Serpentine Prairie Restoration Project: Redwood Regional Park

2012 Annual Report: Year 4

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 a located on land 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 the driest year since the study started; precipitation at the Prairie was about 75% of the annual average. Although our budget did not allow conducting the clarkia population macroplot estimate, we qualitatively observed declines in both population number and distribution. Many areas that were rich in clarkia in 2011 were nearly devoid of the plant in 2012. While most of the core areas remained occupied, the control plots that are censused annually were reduced to about 1/5 of last year's population numbers. While clarkia declined in most experimental plots with the dry year, the tree removal plots showed nearly double the 2011 numbers. The simple restoration procedure of removing trees and scraping away duff seems to allow for the latent seed bank of clarkia to germinate and flower.

Our experimentation with mowing as a stewardship tool presented surprising results. Many of the ecological benefits of three successive years of mowing were negated after only a single rest year. Both nonnative grass and thatch cover increased appreciably. After reviewing the preliminary results in spring, mowing was reinstated in the spring mow plots this year. We look forward to seeing if the mow effect might be recovered in one year.

Clarkia collection and dispersal trials continue with some success. Since this past year was poor for survivorship, many of the recolonization areas contained low clarkia populations, while other areas 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 our positive results up, eventually providing for cost-effective management at the prairie/landscape level. Another almost two (2) acres of Hunt field was mowed strategically to reduce non-native grasses, increase 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 indicate that after three successive years, habitat benefits of reduced annual grass, increased native forb, and increased bare ground cover are substantial.

We have updated the format of this document so that each section's discussion immediately follows results. We believe this new format will make it easier for readers to assess our conclusions.

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 strip of 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). All of these impacts have cumulatively greatly increased nutrient availability in a once nutrient-poor milieu.

In 2008, a prairie restoration plan 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 federally and state-listed endangered Presidio clarkia (*Clarkia franciscana*)[1] as well as the flourishing coastal prairie grassland ecosystem.

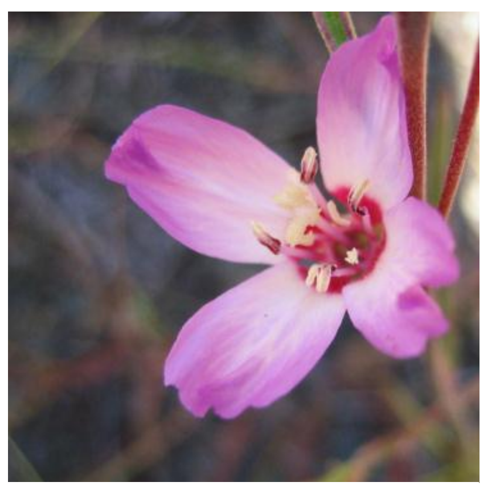


Plate 1: Clarkia franciscana

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.

One factor that influences germination, survivorship and flowering in Mediterranean-region annual plants is annual rainfall. Since clarkia flowers well in late spring, late season rains can be vital for this plant to reproduce successfully. We have been tracking overall rainfall and spring (April 1-June 30) rainfall as potential determinants of clarkia survivorship. This year's 20.8" rainfall marks the lowest annual total for the Serpentine Prairie area in six years (Figure 1), and is about 75% of the annual average of 27.6" (Westmap, 2012). Spring rains were slightly above average at 3.82" (3.1" is the average for the past 100 years).

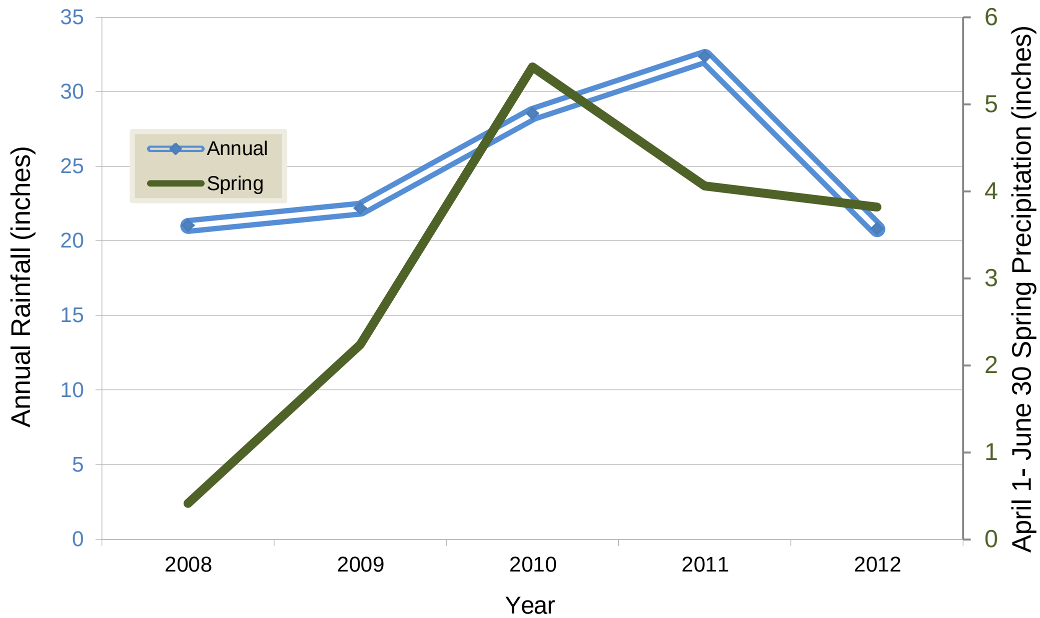


Figure 1: Annual and spring rainfall totals for the Serpentine Prairie

Methods

The experimental design requires 32 permanent plots measuring four treatments: fall rake, spring mow, tree removal, and control (Maps 1-3). Each permanent plot is 10x10 meters in size. 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.

