Serpentine Prairie Restoration Project: Redwood Regional Park

2013 Annual Report: Year 5

A **Creekside Center for Earth Observation** Project
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Executive Summary

The Serpentine Prairie Restoration Project was initiated in 2008 to restore native serpentine flora and monitor the population of Presidio clarkia (*Clarkia franciscana*), a federal- and state-endangered annual forb. The Redwood Regional Park – Serpentine Prairie study area is owned and managed by the East Bay Regional Park District (EBRPD). The following document fulfills the annual reporting requirement for this project.

The past year was another dry year characterized by below average rainfall. Many areas that were rich in clarkia in 2011 (a wet year) were nearly devoid of the plant in 2012 and 2013. While most of the core areas remained occupied, the reference plots that are annually censused were reduced to about one fifth of the 2011 peak population numbers.

Our experimentation with mowing and tree removal as stewardship tools continues to offer valuable results. Some of the ecological benefits of three successive years of mowing were negated after only a single rest year. When we reinitiated mowing, the experimental plots rebounded almost completely to 2011 (pre-mow) conditions. Our two most critical parameters, annual forbs and non-native annual grasses, responded quickly and beneficially to mowing. Unexpectedly, bare ground continued to decrease and thatch cover increased, although both are still within the range of the high quality reference sites. Overall we are very pleased at the effectiveness of this management tool.

Tree removal plots are quickly becoming indiscernible from reference plots in comparing bare ground, thatch, annual forbs and total native cover. The conversion from duff impacted plots under pines to occupied clarkia habitat occurred in a 1-2 year time frame. Through passive recruitment, average clarkia population per plot reached about half that in reference plots in 2012, up from about a tenth of the reference before the experiment began. Numbers dropped to about a third of the reference in 2013, but we are pleased that tree removal is creating additional clarkia habitat on the prairie.

Our scraping trial in Hunt Field produced positive results indicating that portions of this area may require more intensive restoration in order for clarkia to establish. About three inches of topsoil were removed from a 5x15’ site dominated by two invasive grasses and a carpet of thatch. About 1,000 clarkia seeds were scattered in this area in the winter yielding some 149 clarkia individuals, many of which contained multiple, large fruits.

Clarkia collection and dispersal trials continue with some success. Since this past year was poor for overall survivorship, many of the recolonization areas contained low clarkia populations, although the areas on north facing slopes continued to thrive. Soils and microclimates may play an influential role in which areas of the Prairie react to various types of annual weather variability.

We continue to dedicate a significant portion of this study to the process of scaling up successful treatments, providing for cost-effective management at the prairie/landscape level. Almost three acres of Hunt Field and surrounding unoccupied grassland habitat was mowed strategically to reduce non-native grasses, increase native forbs and native perennial grasses, and to create potential clarkia habitat. We hope to continue the large scale mowing of Hunt Field, since our results from test plots show substantial habitat benefits of reduced annual grass, increased native forb, and increased bare ground cover after three successive years.

Introduction

The Redwood Park Serpentine Prairie is the largest undeveloped outcrop of a much larger expanse of exposed serpentine soils that once existed in the Oakland Hills. The remnant, intact serpentine soils are now restricted to a ridgeline paralleling Skyline Boulevard from Joaquin Miller Park on the north to Redwood Ranch Equestrian Center on the south. The low nutrient serpentine soils created from the bedrock have been impacted by a number of significant anthropogenic impacts that have altered the chemistry of the soils and subsequently the composition of plants growing on these soils.

In the 1960s, hundreds of pine and acacia trees were planted to create a more "park-like" habitat. More recently, shrub-dominated vegetation has expanded around the margins of the prairie, and an increasing number of park users have also added to the impacts on the landscape. With increased automobile traffic and congestion, dry nitrogen deposition has increased and is estimated to be in the range of 10 pounds per acre (Bay Area Open Space Council, 2011). Cumulatively, these impacts have greatly increased nutrient availability in a once nutrient-poor milieu.

In 2008, a restoration plan for the grasslands was written "to restore the vitality and botanical diversity of the Serpentine Prairie, manage the site to ensure survival of special status species associated with the prairie, and provide for the enjoyment and appreciation of the park users" (EBRPD, 2008). Although anthropogenic impacts have degraded the serpentine prairie, it is believed that some, if not all, of these impacts can be managed and mitigated with stewardship. Particular emphasis is placed on managing the federal- and state-listed endangered Presidio clarkia (*Clarkia franciscana*)[1] as well as the flourishing coastal prairie grassland ecosystem.

Plate 1: Clarkia franciscana

A key factor that influences germination, survivorship and flowering in Mediterranean-region annual plants is annual rainfall. Since clarkia flowers in late

1 Presidio clarkia will hereby be referred to as "clarkia" throughout the document. Another *Clarkia* species does occur just off of the serpentine bedrock, but it is not considered for this report.

spring, we hypothesized precipitation in April, May and June may be an important contributor to plant survivorship and fecundity. We have been tracking overall rainfall (Oct 1-Sept 30) and spring (April 1-June 30) rainfall as potential determinants of clarkia survivorship. This year's 21.97"annual rainfall is 80% of the annual average of 27.6" (Westmap, 2013). Only 2.04" of spring rain fell, only 66% of the 3.1" average for the past 100 years (Figure 1). We expect that 2013 conditions should have been difficult for clarkia.

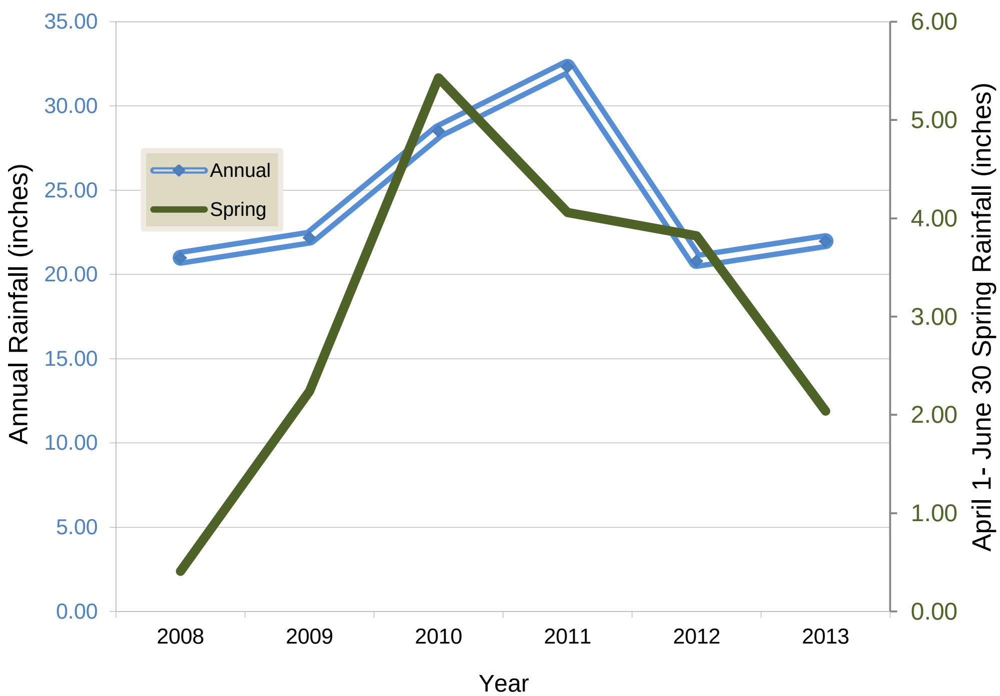


Figure 1: Annual and spring rainfall totals for the Serpentine Prairie

Methods

The experimental design consists of 32 permanent plots measuring four treatments: fall rake, spring mow, tree removal, and reference (Maps 1-3). Each permanent plot is 10x10 meters. Vegetation data were collected in five regularly spaced ½ x ½ meter quadrats within each permanent plot. These quadrats are located away from the edges minimizing potential edge effects. The plots were stratified by whether they were included inside or outside the enclosure fence. Four plots from each treatment were located inside the enclosure, and four outside the enclosure. See the **Monitoring the Permanent Plots** section for more details.

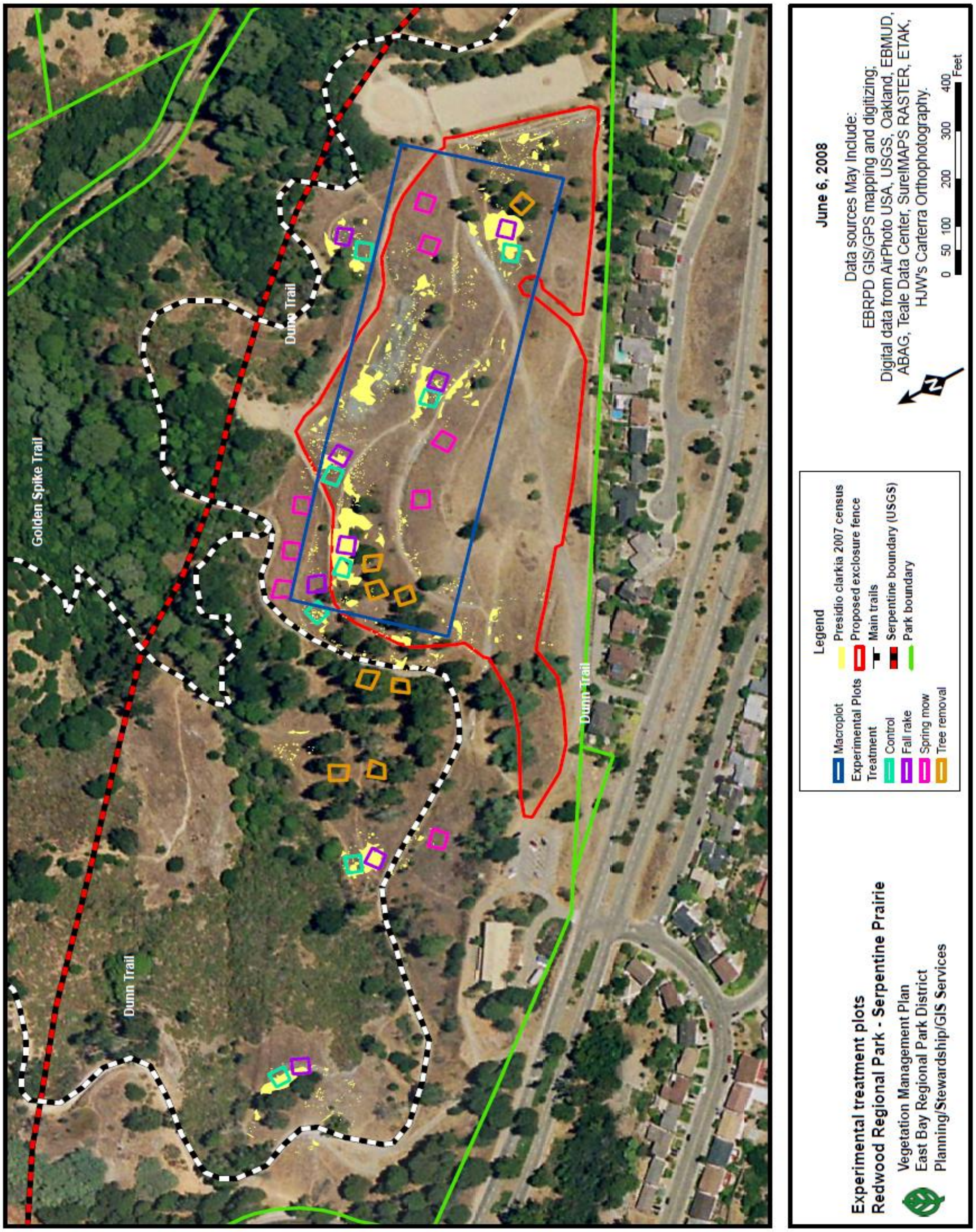
Permanent plot locations were rejected if they were within two meters of another plot or the proposed fence enclosure. Plots were randomly selected within appropriate habitat, which was defined by a number of regulatory and experimental considerations. Each experimental treatment is detailed below.

