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

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Introduction

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

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

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

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

Methods

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

Sampling Transects

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

Burn Area

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

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

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

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

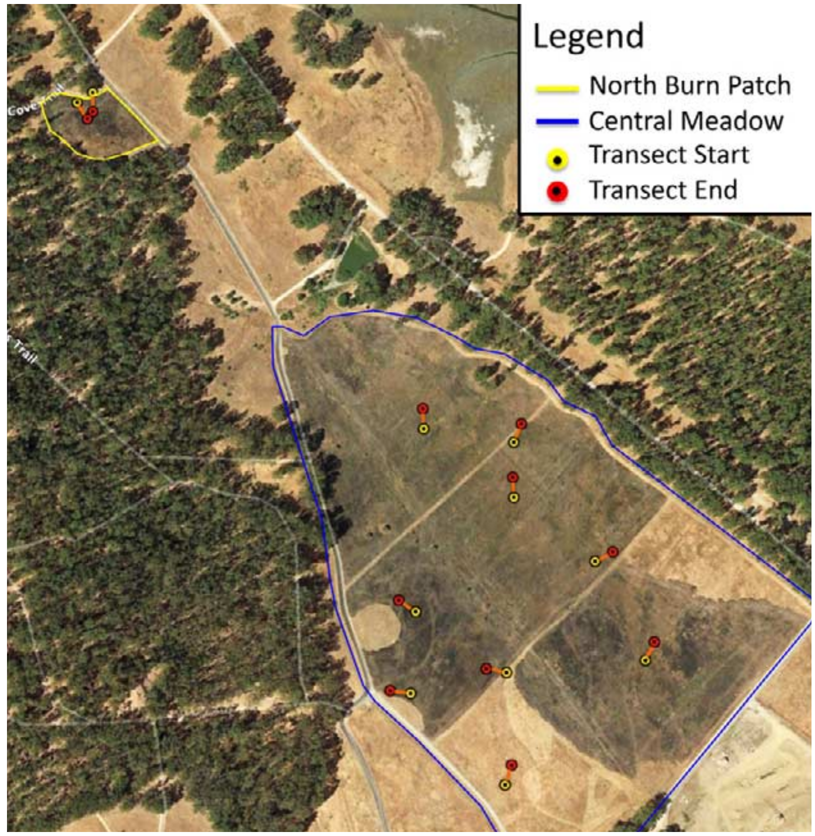

Figure 1. Project area and location of sampling transects. The two transects in the northern portion of the map are in the North Burn Patch. All other transects are in the Central Meadow. Darker areas show the boundaries of the prescribed burn. *Imagery from Google Earth*

Burn Conditions

We observed the following burn conditions during the prescribed burn:

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

Statistical methods

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

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

Germination Trial

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

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

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

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

*California native species

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Results

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

Central Meadow

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

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

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

North Burn Patch

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

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

Medusa Head Germination Trial

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

Conclusions

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

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

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

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

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

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