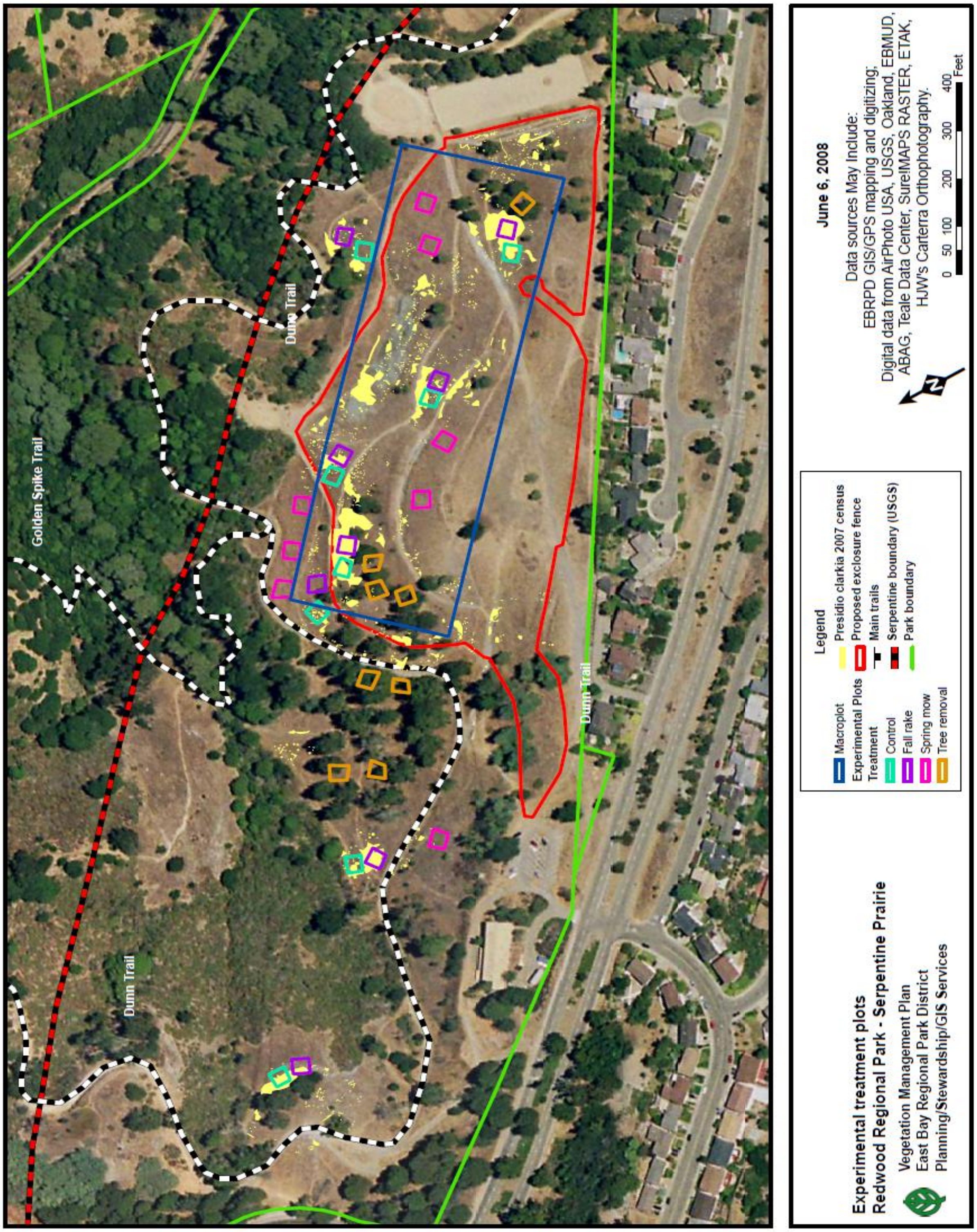
Fall Rake

Eight fall rake plots were located in areas where clarkia and thatch were present, with raking occurring only after seed set. We did not anticipate the population to be negatively impacted by raking the thatch from these plots. Raking was expected to reduce thatch, which has been shown to inhibit germination of forbs such as clarkia.

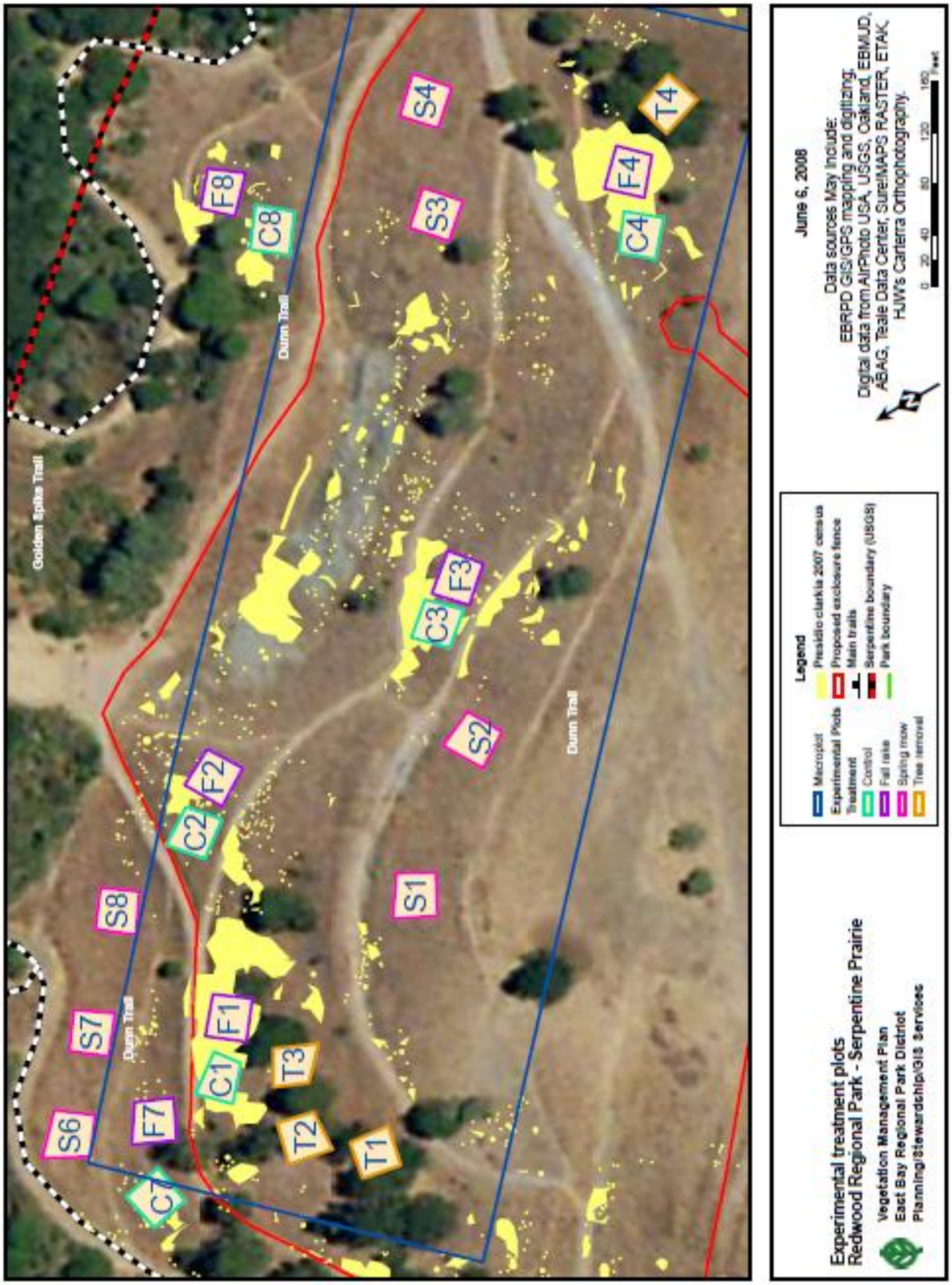
The fall rake treatment is scheduled to occur annually before the first rains but after the majority of the clarkia capsules have opened and dropped their seeds. Raking usually occurs in September or early October. Raking was completed with a metal rake until bare ground was visible (Plate 2).

Plate 2: Fall rake treatment, plot F8

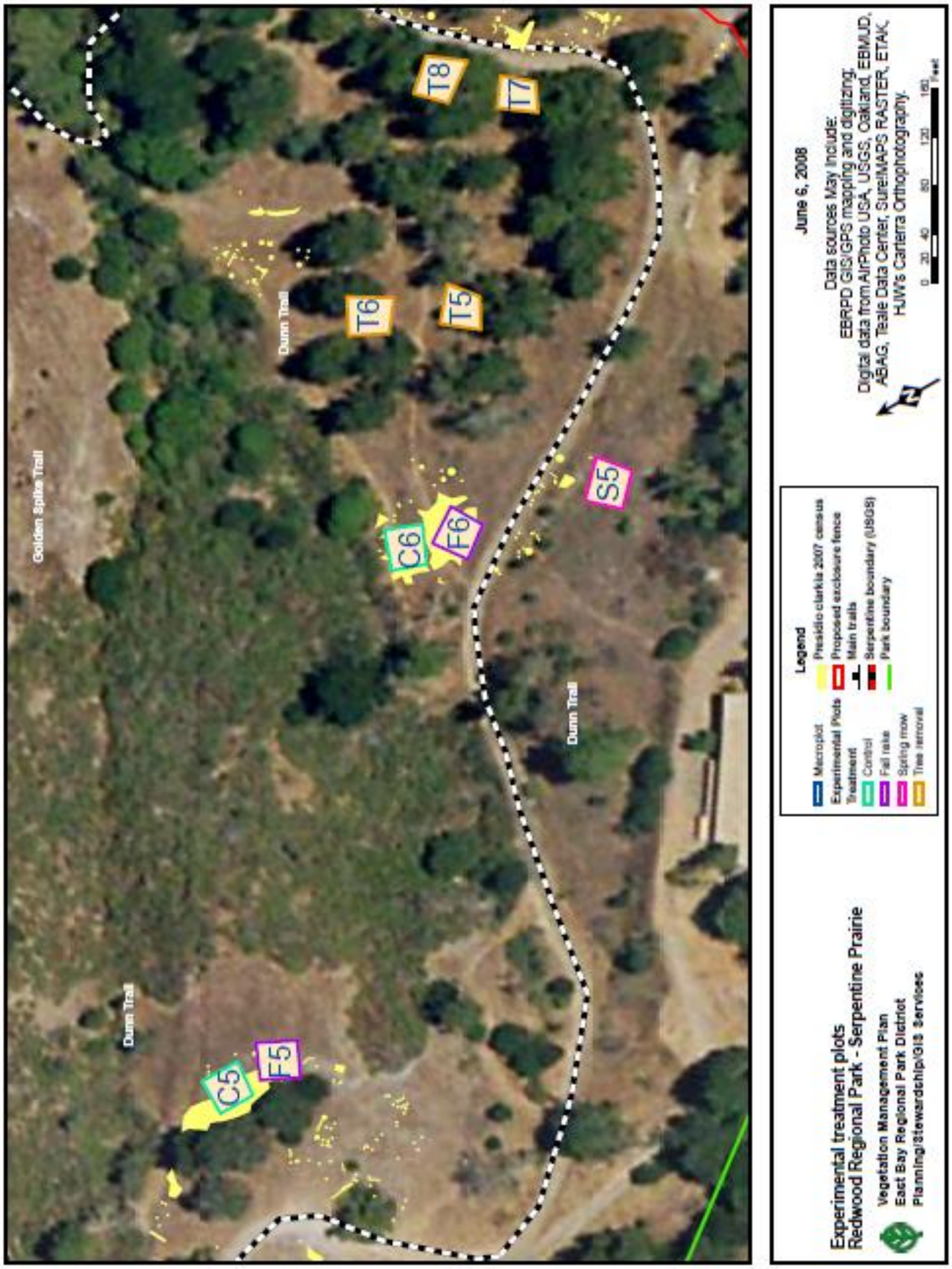
The fall rake treatment was discontinued in the fall of 2011 (no raking occurred in September 2011) because clarkia numbers decreased after the two years of this treatment (while the control had large increases). We explain more in the Results section.