Fall Rake

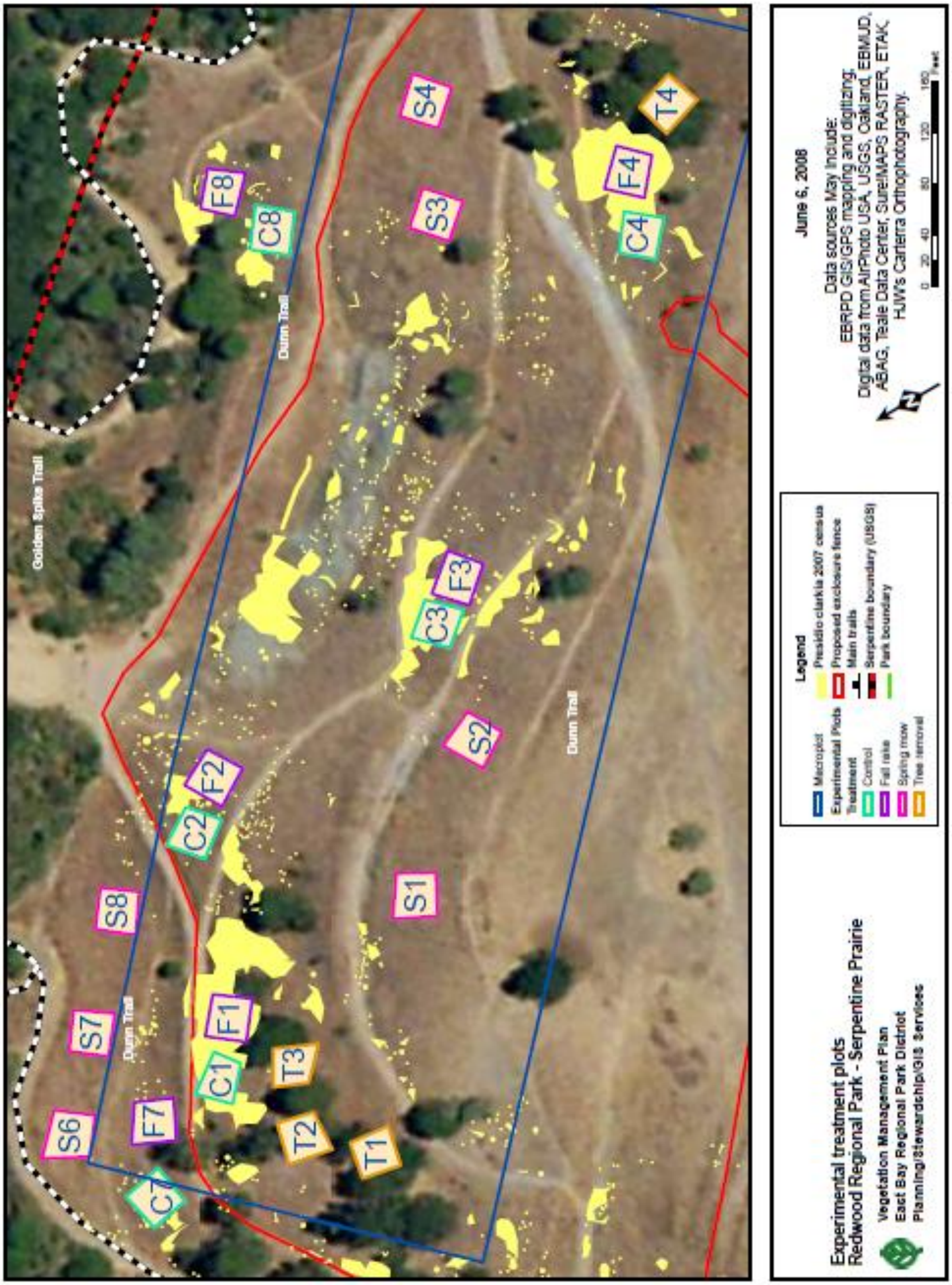
Eight fall rake plots were located in areas where clarkia and thatch were present, with raking occurring only after seed set. Raking was expected to reduce thatch, which has been shown to inhibit germination of forbs such as clarkia.

The fall rake treatment is scheduled to occur annually before the first rains but after the majority of the clarkia capsules have opened and dropped their seeds. Raking usually occurs in September or early October. Raking was completed with a metal rake until bare ground was visible.

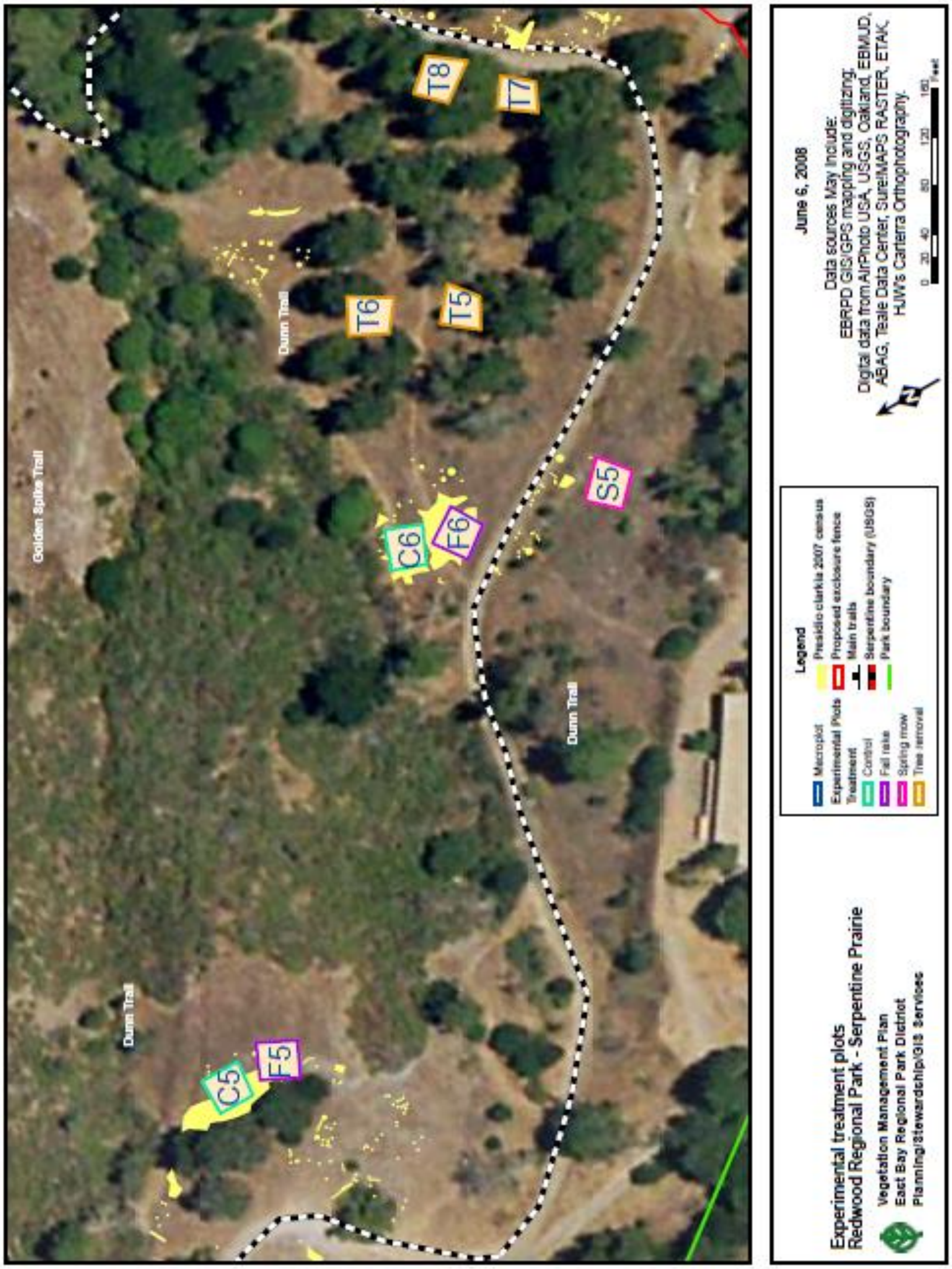
The fall rake treatment was discontinued in the fall of 2011 (no raking occurred in September 2011) because clarkia numbers decreased after the two years of this treatment (while the reference had large increases). We explain more in the **Results** section.



Map 1: Plot locations



Map 2: Close-up of eastern plot locations



Map 3: Close-up of western plot locations

Spring Mow

To avoid take, the eight spring mow plots were located in areas where clarkia had not been observed in previous years. Spring mowing was anticipated to reduce cover of annual grass, which has been shown to outcompete annual forbs such as clarkia.

Italian ryegrass (*Festuca perennis*) and foxtail barley (*Hordeum murinum* ssp. *leporinum*) are the two non-native annual grasses that have the highest cover throughout the Serpentine Prairie. Mowing is timed to occur after the bulk of these grasses are flowering, but before seed maturation. This stage is often called the "soft-dough stage," referencing the texture of the developing seed. The spring mow treatment was carried out in April (2010) and May (2008 and 2009) prior to peak phenology for non-native annual grasses. S2 treatment area is directly downhill, or below, the tape measure (Plate 2). The precise date of this treatment will vary from year to year.

After achieving significant declines in non-native grass cover the previous years, the spring mow treatment plots were not mowed in 2011. The goal of resting these treatment plots was to examine how long the mow effect persists after treatment has stopped.

Because non-native annual grass cover had clearly rebounded after a single year without treatment, the mowing treatment was reinstated in May 2012. This will demonstrate how long it will take to return the plots to their high quality state of April 2011.

Plate 2: Plot S2, spring mow plot in April, 2011. Treatment area located to the left of tape has higher wildflower cover. Untreated area above tape has more nonnative annual grass cover.

Tree Removal

The eight tree removal plots were located in areas of dense pine (*Pinus* spp.) stands where shade from the trees and leaf litter affected the understory making them unlikely to support clarkia.

Phase one of tree removal occurred in August/September of 2009. This phase removed trees that were formerly impacting plots T1, T2, and T3. 2010 represents the first year the vegetation data collected in T1 – T3 reflect tree removal.

In 2010, trees located in and near plots T4, T7, and T8 were removed. Plots T7 and T8 were still partially shaded from trees in the late afternoon.

In fall 2011, the final phase of the tree removal was completed (Plate 3). This final phase removed trees from the vicinity of plots T5 and T6, and completely opened the canopy above T7 and T8. Since the removal occurred after the vegetative season, 2012 marks the first year all plots show the effects of tree removal.

Reference Plots

The eight reference plots were placed in areas occupied by clarkia, to monitor the natural variation in the clarkia population. Reference sites help determine whether changes in experimentally treated plots are actually due to the treatment, or to weather or other variables. The reference plots serve as an experimental control, but we feel this label is misleading since these plots were always densely occupied and represent desirable conditions for clarkia. Previous reports used the term control plots. While the reference plots do not reflect perfect conditions, they illustrate conditions in which dense stands of clarkia can reproduce.

