risk for fire;

RESTORE those areas with California native tree and plant species that are less fire- dangerous; and

RE-ESTABLISH greater local biodiversity of flora and fauna.

By removing flammable non-native trees and shrubs and favoring plant palettes dominated by a fire-resistant mix of annual and perennial native species (ideally ones that have been sourced from nurseries that provide plants with genetics local to the residential site), homeowners can reduce the threat of wildfire while simultaneously improving wildlife habitat and creating a beautiful landscape.

The following are suggested methods for achieving the goal of defensible space, while improving biodiversity and adding natural beauty to a landscape. These methods incorporate the defensible space zones defined in Cal Fire's "Defensible Space and Hardening Your Home:"

Zone One: 0' – 5'

Ideally, the 5' zone should be free of vegetation, and should also exclude combustible materials of any kind, such as wood mulch, brooms, fences, or other materials with the potential to burn. Hardscape design in Zone One can include permeable, non-combustible materials like pavers, gravel, or decomposed granite to increase stormwater infiltration and reduce erosion around the property. Zone One also offers an opportunity — particularly within southern-facing pockets around the main structure that go underutilized and undisturbed — for leaving modest amounts of bare earth. Many native bee species do not nest in hives but rather in individual nests buried in the ground. These bees are far less aggressive than honey bees and still provide the benefits of pollination.

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A gravel path separates groups of flowering perennials and doubles as a fire break.

Designing for Fire *continued*

Incorporating intentional bare earth pockets are welcome and encouraged in Zones Two and Three as well.

Zone Two: 5' – 30'

Traditional defensible space design calls for the 30' zone around the house to be planted with irrigated turf, a low-growing ground cover, or grouped perennials with open space in between (Pacific Northwest Extension 2006). An alternative to this approach is planting a lawn of *Festuca rubra* (a cool-season native grassland species that thrives in partial shade). It requires less irrigation than a typical turfgrass lawn and can be left unmown for a lush prairie look in the cool months, and either kept irrigated or mowed to 2" during summer's fire season. Another native low-growing groundcover with high marks in several firewise planting lists is lippia *(Phyla nodiflora)*, which requires no mowing, needs little irrigation, and produces lavender-pink flowers that attract small butterflies and bees.

Alternatively, homeowners could use Zone Two to seed an annual wildflower meadow of spring-blooming native forbs, such as lupine (*Lupinus succulentus*), California poppy (*Eschscholzia californica*), goldfields (*Lasthenia californica*), baby blue eyes (*Nemophila menziesii*), phacelia (*Phacelia* spp.) and tidy tips (*Layia platyglossa*). Mixed with a perennial bunchgrass like onion grass (*Melica californica*) or purple needlegrass (*Nassella pulchra*), such a wildflower meadow would bloom profusely during the spring and could then be mowed and raked when things start to dry out in the summer months. For a shady area, wild strawberry (*Fragaria chiloensis* or *F. vesca)* could be used as a groundcover; it spreads easily and stays green year-round.

Groundcovers that remain low to the ground, require little maintenance and minimal water, and remain green and healthy during the dry season make ideal candidates for Zone Two. Instead of planting groundcovers of periwinkle (*Vinca major*) and English ivy (*Hedera helix*) in the 30' zone — both of which appear on many of the firewise planting lists, but can be extremely invasive — homeowners could consider planting low-growing white yarrow (*Achillea millefolium*), California lilac (*Ceanothus thrysiflorus*), or prostrate varieties of manzanita (*Arctostaphylos hookeri or A. uva-ursa*) (Bethke 2015). These spreading groundcovers burn slowly when pruned and irrigated properly and can delay the spread of a wildfire, especially if they're located in beds surrounded by walkways and paths. When allowed to form a dense mat of foliage and roots, native groundcovers can also help reduce soil erosion and minimize invasive weeds, which only contribute to fire hazard.

Islands or clusters of plants are often recommended for the 30' landscape zone near the house because they create a discontinuous path of vegetation and make it more difficult for the fire to find a direct path to the building. Flowering grassland perennials that look good planted in clusters and are included on many California firewise planting lists include yarrow (*Achillea millefolium*), buttercups (*Ranunculus californicus*), goldenrod (*Solidago californica*), coyote mint (*Monardella villosa*), blue-eyed grass (*Sisyrinchium bellum*), or yellow-eyed grass (*Sisyrinchium californicum*), and mimulus (*Mimulus* spp.)(Bethke 2015). Mixed with native ornamental grasses like deergrass (*Muhlenbergia rigens*), California fescue (*Festuca californica*),

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or blue wildrye (*Elymus glaucus*), the flowers would pop against a meadow matrix, all the while providing native insects and pollinators with food and habitat. In the shade, a combination of coral bells (*Heuchera spp.*) and douglas iris (*Iris douglasiana*) would stay green all year and provide beautiful spring color.