Map 1: Plot locations



Map 2: Eastern plot locations



Map 3: 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 3). 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 quickly we can return the plots to their high quality state of April 2011.

Plate 3: Plot S2, spring mow plot in April, 2011. Treatment area located to left of the 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 4). 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, this marks the first year all plots show the effects of tree removal.

Plate 4: Tree removal progress at the Serpentine Prairie. Images from Google Earth.

Control

The eight control plots were placed in areas occupied by clarkia, to monitor the natural variation in the clarkia population. Controls help determine whether changes in experimentally treated plots are actually due to the treatment, or to weather or other variables.

Monitoring the Permanent Plots

Thirty-two (32) 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 3). The data from a group of treatments is averaged to provide an estimate of cover for that treatment type.

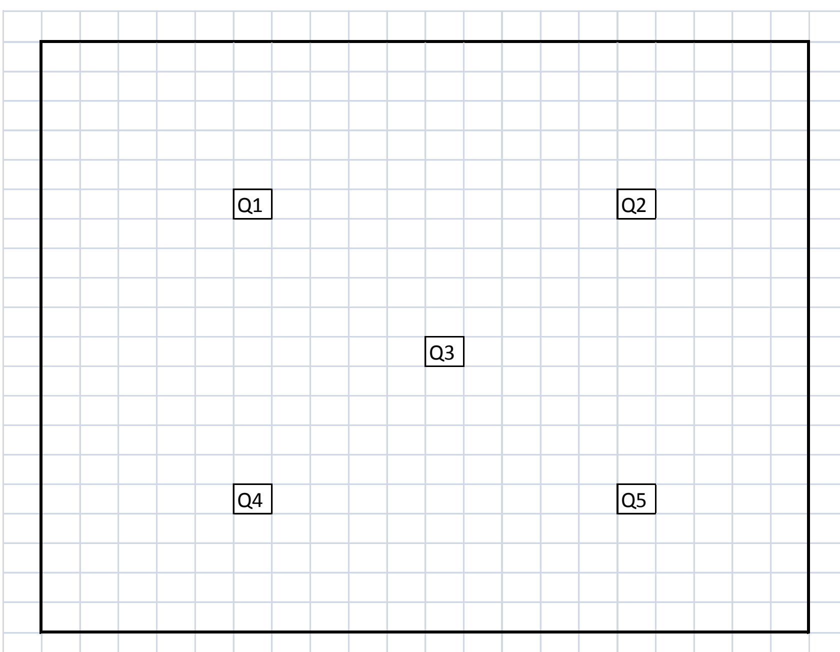


Figure 2: Location of 0.5x0.5m quadrats in each treatment plot, plots were aligned facing uphill.

Plate 3: Data collection at one of the 32 permanent plots

Adaptive Management Techniques

Fenced Enclosure

A fence circumscribing a significant portion of the serpentine prairie was planned for completion in 2008, but was 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 third full year the enclosure plots can be separated from those not protected by a fence.

Additional Hunt Field Mowing – Civicorps Collaboration

In 2011, Civicorps was hired to mow a portion of Hunt Field (Plate 4). 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, 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 to be scheduled to complete the time sensitive work of mowing the Prairie, meanwhile Civicorps can be utilized in supplement if their schedule permits.

Creekside trained staff mowed nearly 2 acres in 2012 to try to convert the non-native grass dominated areas of Hunt Field into potential habitat for clarkia. Trained contractors can mow swaths of high density non-native grasses while minimizing impact to native perennials and desirable forbs.
All areas mowed in 2012 were also mowed in 2011. With limited resources, we feel it is important to continue to concentrate efforts in areas that have already been treated twice.