Plate 3: Tree removal progress at the Serpentine Prairie. Images from Google Earth.

Fenced Enclosure

A fence circumscribing 60% of the serpentine prairie was planned for completion in 2008, but was actually completed in December 2009. Starting with the Year 2 report, plots numbered 1, 2, 3 and 4 are located inside of the fence enclosure, while plots 5, 6, 7, and 8 are outside of the enclosure, where dog and pedestrian traffic still regularly occurs. This is the fourth full year the enclosure plots can be examined.

Monitoring the Permanent Plots

Thirty-two 10 X 10 meter permanent plots were established on serpentine soils. Clarkia counts took place in the entire 10x10 meter plot, providing census data for each permanent plot. Vegetation composition data are collected annually at peak phenology. Percent cover of all species present (minimum percent cover is 1%), bare ground, thatch, rock and moss are recorded in five 0.5x0.5 meter quadrats located systematically in each of the 10x10 meter plots (Figure 2, Plate 4). The data from a group of treatments is averaged to provide an estimate of cover for that treatment type.

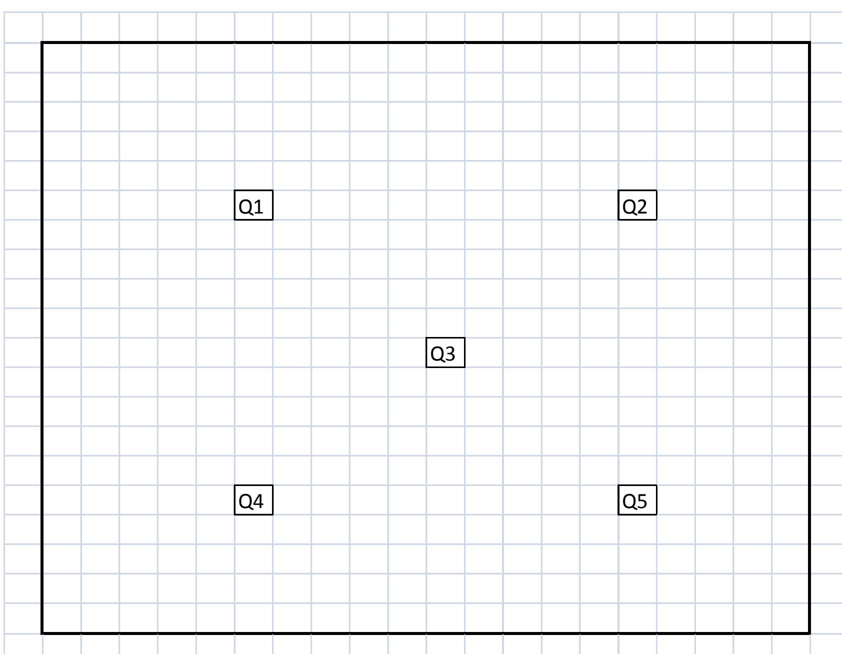


Figure 2: Location of 0.5x0.5m quadrats in each treatment plot, plots were aligned facing uphill.

Plate 4: Data collection at one of the 32 permanent plots

Hunt Field Mowing and Civicorps Collaboration

In 2011, Civicorps was hired to mow a portion of Hunt Field (Plate 5). Creekside mapped areas where clarkia was not observed in past or the present year, but that appeared be appropriate unoccupied habitat. The mow project was designed to cut wild rye (*Festuca perennis*), barley (*Hordeum spp.*), and other non-native annual grasses before they had developed mature seeds (Map 4). The mow occurred in May 2011. Both Creekside and Civicorps mowed approximately 3.5 acres in Hunt Field, plus other areas in the Prairie for a total of about 5.5 acres.

In 2012 and 2013, coordination with Civicorps was not successful. Although we believe that a partnership with Civicorps could be fruitful, their schedule lacked flexibility to cut annual grasses at the proper time. The Civicorps program is fundamentally education-driven, with scheduling occurring up to six months before the project. When considering optimal mow timing for annual grasses, it is impossible to plan this far ahead. Since timing is paramount to success, we recommend park staff, interns, or contractors are scheduled to do the time sensitive work of mowing the Prairie and while Civicorps is utilized in a supplementary fashion.

In 2013, Creekside staff worked alongside EBRPD employees mowing nearly 3 acres of non-native grassland adjacent to occupied clarkia habitat. Trained contractors can mow swaths of high density non-native grasses while minimizing impact to native perennials and desirable forbs. Most areas mowed in 2013 were also mowed in 2012 and 2011. With limited resources, we feel it is important to concentrate efforts in areas that have already been treated in order to maintain habitat improvements.

Plate 5: Civicorps mowing portions of Hunt Field, spring 2011.

Map 4: Mowing completed at Serpentine Prairie, spring 2011-2013

Seed Collection and Dispersal

In September 2010, November 2011, November 2012, and October 2013 Creekside staff collected seeds from mature Presidio clarkia plants and stored them in paper envelopes (Plate 6). No more than 5% of seeds from any given plant were collected to minimize impact to the existing population. Seeds were sown after the first considerable winter-spring rain event.

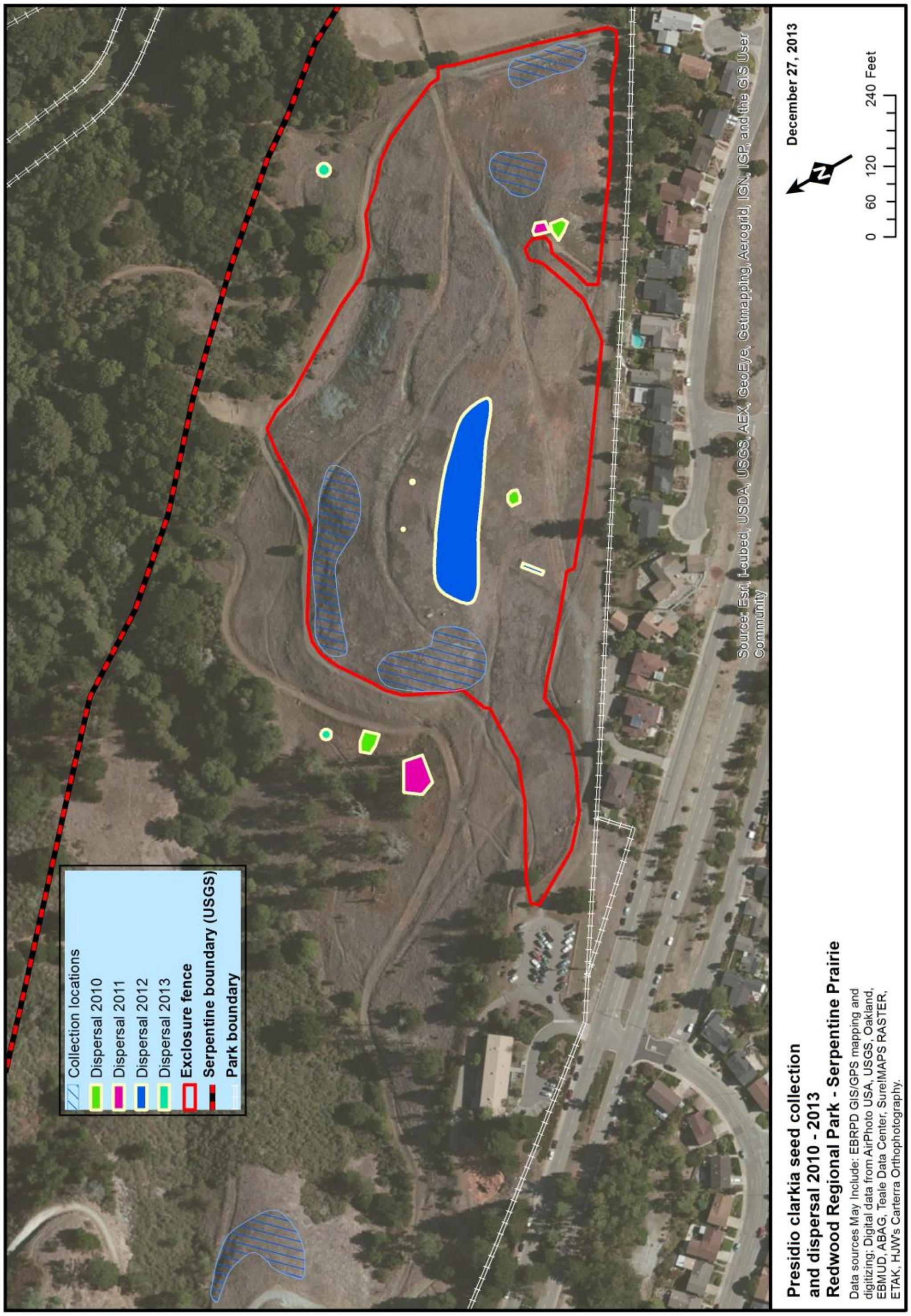
Plate 6: Seed collection on a south-facing slope, November 2011

We report four years of seed translocation trials. The following techniques and strategies were used to sow seed into unoccupied areas:

A. large scale (~ 1 acre) broadcast seeding with no soil disturbance,
B. targeted seeding of small localized patches (~300 m^2) of bare soil from animal disturbance, and
C. seeding of a hand-scraped area (~150 m^2) removing all thatch and organic matter.

Seeds were never sown into existing experimental treatment plots.

Presidio Clarkia Seed Collection and Dispersal: 2010-2013



Map 5: Location of clarkia seed collection and dispersal

Data Analysis

Data were entered into Microsoft Excel and then imported into a Microsoft Access database for analysis. Graphing is completed in Excel. All data were checked for quality control. All data in figures are displayed as means with 90% confidence intervals unless otherwise noted. Entries with error bars that overlap the means of other entries are considered similar.

Due to the diversity of grassland flora, data for the experimental plots are categorized by guild. Surveyed plants were categorized into functional groups, or guilds, based on their growth form: annual grasses, perennial grasses, annual forbs and perennial forbs, further divided between native and non-native species. Each of these guilds represents different ecological strategies for survival in grasslands. Presidio clarkia represents a small portion of the (native) annual forb data presented.

Results and Discussion

Completed Land Management and Monitoring Tasks: 2008-2013

Tasks completed by Creekside Center for Earth Observation from 2008 to 2013 include:

- Establishing a 100 x 300 meter macroplot inside the core Presidio clarkia population. Macroplot corners were established with 6 foot T-bar posts hammered approximately 24 inches deep.

- Establishing 32 permanent plots (Maps 1-3) with wooden stakes. All locations were mapped with a sub-meter accurate Garmin GPS.

- Annually collecting vegetation composition data and clarkia censuses for 32 permanent plots.

- Spring mowing eight treatment plots in April 2008, May 2009, May 2010, May 2012, and May 2013 after reviewing the vegetation composition data. Mowing was completed with a handheld string cutter. Mowing was intentionally skipped in 2011 to test the effect of a “rest” (non-mowing) year.

- Fall raking and removing thatch in September 2008, October 2009, and September 2010 with metal-tined rake.

- From 2008 to 2011, providing meter-by-meter distribution and density data for clarkia located within the macroplot. These data were used by EBRPD staff to create a density grid within the surveyed area (Appendix A).

- In 2011, helping staff study and evaluated a proposal to implement seasonal sheep grazing at the Serpentine Prairie. The proposal was asked for upwards of $3000 an acre and ultimately rejected.