Bulbiferous plants are not often discussed in the defensible space literature, but a surprisingly large number of California native grassland bulbs are included in firewise plant lists such as one-leaf onion (*Allium unifolium*), bluedicks (*Dichelostemma capitatum*), Mariposa lily (*Calochortus* sp.), soap plant (*Chloragalum pomeridianum*), and chocolate lily (*Fritillaria biflora*). Several of these species attract butterflies and create optimal habitat when planted in islands or clusters.

Zone Three: 30′ – 100′

Well-spaced shrubs and small trees are allowed in the 30-100' zone. Remembering that arrangement, spacing, density, and dryness of the vegetation is more important than the actual plant species planted, homeowners should be focused on selecting shrubs and trees that meet the dual standards of habitat enrichment and fuel ladder prevention. The darling of all fire-resistant plant lists is the toyon (*Heteromeles arbutifolia*), with Los Angeles, San Diego, Orange, and Inland Empire counties giving it high marks for its wildlife value (flowers and berries), drought tolerance, and low flammability (Bethke 2015). Other noted evergreen shrubs and small trees include low varieties of manzanita (A*rctostaphylos* spp.), lemonade berry (*Rhus integrifolia*), coffeeberry (*Frangula californica*), and California lilac (*Ceanothus* spp.). California buckeye (*Aesculus californica*), redbud (*Cercis occidentalis*), golden currant (*Ribes aureum*), and spice bush (*Calycanthus occidentalis*) top the lists for deciduous species (Bethke 2015). All shrubs and trees within Zone 3 should be pruned up high and thinned. For more ideas on California native plants to use in the landscape, homeowners can go to Calflora's "What Grows Here" webpage (**https://www.calflora.org/entry/wgh.html**) and Calscape's webpage (**https://calscape.org/**).

Interstitial Spaces

While the recommended plant species above can increase native biodiversity and ideally improve fire-resiliency at the site scale, the interstitial spaces *between* homes or along property edges are often overlooked or under-managed. After California-imposed water restrictions during recent droughts, homeowners' associations statewide were confronted with difficult decisions concerning shared landscapes. This left many communities with few options for shared spaces, forcing them to install artificial turf or remove vegetation altogether. While many changes were effective, they were often made in haste and without considerations for local wildlife habitat or the long-term functionality of these modified spaces. For example,

If irrigated, this mixture of native perennial flowers and grasses will bloom through summer and function as a groundcover in the 30′ zone around a residence.

artificial turf still requires significant maintenance (regular rinsing to remove dirt and pet waste, irrigation to keep it from becoming too hot for human use) and is often not preferable to natural turf for sport or recreation. In contrast, while natural turf might slightly increase water demands on a community, evidence shows that, as a well-irrigated landscape, grass turf might actually serve as a fire break within developed areas. By applying the rules and methods gleaned from residential defensible space to these shared spaces, WUI communities can integrate locally native species into interstitial spaces to accomplish aesthetic goals, create habitat for wildlife, and still abide by fire resistance guidelines.

Conclusion

Homeowners have the ability to incorporate beauty and create habitat space — without sacrificing fire safety — through the thoughtful consideration of plant selection, spacing, and maintenance in their landscapes. Of equal importance is consideration for the spaces and environments adjacent to and between private homes in the WUI. Collaboration at the street- and neighborhood-levels can enhance aesthetic and property value while further increasing survivability of surrounding landscapes. WUI neighborhoods can take advantage of

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Designing for Fire *continued*

creating fuel breaks between neighbors to protect wildlands and reduce the threat of fire. As neighborhoods become more involved in fire resiliency planning, native biodiversity in both developed and undeveloped lands will be given the potential to thrive.

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Front and back covers: Grassland burn at UC Davis Putah Creek Riparian Reserve, with West Valley Regional Fire Training Consortium (June 2018). *Photo: JP Marié, Manager, UC Davis Putah Creek Riparian Reserve, and Board Member, CNGA*