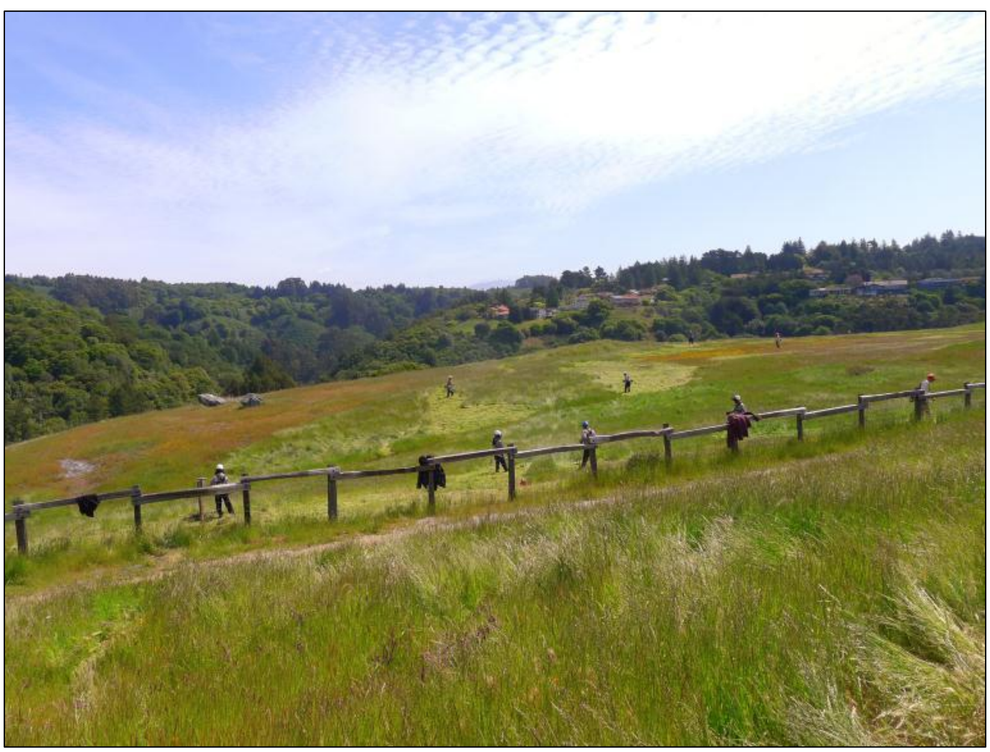
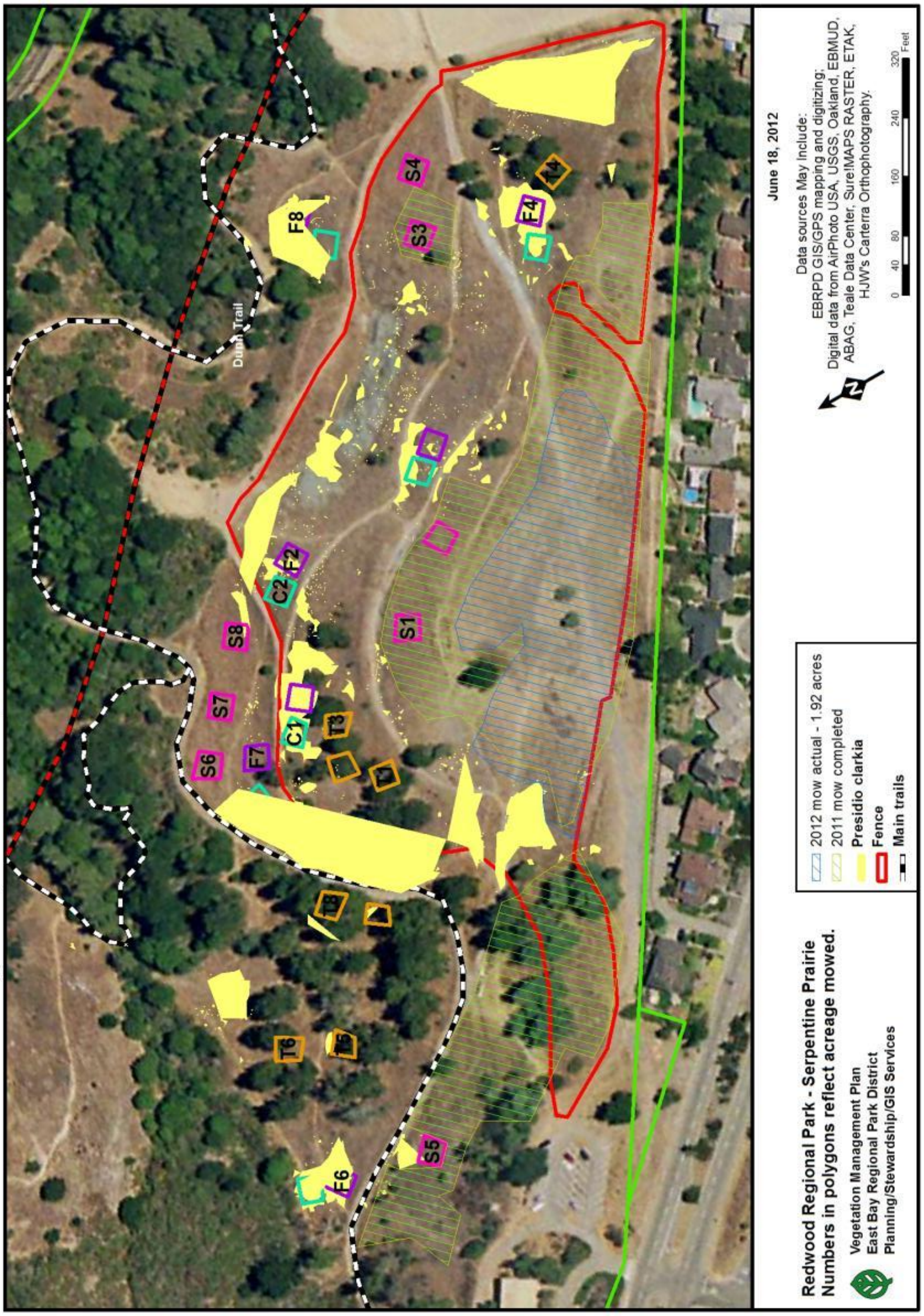


Plate 5: Civicorps mowing portions of Hunt Field, spring 2011.



Map 4: Mowing completed at Serpentine Prairie, spring 2011 and 2012

Seed Collection and Dispersal

In September 2010, November 2011, and November 2012 seeds from mature Presidio clarkia plants were collected in paper envelopes (Plate 5). No more than 5% of seeds from any given plant were collected to minimize impact to the existing population.

Plate 5: Seed collection on a south-facing slope, November 2011

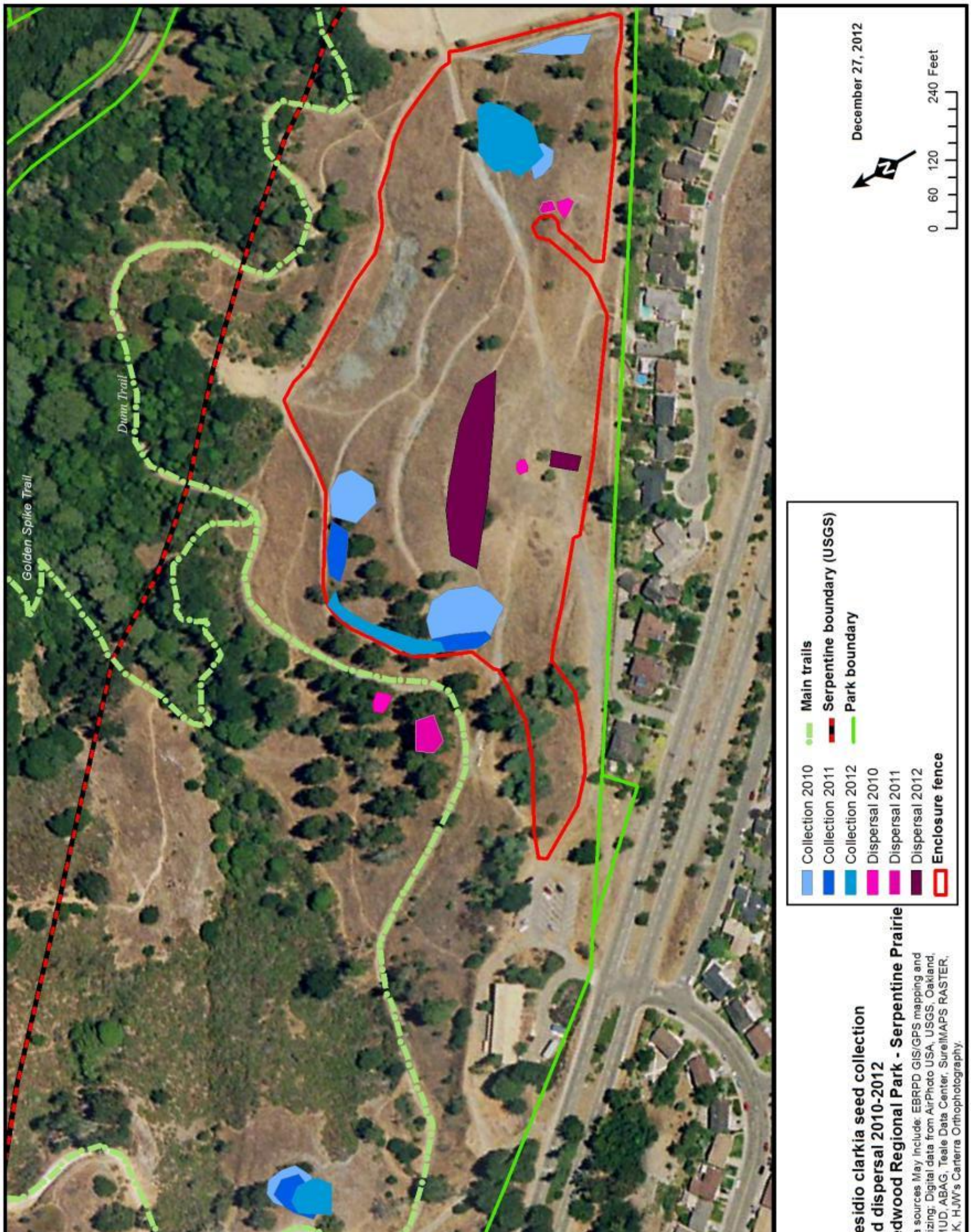
In 2012, we attempted a larger scale seed dispersal in Hunt Field. Approximately 7,000 seeds were scattered in high quality serpentine habitat (as determined by soil and vegetation) over an area of approximately 1.5 acres. This area has been named Greater Hunt 2012 for reference. Additionally, we transferred approximately 1,000 seeds to a second area in Hunt Field near an obvious poison oak thicket. We scraped away about 1 inch of organic material to provide bare ground for the seeds. This small area is on flat ground which is normally heavily dominated by non-native grasses. We call this experimental dispersal treatment area PO 2012.