- In 2010-2013, collection of clarkia seed on site by methods specified by CDFW and USFWS. Seed was redistributed on site each year in potential, unoccupied habitat.

- Delineating work area and leading a large work crew of Civicorps students on mowing in Hunt Field May 2011.

- Mowing approximately 3 acres on the Prairie in 2012 and 2013, including the avoidance of dense stands of native forbs and native grasses

- Coordinating 2012 and 2013 tree removal efforts with EBRPD staff, including a site visit identifying serpentine habitat that may respond well to tree removal and provide future habitat for clarkia.

- Providing informal outreach and education to dozens of visitors each year during field work. Creekside staff educates the public about the goals of this EBRPD project in language similar to that found on interpretive signs. Nearly all visitors have expressed appreciation of the project and the information we share with them.

Clarkia Macroplot

Due to funding constraints, the macroplot census was not completed in 2012 or 2013 (Table 1). In 2013, the Presidio Trust, which monitors a population of *Clarkia franciscana* in their own macroplot, reported a 2-3 fold decline in clarkia from the high population count in 2011.

Table 1: Clarkia population within the macroplot, Oakland, CA

Year	Population	± 80% Confidence Interval
2008	15,569	1,888
2009	63,210	8,627
2010	85,830	17,607
2011	105,918	25,532
2012	N/A	N/A
2013	N/A	N/A

Clarkia Census

Clarkia individuals are annually censused in the experimental plots (Table 2). Baseline data are shown in 2008. Reference plots were occupied by similar numbers of clarkia in 2013 as in 2012. Clarkia were not actively seeded into these plots.

Table 2: Total clarkia individuals per treatment

	2008	2009	2010	2011	2012	2013
Reference	1,229	3,030	5,728	11,130	2,268	2,301
Fall rake[2]	1,238	3,254	935	2,317	N/A	N/A
Spring mow[3]	0	24	2	41	3	28
Tree removal	15	184	810	621	1183	728

Over the course of our experiment, total rainfall and clarkia populations are well correlated ($r^2 = 0.90$) (Figure 3). Years 2010, 2011, and 2013 show that spring rainfall is not the critical determinant for clarkia survivorship. Clarkia is not as well correlated with spring rainfall as we initially expected ($r^2 = 0.58$).

Clarkia continues to germinate and reproduce in spring mow plots, and notably, numbers rebounded from the rest year when spring plots were not mowed. Only plots S5 and S8 contained populations of clarkia, the same two plots where clarkia was found in 2012.

Tree removal numbers declined. We believe that the ground disturbance from tree removal may have stimulated clarkia germination in years of active tree removal

[2] Fall rake plots were discontinued in 2011. Data collection in these 8 plots was dropped as a cost savings measure.

[3] Spring mow plots were deliberately chosen in areas where clarkia was not present in order to avoid take.

projects, but since no tree removal was actively completed within or around the plots since spring 2012, numbers declined.

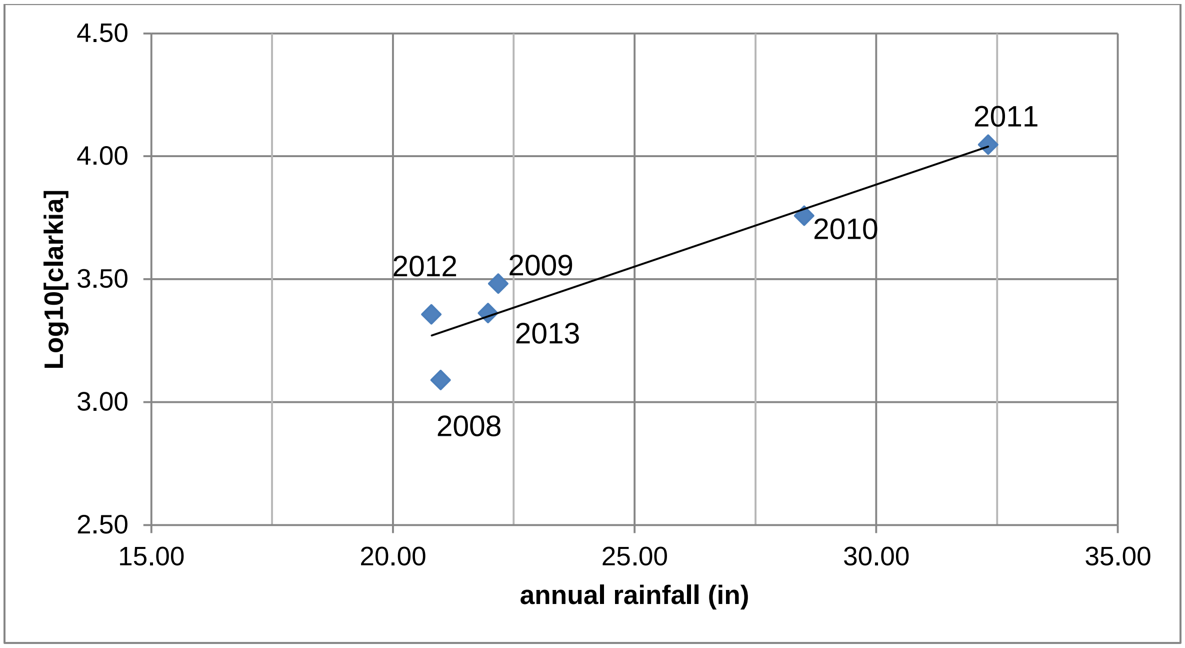


Figure 3: Regression analysis of log transformed clarkia population in reference plots and total annual precipitation

Experimental Plot Data

Baseline data for all treatments are shown in 2008. Because the fall rake treatment was reducing the number of clarkia, the treatment was discontinued in 2011. Fall rake plots were not read in 2012 or later, and will not be discussed in this section.

The spring mow plots were treated for three years, and showed increasing habitat gains of decreased non-native annual grasses, increased bare and decreased thatch. One year of treatment was skipped to observe how long it would take for these plots to revert to their previous state. After a quick decline, mowing was reinstated after one year to determine how quickly an area could achieve its previous habitat quality gains with retreatment. Baseline data are shown in 2008, 2009-2011 show mowing results, 2012 shows the resting result, and 2013 shows the reinstatement result.

Tree removal plots were partially treated in 2010 and 2011. 2012 shows the first year all plots were treated.

Data are presented roughly in order of importance, starting with treatment effects on annual forbs and non-native grasses.

Annual Forbs

Nearly all annual forbs in the Serpentine Prairie plots are native. Of the average 15.5% annual forb cover (averaged across all plots), 90.3% of this cover is represented by native annual forbs. Annual forbs are perhaps the most critical component of the prairie because 1) clarkia is an annual forb, 2) annual forbs are the native component most quickly lost to competition with nonnative annual grass, and 3) annual forbs are often showy wildflowers enjoyed by the public. After only one year of mowing (2009), a fourfold increase in annual forbs was observed and was retained for 2 years. After only one year of removing mowing, annual forb cover was reduced by 50% from the previous year, but remained above the baseline (Figure 4). After reinitiating mowing, annual forb cover rebounded from 10.8% in 2012 to 17.6% in 2013. Annual forbs respond favorably and quickly to mowing.

For the second successive year, the tree removal plots showed a significant increase in annual forb cover over the baseline year. This increase is attributed to all the tree removal work finally being finished, allowing for the forbs to colonize newly uncovered habitat. Additionally it is notable that Clarkia continues to establish and reproduce in areas once heavily dominated by mature pines. Forb cover in tree removal plots is now as high as reference plots, which is especially impressive when one notes how few forbs were noted in the baseline.

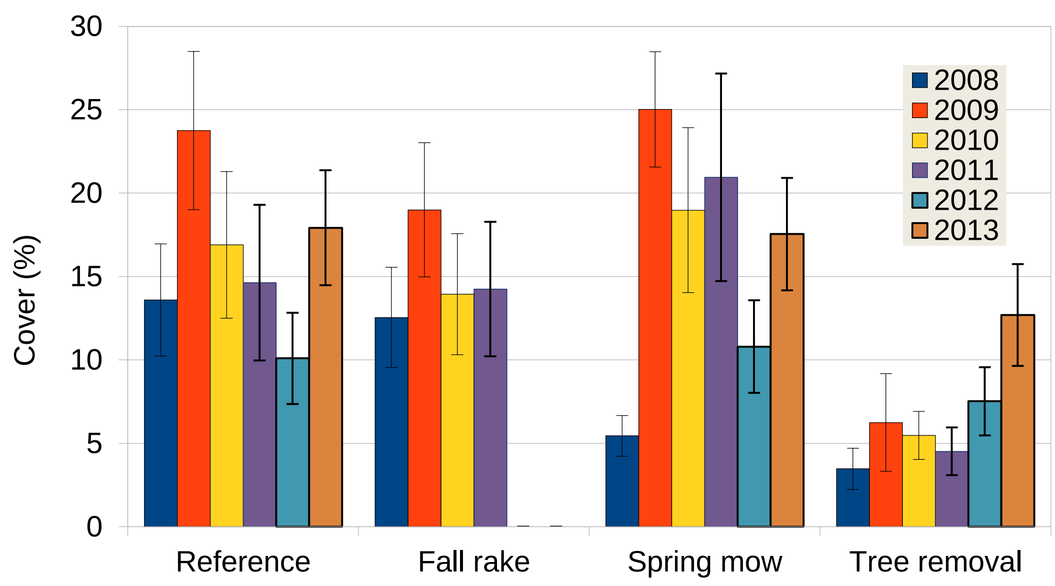


Figure 4: Percent cover annual forbs

Non-native Annual Grasses

Nonnative annual grass competes aggressively against clarkia and other native forbs. It is the key guild Creekside is trying to reduce on the prairie. Spring mow plots exhibited a decrease in annual grass cover from baseline conditions through 2011 (Figure 5). One year after mowing ceased (2012), the annual grass cover in the spring mow rebounded to near baseline conditions. In 2013, after one mow, non-native annual grass cover was reduced back to 2011 levels. Reaching this level of annual grass control initially required two successive years of mowing, but after one rest year, those results can be reached in a single treatment.

It is important to remember that many spring mow plots were placed in areas with deeper soils and dense non-native grasses, whereas reference plots were strategically located in high quality (occupied) clarkia habitat. The fact that the mow treatment plots rival the reference plots is a notable success. It is disconcerting that the non-native grasses seem to recover very quickly once mowing is removed.

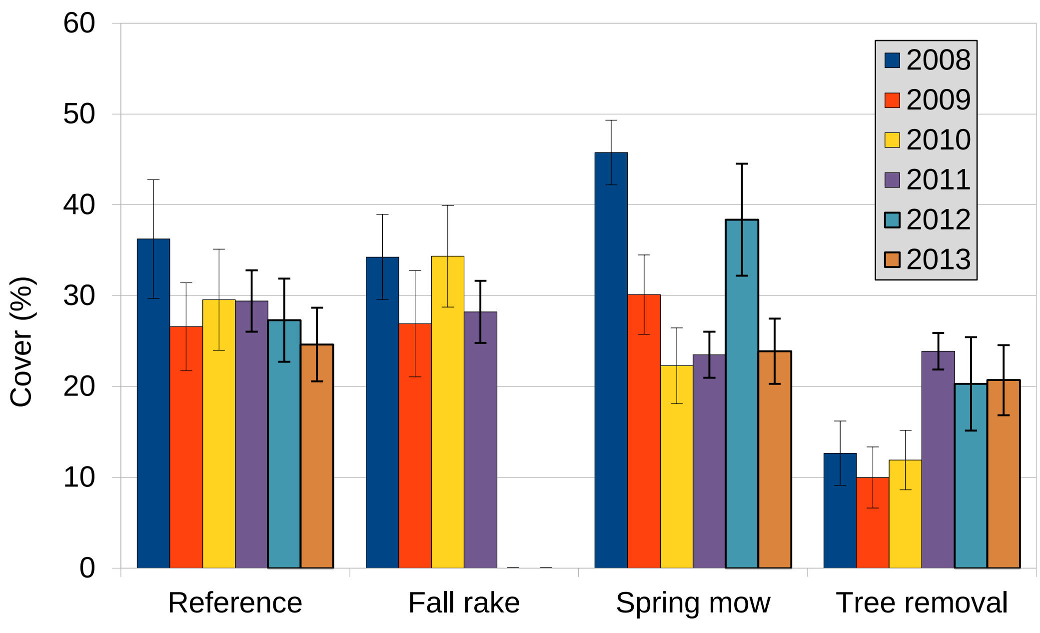


Figure 5: Percent cover non-native annual grasses

Tree removal plots contain about double the cover of non-native annual grasses as compared to pre-treatment, but these numbers have stabilized over the past three years. They are also well within acceptable reference levels.

The effect of rain on annual grass cover was less pronounced than anticipated. Whether a dry or wet year, annual grasses continued to occupy about a third of absolute cover in the reference plots.

Bare Ground and Thatch

Bare ground is desirable because clarkia and many annual native forbs benefit from ground free of litter and thatch (Carlsen, 2000). Bare ground has increased in the tree removal and spring mow plots since baseline data were collected in 2008 (Figure 6), although the spring mow trend isn't as pronounced since the rest year.

After skipping one year of mowing (resting), bare ground declined from 42.8% to 32.8%, indicating rapid reversal of the mow effect. After reinitiating the spring mow treatment after one year, bare did not respond as expected. It continued to decrease, although it still remains well above baseline conditions.

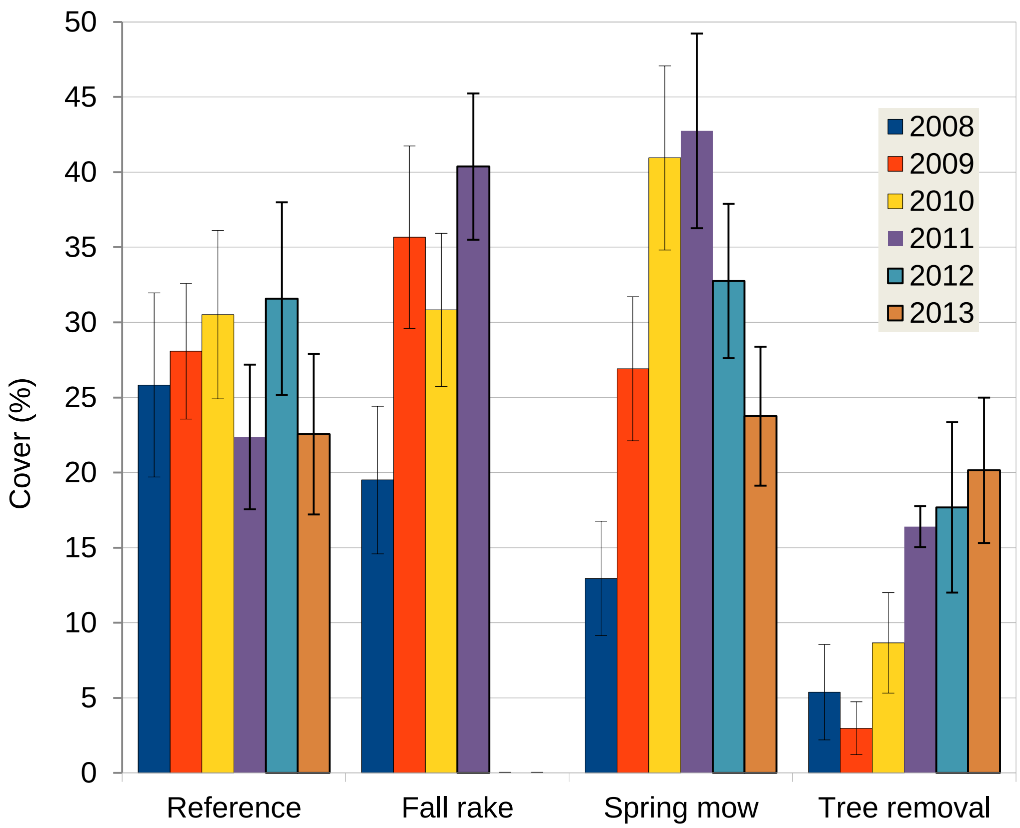


Figure 6: Percent bare ground

Thatch, for our experimental purposes, describes all the organic material on the ground that is at least one year old. Thatch decreased in tree removal plots, after the first year of treatment, and has since remained steady near reference levels.

Thatch in spring mow plots decreased in the first three years of treatment, then increased with when treatment was suspended. Renewal of treatment showed a continued increase to pre-treatment levels, but still in line with reference plots, which have also increased over time (Figure 7). We believe two effects are responsible for this: 1) since total vegetation is less dense in drier years, even very thin layers of thatch become more apparent to the eye and 2) thatch is breaking down more slowly in dry years.

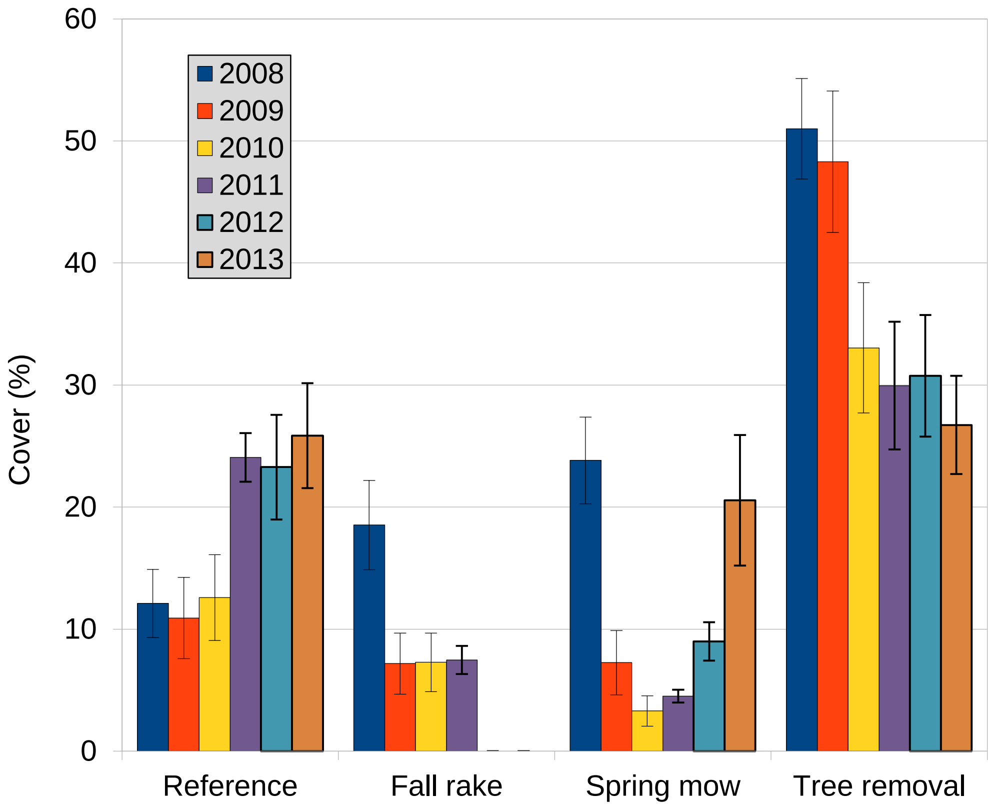


Figure 7: Percent cover thatch

Native Perennial Grasses

Native perennial grasses constitute anywhere from 2 to 5 percent cover in most of the treatment plots, except the tree removal. Tree removal plots have well-established understories of native perennial grasses that are dominated by different taxa than what is observed in the open grasslands of the serpentine prairie.

We observed a large decrease in native perennial grass cover in tree removal plots from 2010 through 2013, although this decrease is not notably different from baseline conditions (Figure 8). We do expect that some perennial native grasses that prefer shadier habitat (*Agrostis pallens, Festuca idahoensis and F. rubens*) will decrease in cover in the tree removal plots. While some tree removal had taken place by 2010, the data show a subsequent decline in native perennials with further tree removal (Figure 8).

In 2013, we also observed an unprecedented increase in of native perennial grasses in the spring mow plots from 3.5% to 10.3% cover.

No non-native perennial grasses are found in the experimental plots.

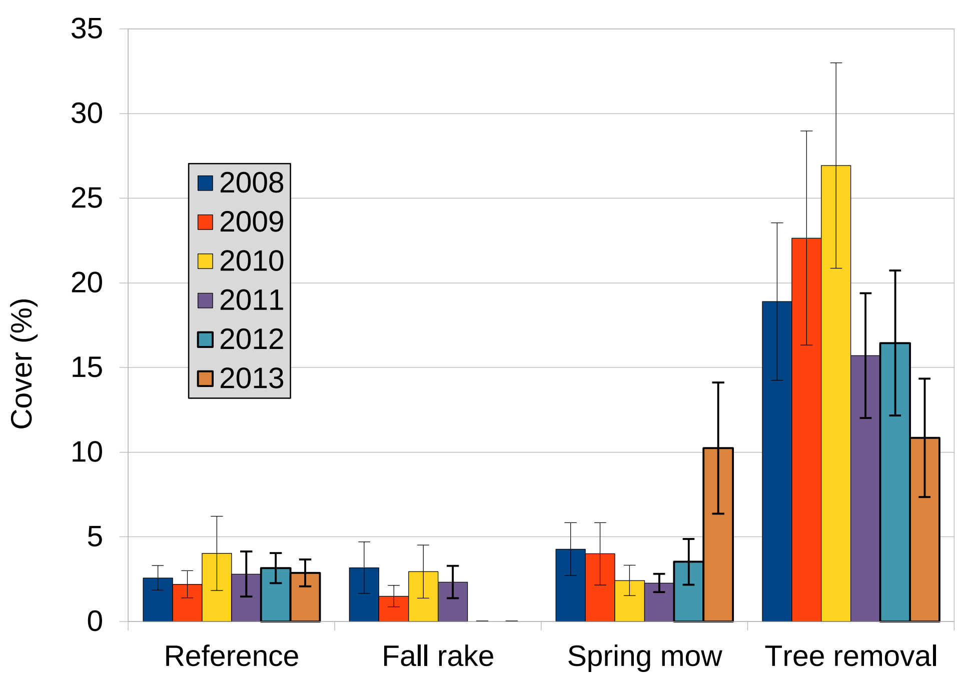


Figure 8: Percent cover native perennial grass

Perennial Forbs

No appreciable effect on perennial forb cover was observed from 2008 to 2013 in reference or treatment plots (Figure 9). The majority of the perennial forbs observed are native. All non-native perennial cover that occurs in plots is *Rumex acetosella,* which in 2013 accounted for 0.6% of the total cover in all plots. We do not anticipate this guild to be affected by our experimental treatments.