In 2010, seeds were collected from five different sites throughout the Serpentine Prairie. In 2011 and 2012 seed collection was streamlined to three locations where we observed high clarkia densities that year.

Our collection and dispersal procedure was slightly different in 2011 and 2012 than in 2010. In 2010, seeds were stored in a cool dry place until late October, when they were seeded into three areas where clarkia was not previously surveyed: two areas in the former Hunt Field, where the slope was nearly 0 and bedrock was visible, and near the T7 and T8 plots where a portion of the existing dense pine stand was removed in 2010. For reference purposes, dispersal sites are named Keyhole 2010, Hunt 2010, and T7-T8 2010. All areas where seeds were introduced are free of overstory trees. Collected seeds were evenly divided between the three relocation sites (200 seeds per site), ensuring that seeds from each of the five collection areas were disseminated in each relocation area. Relocation areas where seeds were spread were limited to 4 meter diameter circles so that any new germinating plants could be easily found the following year.

In 2011 and 2012, collected seeds were immediately dispersed on site. Two new sites were selected for dispersal in both 2011 and 2012. In 2011, one site is near a previous dispersal site (Keyhole 2010) where soils are thin and bare ground is present (Map 5). This site was selected for both its interpretative value (close to a user trail that is slated to have a new interpretative sign) and also because we will be able to compare Year 3 and Year 4 seeding results on similar soils and aspects in Hunt Field. The second dispersal site selected was in the newly logged area, between plots T5 and T7 (Map 5). For reference purposes we have named the 2011 dispersal sites Keyhole 2011 and Pine Removal 2011.

Soil preparation was similar in all years, except as noted for site PO 2012. Soils were scarified with a hand tool, and then seeds were sprinkled onto the soil and lightly worked in.



Map 5: Location of clarkia seed collection and dispersal

Data Analysis

Data were entered into Microsoft Excel and then converted 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 several 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: 2008-2012

Tasks completed by Creekside Center for Earth Observation from 2008 to 2012 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, and May 2012 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.

- In 2010-2012, collection of clarkia seed on site by methods specified by CDFG and USFWS. Seed was redistributed on site each year in potential, unoccupied habitat.

- Helping to investigate the logistics and cost of a seasonal grazing program for the Serpentine Prairie.

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

- Delineating and surgically mowing 2 acres of potential clarkia habitat in 2012.

- Precision mowing of Hunt Field in May 2012, avoiding large stands of native grasses.

- Providing informal outreach and education to dozens of visitors during field work. Creekside staff educates the public about the goals of this EBRPD project with the public in language similar to that found on interpretive signs. Nearly all current 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 (Table 1). The Presidio Trust, which monitors a population of *Clarkia franciscana* in their own macroplot, also reported a decline in clarkia from the previous year (Figure 3 – 2012 data not yet reported). Based on low total precipitation, decreasing clarkia in control plots, and qualitative assessment of clarkia declines in clarkia numbers and distribution throughout the prairie, we expect numbers in the macroplot would have declined this year.

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

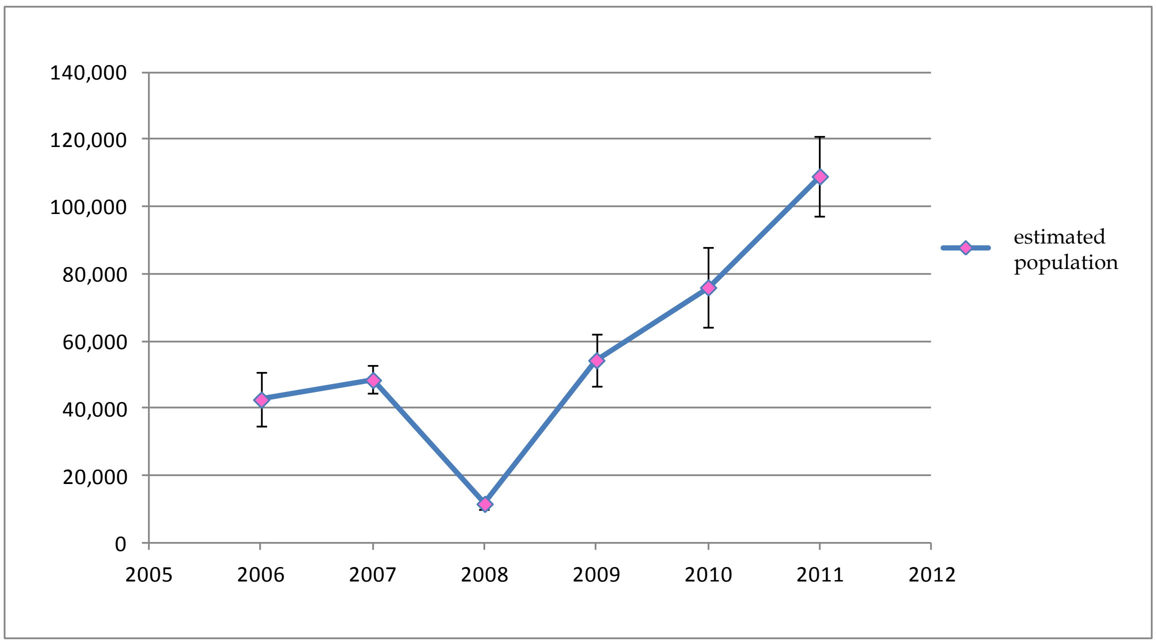


Figure 3: Results of clarkia macroplot sampling at Inspiration Point, San Francisco. Data from L. Stringer, The Presidio Trust.

Clarkia Census

Clarkia individuals are annually censused in each of the 32 experimental plots (Table 2). In 2012, clarkia individuals decreased in the control, fall rake and spring mow plots. We continue to be encouraged and surprised by the immediate response of clarkia in the seed bank to tree removal. Tree removal plots showed an increase in number of clarkia, corresponding to the removal of trees above plots T5 thru T8. This flush of clarkia in tree removal plots, while control plots decreased sharply, indicates that habitat management may even trump the effect of precipitation availability.

Table 2: Total clarkia individuals per treatment

	2008	2009	2010	2011	2012
Control	1,229	3,030	5,728	11,130	2,268
Fall rake	1,238	3,254	935	2,317	1,200[2]
Spring mow[3]	0	24	2	41	3
Tree removal	15	184	810	621	1183

Although total precipitation in 2012 was below normal, we anticipated that the above-average spring rains would still allow for vigorous clarkia growth. Conversely, we found that clarkia decreased to 20.4%of last year's numbers in control plots. Although we still believe that spring rains are an important factor for determining clarkia survivorship, we believe that total precipitation must meet a certain threshold of total rainfall as well as frequency in order for the small seedlings to survive the winter months. Over the course of our experiment, total annual rainfall correlates best with clarkia population (Figure 4).

Fall rake plots declined to about half of last year's levels, even with cessation of raking. The latest count puts them at baseline level. Spring mow numbers remained low and at such levels cannot adequately reflect clarkia's response to treatment.

[2] Denotes an estimate based on census of 4 plots and multiplying by 2.

[3] Spring mow plots were deliberately chosen in areas where clarkia was not present (in 2008 survey) in order to minimize and avoid take.