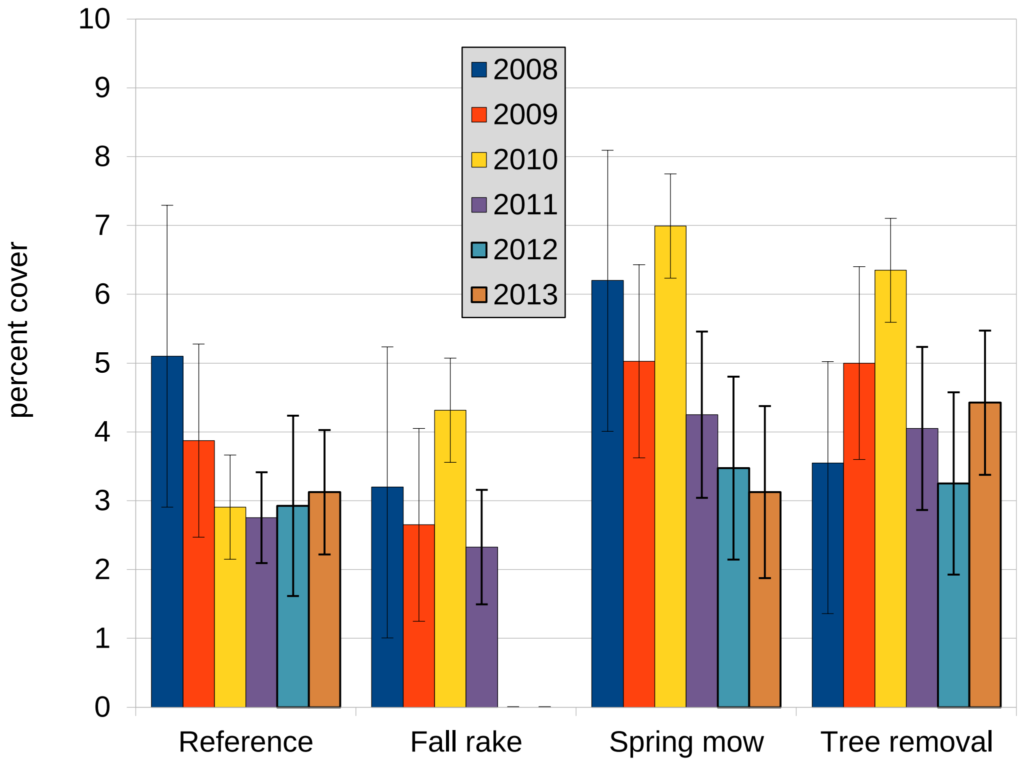


Figure 9: Percent cover perennial forbs

Native and Non-native Plants

Perennial grasses are a small component of the prairie and perennial forbs cover is relatively stable; therefore change in native cover is largely driven by native annual forbs. Spring mowing was the only treatment to increase native cover and decrease non-native plant cover after one year of treatment. Gains continued to be made with multiple years of treatment, over a range of climatic conditions. With the cessation of mowing in year 3, native cover dipped to 2008 baseline levels, mostly due to the rebound effect of non-native annual grasses displacing native annual forbs. **This shows clearly that well-timed spring mowing reduces nonnative annual grass cover, allowing native forbs to increase.** This result also indicates that native plant cover declines quickly with a one year break in mowing, but can rebound in a year of reinstating treatment.

Tree removal increased native cover in years 2009 and 2010 only, then returned to baseline levels. In 2011, non-native cover in tree removal plots doubled. 2012 was the first year all the tree removal plots were free from a pine overstory, and non-native cover remained elevated over baseline conditions. 2013 readings are almost identical to 2012. It is promising that the percent cover of non-natives stabilized from 2011 to 2013, indicating that natives have established and competed with non-native plants. Tree removal plots are showing some loss in native perennial grasses countered by gains in native annual forbs, including clarkia. We are seeing the tree removal plots become quite similar to the high quality reference plots, as desired.

Native and nonnative cover in the reference plots was largely stable over the course of this experiment. It is interesting to note the decrease in native cover in 2012 (driven by decreased annual forbs) was mirrored in the spring mow plots. While the spring mow plots showed a related increase in nonnative cover (annual grass), the reference plots did not (Figures 10 and 11).

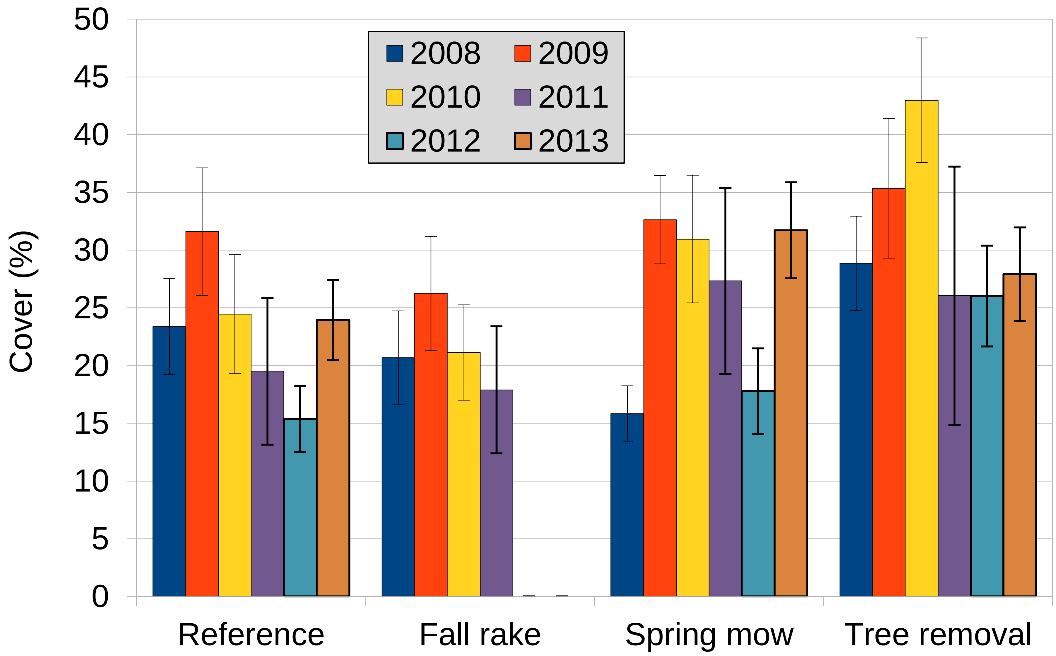


Figure 3: Percent cover native plants

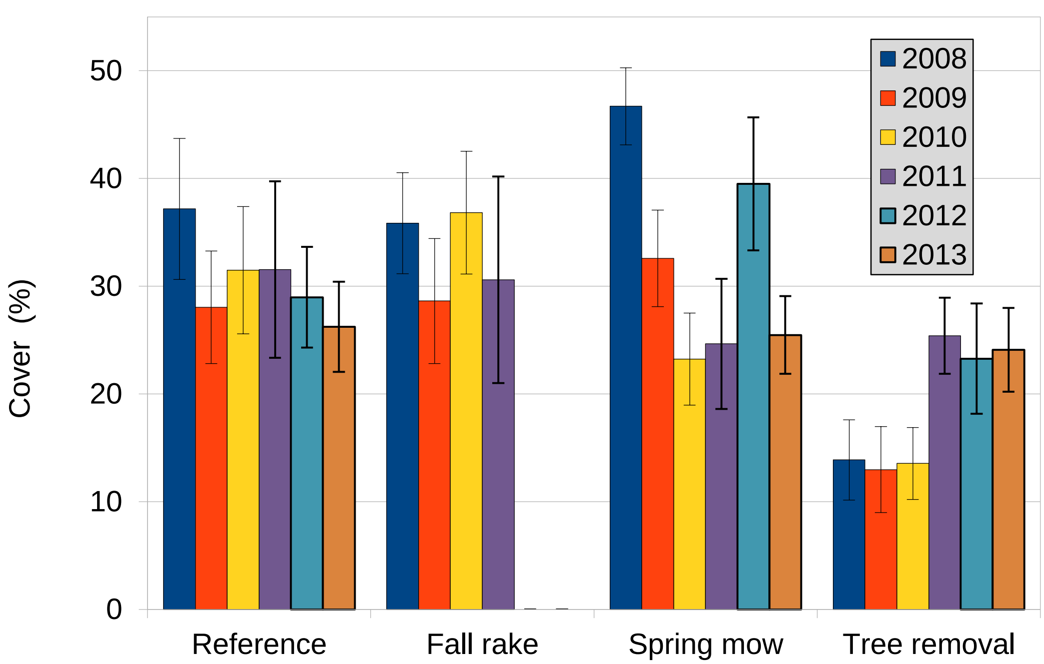


Figure 11: Percent cover of non-native plants

Native Richness measures the diversity of native plants. We have included native richness as an additional analysis in order to demonstrate that the experimental sites have retained a diverse community of native plants on par with the reference plots (Figure 12).

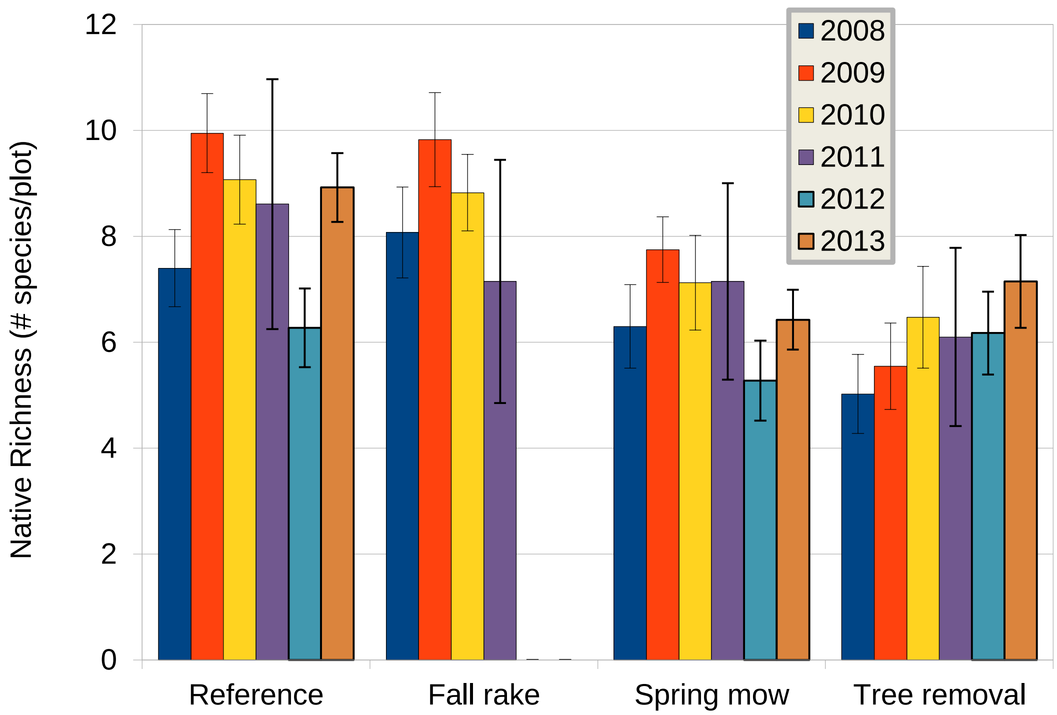


Figure 12: Native Richness

Experimental Plot Summary Table

Table 3 presents a summary of current treatment results. This easily allows for side-to-side comparison of the effects of the treatments on the experimental plots.

In this report, the reference treatment is always neutral, as it reflects the high quality clarkia-occupied habitat we are seeking to replicate through management.

The fall rake treatment was discontinued in 2011 after it caused declines in clarkia. Its impacts are summarized here compared with the 2008 baseline.

The spring mow 2011 column reports the effectiveness of three years of successive mowing compared with the baseline. Rest 2012 reports how one rest year impacted the 3 years of successive mowing, comparing 2012 to 2011 data. Spring mow 2013 reports the change from 2012 data.

The tree removal column shows the effect of tree removal in 2013 compared with the 2008 baseline.

Many benefits of three years of spring mowing were reversed with a one year rest, but many of those lost benefits were recovered with the mowing reinitiation. This system responds quickly and favorably to a single spring mowing treatment.

Table 3. Effect of Experimental Treatments

	Improvement (+) Degradation (-) Neutral/Marginal Change (0)					
Species or guild	**Refer-ence**	**Fall rake (discon-tinued in 2011)**	**Spring mow 2011**	**Rest 2012**	**Spring mow 2013**	**Tree removal**
Clarkia individuals	0	-	+	-	+	+
Annual forbs cover	0	0	+	-	+	+
Non-native annual grass cover	0	0	+	-	+	-
Bare cover	0	+	+	-	-	+
Thatch cover	0	+	+	-	-	+
Native perennial grass cover	0	0	0	0	+	-
Native perennial forbs cover	0	0	0	0	0	0
Native cover	0	0	+	-	+	0
Non-native cover	0	0	+	-	+	-
Total positive effects (+)	**0**	**2**	**7**	**0**	**6**	**4**
Total neutral effects (0)	**9**	**6**	**2**	**2**	**1**	**2**
Total negative effects (-)	**0**	**1**	**0**	**7**	**2**	**3**

Exclosure Comparisons

The current experimental design does not adequately address the question of how the exclosure is affecting the prairie. In the absence of active management such as mowing (or trampling), we expect some areas within the fence may become heavily grassed over and no longer support high numbers of clarkia.

The experimental design was originally set up to test three treatments (fall rake, spring mow, and tree removal) against a set of reference plots. In addition, half the plots for each treatment were placed inside an exclosure installed to reduce disturbance (mostly human and dog trampling) on the Hunt Field and the adjacent clarkia-occupied slope.

Results have been mixed (Figure 13). We believe the experimental plots do not adequately address the question of the exclosure's effect. Reference plots were subjectively picked in areas with dense clarkia populations. These areas had thin, rocky soils, and were not expected to be easily invaded by annual grass. Based on edaphic conditions, they were expected to be relatively stable. A fence is unlikely to affect these plots.

The spring mow plots are being actively managed through mowing, so the effects of an exclosure are muted here. The same is true of the tree removal plots.

There are no plots in the Hunt Field, or in the adjacent thick-soiled, grassy swales. These areas should be included in the question of how the exclosure affects the prairie.

We recommend supplemental plots that are more fully capture the heterogeneity of the prairie be installed to fully investigate the effect of the exclosure.

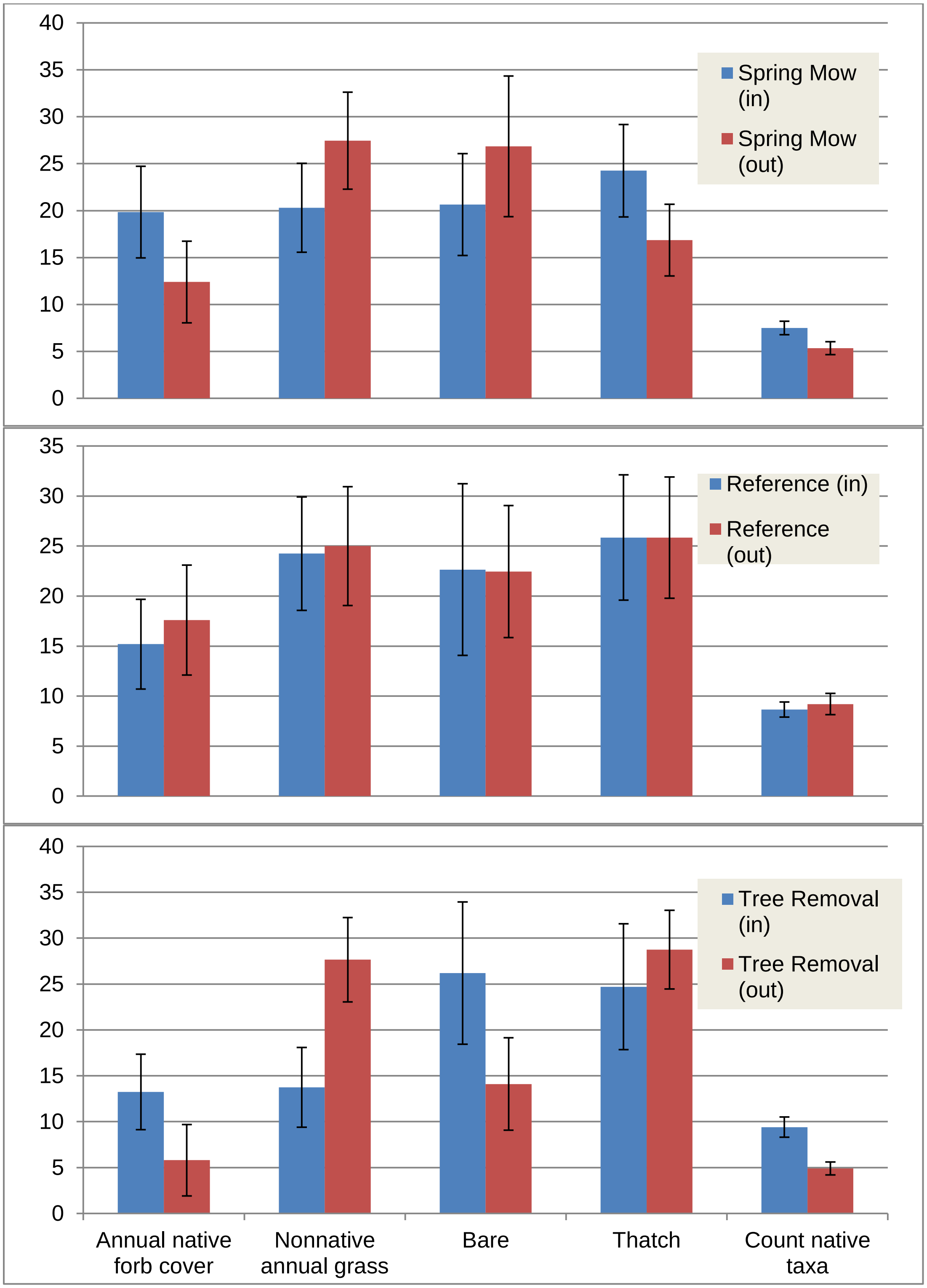


Figure 13: Exclosure effects on spring mow, reference and tree removal plots

Seed Dispersal and Survivorship

Annual forbs are often limited by dispersal (Seabloom et al. 2003). Seed survivorship among the three dispersal methods varies widely. Given our current results, we cannot reliably recommend the best method for dispersal, although trends are beginning to indicate that targeted seeding and pre-scraping treatments provide the highest percentage of surviving plants.

Seeding dispersal overall is considered successful, with survivorship varying from 0 to 82.5%. Survivorship rates using a similar method in the Presidio are around 20% (Stringer, personal communication). Our results varied based on which of the three techniques we used:

A. large scale (~ 1 acre) broadcast seeding with no soil disturbance,
B. targeted seeding of small localized patches (~300 m^2) of bare soil from animal disturbance, and
C. seeding of a hand-scraped area (~150 m^2) removing all thatch and organic matter.

Table 5: Seed Dispersal Results for 2010 - 2013

Technique	Site	Year seeded	# Seeds sown	% Clarkia survivorship 2011	% Clarkia survivorship 2012	% Clarkia survivorship 2013
B	Keyhole 2010	2010	200	13	0	0
B	Hunt 2010	2010	200	21.5	9	9.5
B	T7-T8 2010	2010	200	39	33.5	**82.5**
A	Keyhole 2011	2011	2100	-	<0.01	<0.01
A	Pine Removal 2011	2011	2900	-	<0.01	<0.01
A	Greater Hunt 2012	2012	7000	-	-	<0.01
C	PO 2012	2012	1000	-	-	14.9

B	T8 2013	2013	1000	-	-	-
B	S1 2013	2013	250	-	-	-
B	S2 2013	2013	1000	-	-	-
B	C8 2013	2013	250	-	-	-

Large scale broadcast seeding (Technique A) was used at 3 sites. Each of the three locations had slightly different soil and plant composition – two are located on the former Hunt Field and they have little soil development and lots of bare ground, in contrast, the Pine Removal site is characterized by thicker soils on a slight northeastern-facing slope where pine duff and organic matter has accumulated on the ground. In total, each of these sites has less than 1% of clarkia surviving. The 2011 Keyhole site likely failed due to thin soils. The 2011 Pine Removal site likely still contains too much pine litter and competition for clarkia. Seed survival at the 2012 Greater Hunt site is likely limited by soil depth. We do not recommend continuing this technique.

Targeted seeding of small localized patches (Technique B) was used at seven sites, four of which were sown in 2013. After three years, survivorship in these patches varies from 0% (on a thin soil site) to 82.5% on a north facing slope where tree removal occurred. We recommend highly targeted seeding of clarkia in strategic areas where soils are disturbed, thatch is low, and the soil has a visible A layer.

Seeding of a hand scraped area (Technique C) was used at PO 2012. The site was formerly dominated by thick annual grass. We removed 1-3 inches of thatch and organic in order to reduce the competition and non-native seed bank. Our results show this technique may be promising for getting clarkia established in non-native grass dominated areas. We will follow year 2 closely in 2014. We recommend scaling this treatment up.

We recommend a simple soil depth measurement wherein we can systematically measure soil depth on a number of locations in the prairie. GIS interpolation could then provide a soil depth map of the prairie, which could guide seeding and restoration locations within the prairie. A sample map provided for the Presidio is shown in Figure 14.