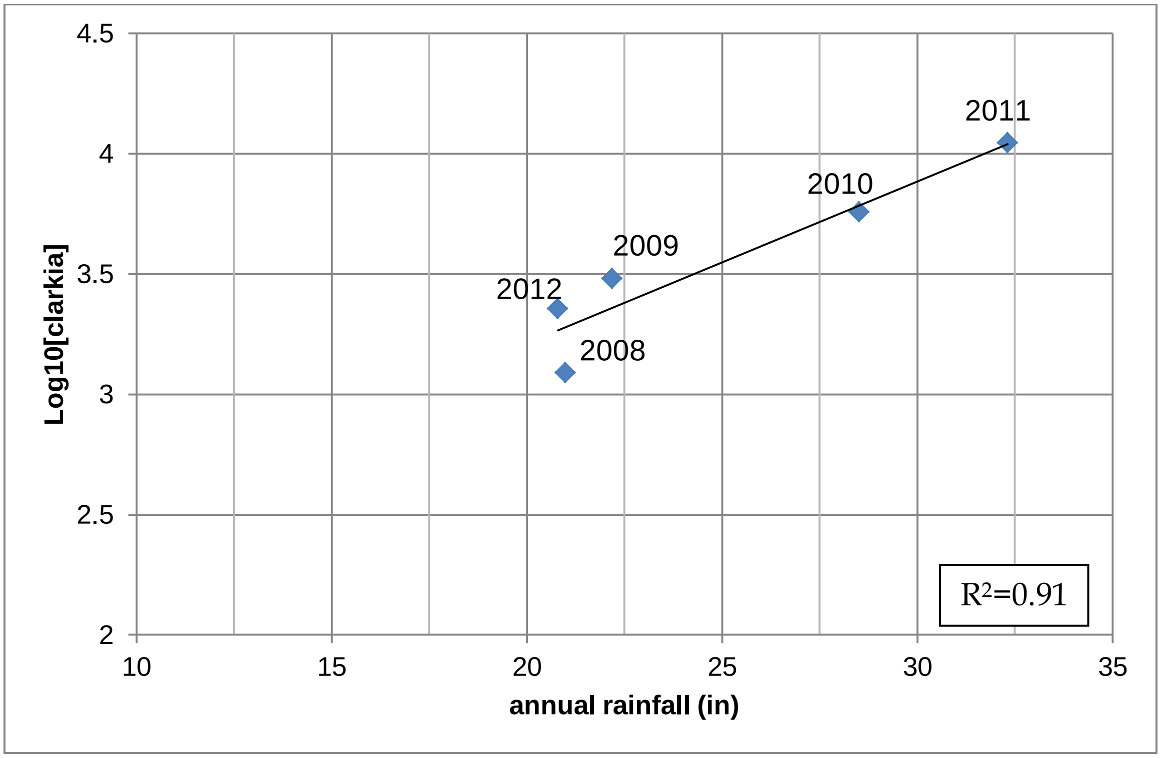


Figure 4: Regression analysis of log transformed clarkia population in control plots and total annual precipitation

Experimental Plot Data

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, and will not be discussed in this section. The spring mow plots show one year of skipped treatment. The spring mow treatments were discontinued to observe how long it would take for these plots to begin to lose the habitat gains from three years of treatment: decreased non-native annual grasses, increased bare and decreased thatch over time.

Bare Ground and Thatch

Bare ground has increased in all three experimental treatments since background data were collected in 2008 (Figure 5). Bare ground is desirable because clarkia and many annual native forbs require ground free of litter and thatch in order to germinate and grow. The spring mow treatment increased absolute bare ground by 30 percent by year 3 (2011), after three consecutive years of mowing (Figure 5).

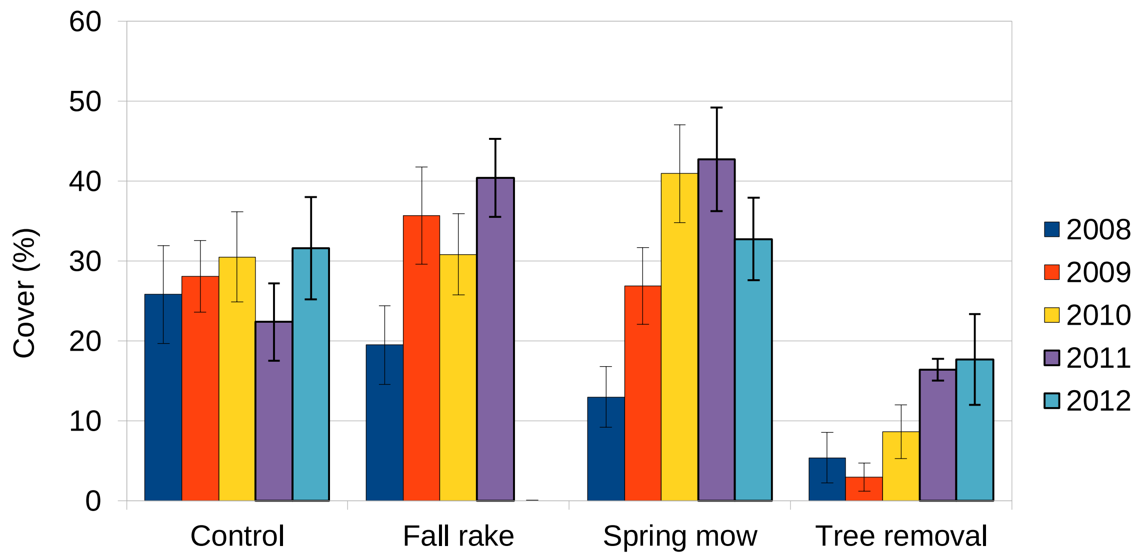


Figure 5: Percent bare ground

After skipping one year of mowing, bare ground declined from 42.8% to 32.8%, indicating rapid reversal of the mow effect. Bare ground remains well above the baseline state of 13% cover.

Thatch, for our experimental purposes, describes all the organic material on the ground that is at least one year old. All experimental treatments reduced thatch (Figure 5). After one rest year from mowing, thatch measurements increased from 4.5 to 9.0%, indicating that the mowing effect may fade quickly. Thatch cover of 9.0% is well below the baseline of 23.8% (Figure 6).

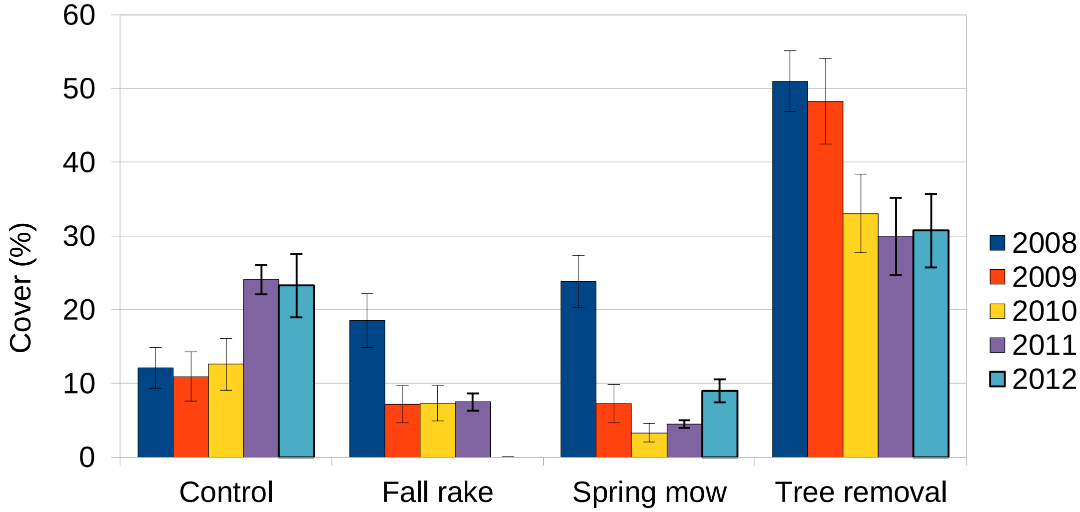


Figure 6: Percent cover thatch

Annual Forbs

Nearly all annual forbs in the Serpentine Prairie plots are native. After only one year of mowing (2009), a fourfold increase in annual forbs was observed and was retained for 3 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 7). Due to the drier year, there was a decline in the control plots also, but this was less pronounced than in the spring mow plots. After a one year rest from mowing, the spring mow and control plots contained the same absolute percent cover of annual forbs.

For the first time in four years, 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 flower in areas once heavily dominated by a mature pine overstory.