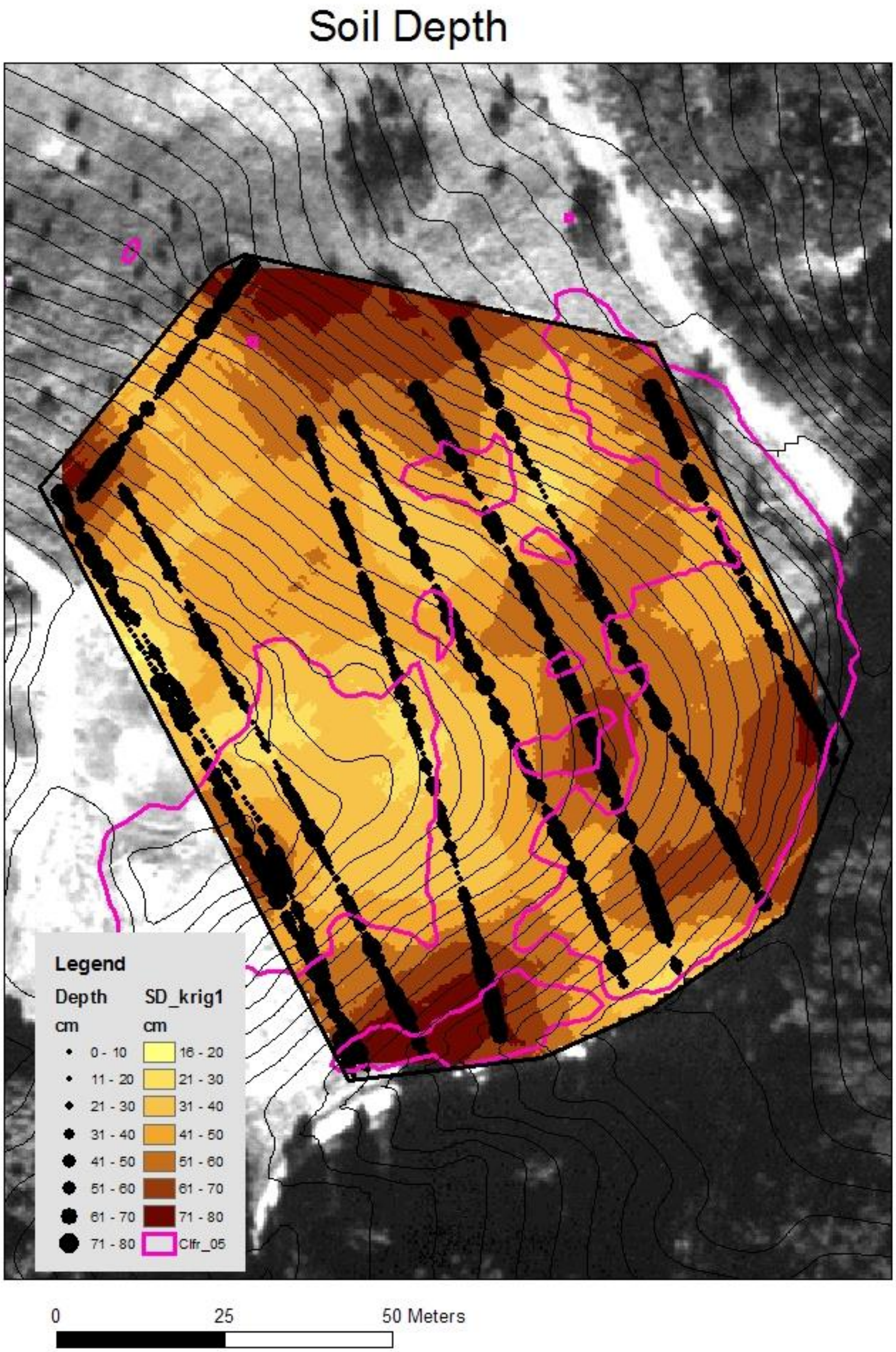


Figure 14: Soil depth map completed for the Presidio. Depths of 2-4" are prioritized.

Conclusions

The Serpentine Prairie restoration project is well underway, with several results that will guide effective management in the future.

1. Tree removal has shown to be the most effective technique for creating more clarkia habitat. The seedbank in the tree removal areas has responded favorably, increasing clarkia numbers without the need for active seed dispersal or planting. We have noted the disturbance from tree and duff removal produces bare ground, which is amenable to substantial passive clarkia recruitment in the first year. Following that first year of disturbance, the tree removal experimental plots became colonized with non-native annual grass. Initial duff reduction and ongoing non-native annual grass management will be critical to expand and maintain habitat in tree removal plots, as well throughout the entire prairie. Although non-native grass cover is a concern, tree removal plots still contain the lowest cover of this guild.

2. Restoring and maintaining occupied clarkia habitat will require regular stewardship input. Serpentine grasslands respond favorably and quickly to mowing by increasing bare ground and native annual forbs, and decreasing non-native grass. The quality of this newly restored habitat will relapse to pre-treatment levels if mowing is stopped (Figure 15). We initially thought three years of successive mowing would exhaust the non-native annual grass seedbank. Instead we found that non-native grasses in these plots rebounded to pretreatment levels after only one year of rest. These observations indicate that annual mowing will be required to maintain habitat quality until the *Festuca perennis* and *Hordeum murinum* seedbanks are exhausted. Even then occasionally mowing is likely to be needed as these common grasses colonize from adjacent areas.

   Annual spring mowing is critical in managing the prairie, preventing annual grass and thatch from outcompeting native annual forbs. Spring mowing treatments should be expanded throughout the prairie, including targeted mowing in tree removal areas and areas that still contain native forbs.

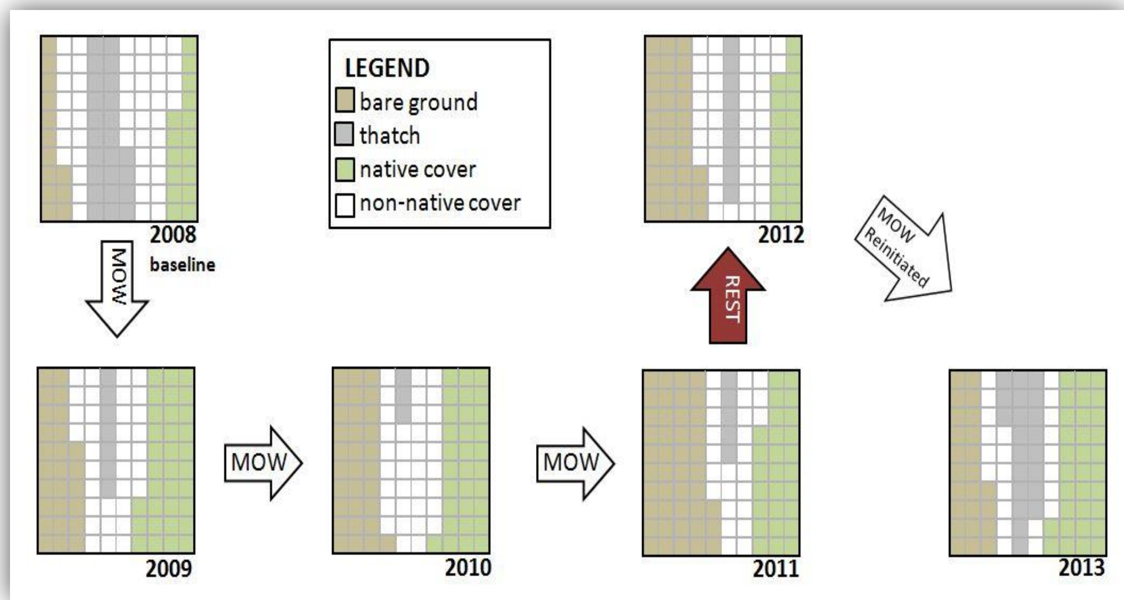


Figure 15: Percent cover of bare, thatch, and native plants in the spring mow plots from 2008 to 2013

3. The presence of clarkia in the spring mow plots, which were specifically chosen based on clarkia absence, indicates that spring mowing is compatible with clarkia management. Interestingly, in our one rest year, we surveyed the lowest number of individuals since the inception of this experiment. We expected to see a flush of clarkia in the rest year, but in fact, there was a decline with only 3 individuals found in all 8 plots. Direct competition from annual grasses appears to be reducing clarkia germination and/or survivorship. One year after reinitiating mowing we observed the highest number of clarkia individuals found in spring mow plots (41).

4. We believe spring mowing on a landscape scale is compatible with low density clarkia-occupied habitat. In 2011, upon inspecting our 5.5-acre mow area two months after treatment, we observed 20 clarkia individuals that were mowed inadvertently. All of these individuals were located within 2 feet of the mow perimeter. Two months later, more than 50% of the individuals developed lateral shoots that eventually developed both flowers and fruit, which is strong evidence of compensatory regrowth. Some of the smaller plants did not complete their annual cycle. It is common for some percentage of annual plants to not complete the reproductive cycle under

normal conditions. We believe there was a net positive impact on the clarkia, especially in light of the late spring precipitation.

Medium to high density clarkia-occupied areas (>20 plants m^2) should not be mowed to minimize take because the clarkia is already doing well in such areas.

5. Weather variability affects the local population size and distribution of clarkia, which can change dramatically on an annual basis. Areas that may be replete with clarkia in one year may have only a few individuals the following year. Clarkia counts correlate very well with total annual rainfall ($r^2 = 0.9$).

6. Survivorship from seed translocation on site is mixed. In wetter years, 10-20% of the seeded clarkia germinated on bare, thin soils. In dry years, north facing slopes with deeper soils had 25% germination. All the successful translocations occurred on bare soil which was either targeted for seed dispersal or hand-scraped. Large-scale broadcast seeding of clarkia on habitat similar to reference sites was not successful.

Year 6 Proposals

We recommend the completing the annual clarkia census in the reference, tree removal, and spring mow plots (Table 2). These provide an invaluable data set for future management.

Given the record dry water year (2013-2014) which is currently underway, we recommend re-instating the macroplot survey which provides a statistically robust measurement of clarkia in the macroplot (Table 1). In this record drought year, we may be able to document a record low at this site, which would be important for understanding natural variation in population. The GPS-mapped site distribution of clarkia illustrates how the population changes spatially over time, and should also be repeated (Appendix A).

The tree removal experimental treatments have been completed, and we shift focus from creating new clarkia habitat to managing it. EBRPD removed a few more stands of invasive trees as recently as September 2013, and we believe these areas would benefit from management. We believe these newly treated areas serve as high quality potential habitat for clarkia. Removal of any remnant duff and creation of bare ground generally creates a flush of clarkia plants the following spring. Three to four years of follow-up monitoring for tree recolonization, new invasives and clarkia are recommended.

Our data clearly show the benefit of biologically-timed mowing. For this reason we don't recommend spending any more resources on studying its effects on vegetation. We highly recommend spending these resources on mowing in areas which will benefit from this technique. It is critical for any land manager to be responsive to ecological cues effective management. EBRPD and Creekside staff are critical in executing the spring mowing and ensuring that the progress made in 2011 thru 2013 is not lost.

We recommend targeting additional areas for mowing, especially in tree removal areas. This follow up may stabilize the increase in nonnative annual grasses while maintaining bare ground preferred by clarkia. These areas will be identified by Creekside in spring as grass growth accelerates. Because the site is subject to high nitrogen deposition, high grass growth years are inevitable.

Our highest survival of seeded clarkia was in a small hand-scraped area in Hunt Field. We believe scraping a site formerly dominated by thatch and non-native grasses allowed for high germination and survival of seeded clarkia. We recommend scaling up this method in appropriate areas. Survivorship may be linked with soil depth. We believe a sampling of soil depths throughout the site would provide value information and insights into where clarkia is distributed and translocation success. We recommend a simple soil depth measurement wherein we can systematically measure soil depth on a number of locations in the prairie. GIS interpolation could then provide a soil depth map of the prairie, which could guide seeding and restoration locations within the prairie.

Additional GIS analyses can help pinpoint appropriate areas for clarkia reintroduction and expansion. Fine scale DEM, topographic moisture index, and solar radiation provide cutting-edge information needed for efficient restoration.

Raking and removal of duff and pine litter in the newest mow area where plots T5-T8 exist would allow for a better comparison of tree removal plots. We also believe that this removal will allow for quicker emergence of the latent clarkia seed bank. This task may be suitable for a Civicorps crew, but removal should occur either before clarkia germination or after clarkia seed set.

We recommend implementing a monitoring program specifically designed to compare vegetation inside and outside the exclosure. This would highlight critical areas within the exclosure, such as the once heavily trampled Hunt Field, and the grassy deep-soiled swale bottoms. Because these areas are not currently sampled, the effects of the fence are not being adequately tracked.

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Appendix A: Density Grid of Clarkia within the Macroplot (sample from T4-C4 plot area)