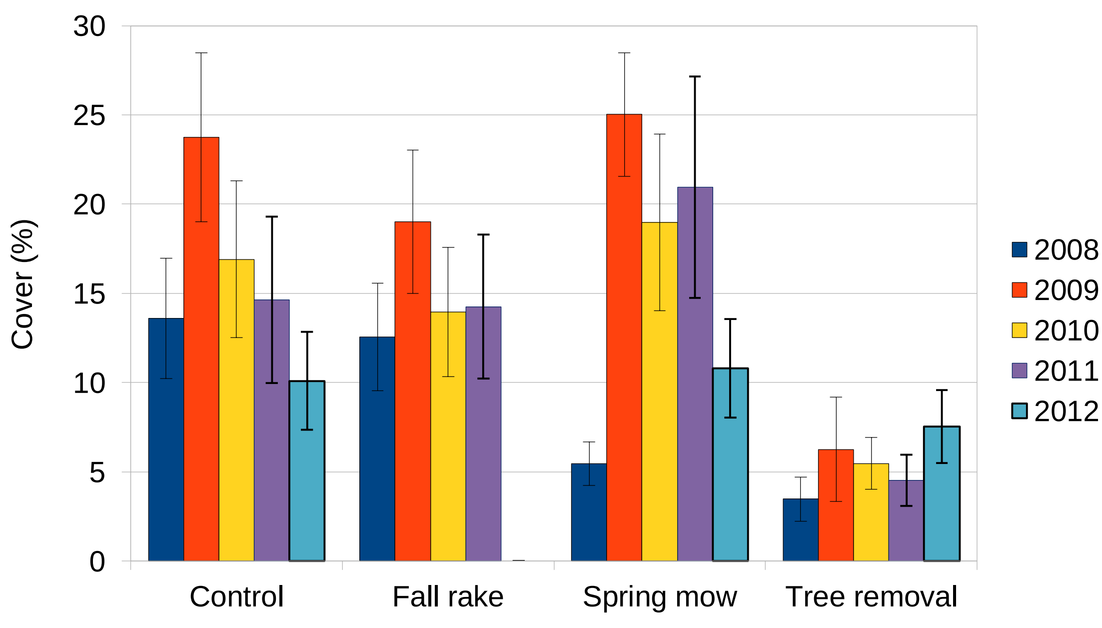


Figure 7: Percent cover annual forbs

Non-native Annual Grasses

Spring mow plots exhibited a decrease in annual grass cover from baseline conditions through year 3 (Figure 8). One year after mowing ceased (2012), the annual grass cover in the spring mow rebounded to near baseline conditions.

Tree removal plots also have increased non-native annual grass cover with the removal of trees and associated duff. Annual grass cover increased almost two-fold in tree removal plots in 2011, remaining mostly steady in 2012. While this increase is undesirable, it is still a relatively low cover value. Control plots show no notable change in annual grass cover over the course of the study. Although the confidence intervals are large (10-20% of mean), 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 control plots.

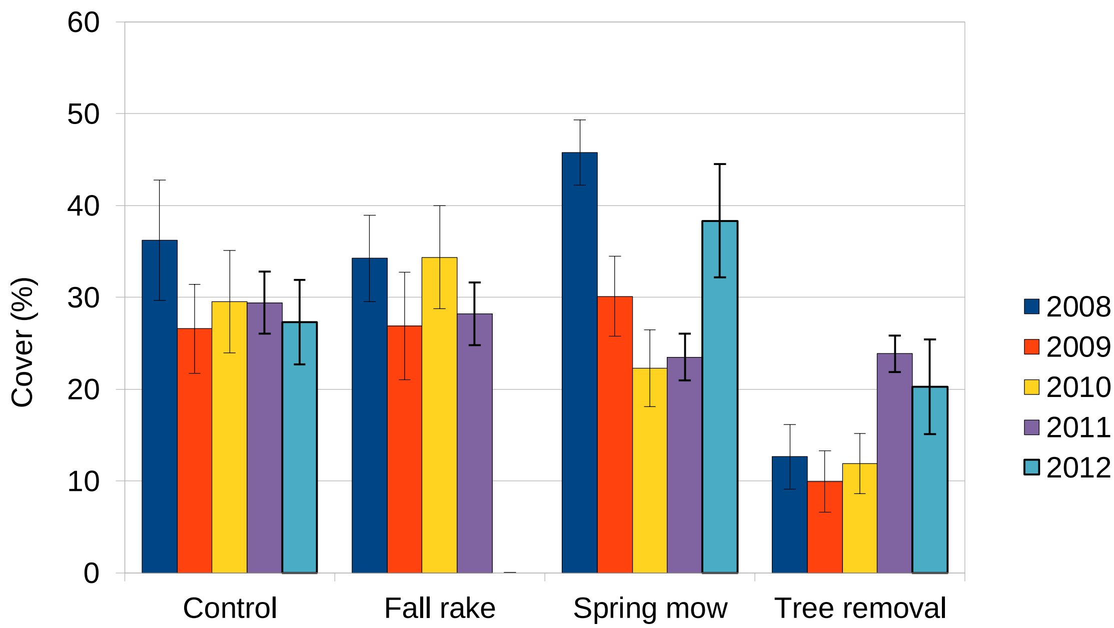


Figure 8: Percent cover non-native annual grasses

Native Perennial Grasses

Native perennial grass constitutes 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 to 2011, although this decrease is not notably different from baseline conditions (Figure 9).

Otherwise, no difference was observed in the cover of native perennial grasses from 2008 to 2012. No non-native perennial grasses are found in the experimental plots.

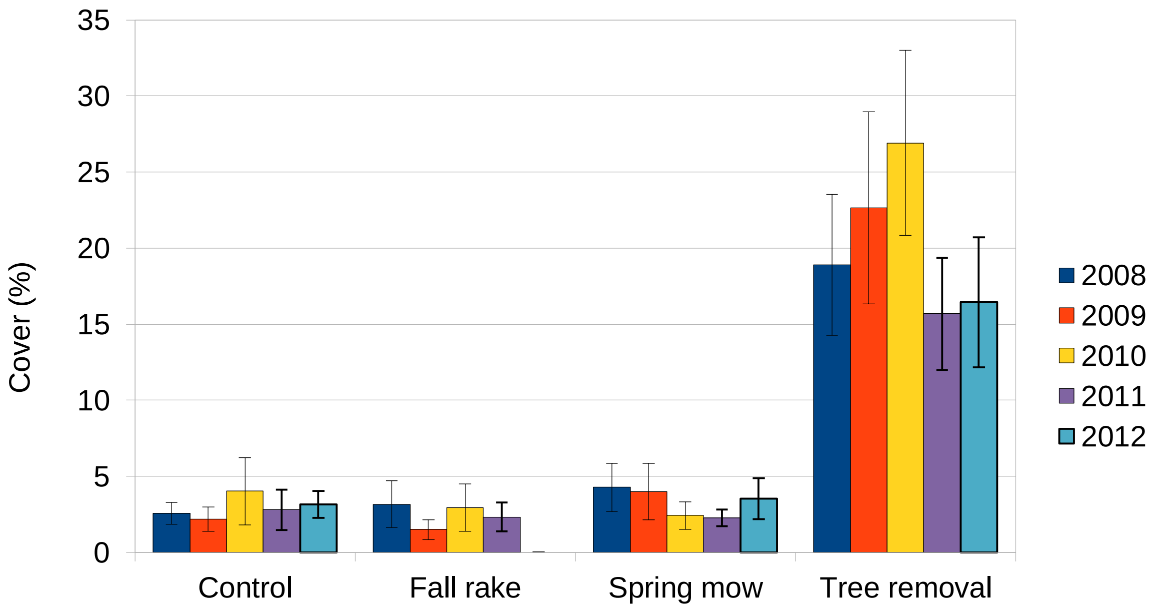


Figure 9: Percent cover native perennial grass

Native Perennial Forbs

No appreciable effect on native perennial forb cover was observed from 2008 to 2012 when compared with changes in control cover (Figure 10). We do not anticipate this guild to be affected by our experimental treatments.

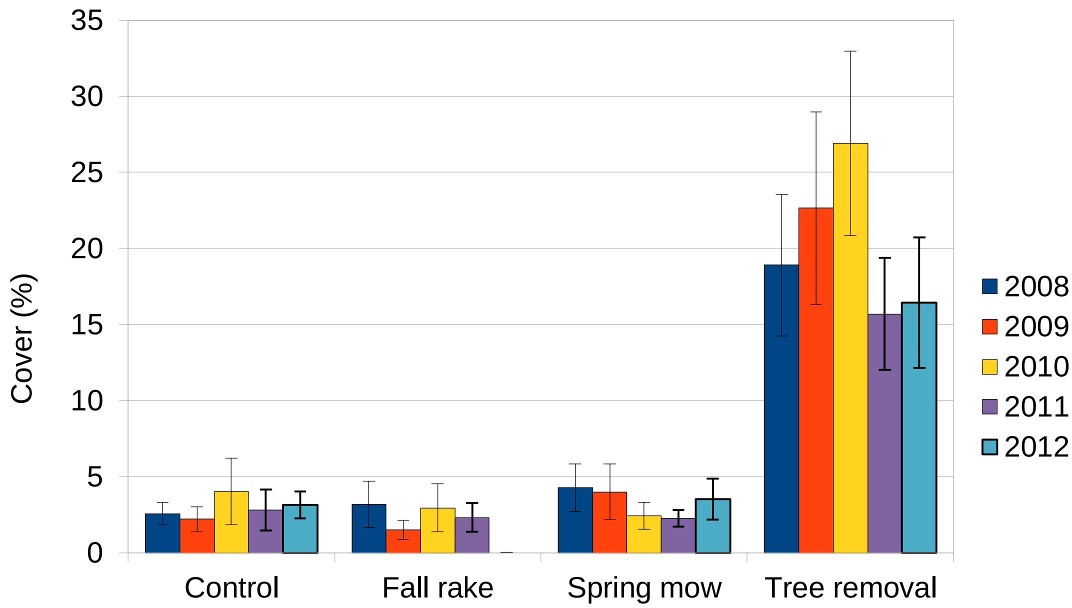


Figure 7: Percent cover native perennial forbs

Native and Non-native Plants

Spring mowing was the only treatment to increase native cover and decrease non-native plant cover after one year of treatment (Figures 11 and 12). This effect is still apparent in year 3. With the cessation of mowing in year 3, native cover dipped to 2008 baseline levels. This result indicates that native plant cover declines quickly with a one year break in mowing.

Tree removal increased native cover in years 2009 and 2010 only. 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. This result was expected because any time a previously stable habitat is disturbed, weed invasion is expected. It is promising that the percent cover of non-natives did not continue to increase from 2011 to 2012, so we are hopeful that natives will establish and compete with non-native plants, stabilizing these restored prairie areas. It should also be pointed out that non-native cover in the tree removal plots is relatively low.

Notably, control plots show a decrease in native cover over the course of this experiment (Figure 11). The first three years of this experiment are within range of baseline data. The last year's decline is driven by decline of annual forbs, which often drop in dry years. This trend should be watched, however, to ensure management is triggered if native cover is in a real decline.

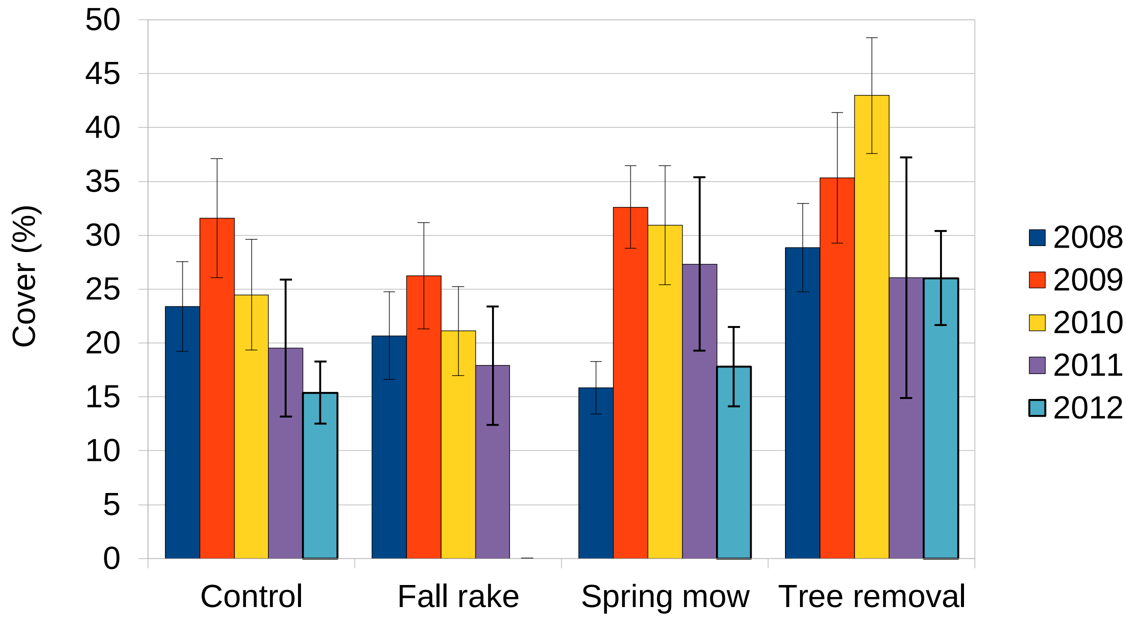


Figure 8: Percent cover native plants

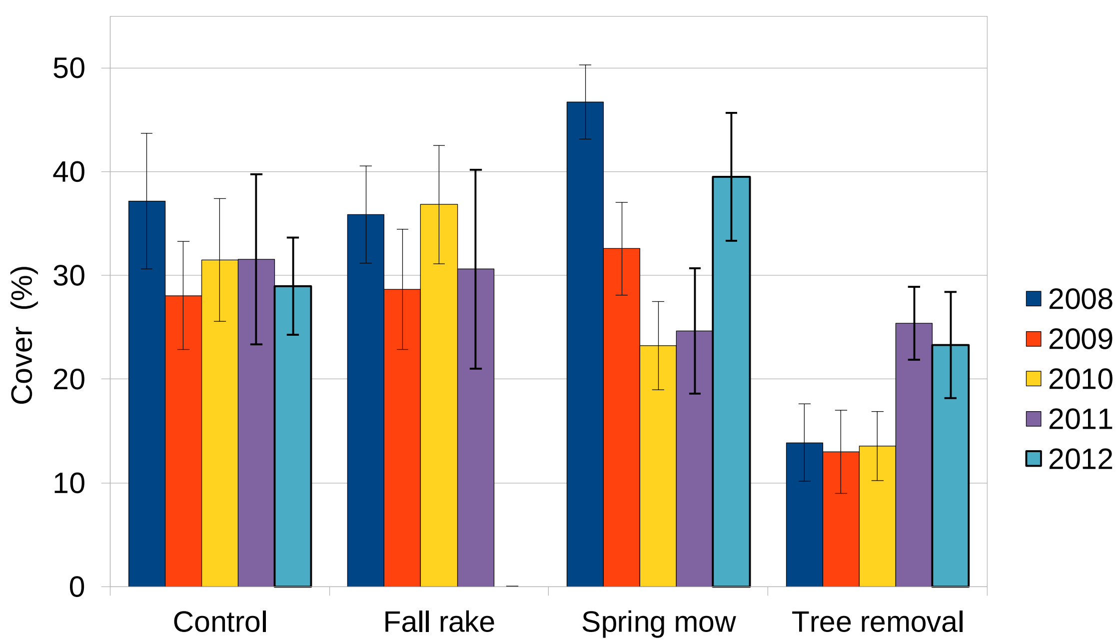


Figure 9: Percent cover of non-native plants

Experimental Plot Summary Table

Table 3 presents a summary of current treatment effects compared with baseline data. This easily allows for side-to-side comparison of the effects of the treatments on the experimental plots. This table also shows trends that we observed in the control plots over the course of this experiment, including an increase in thatch and a decrease in native cover, both of which are considered a degradation of the prairie environment. The degradation of the control plots hints that no stewardship will eventually cause degradation in the habitat quality of the prairie.

In this report, the spring mow column specifically reports the effectiveness of three years of successive mowing followed by one rest year. The column "Spring mow 2011" reports the results through 2011, excluding the rest year. Many benefits of three years of spring mowing were rendered inconsequential with a one year rest. Notably, the small gains in clarkia numbers were erased, the non-native annual grass cover returned to baseline levels, and native cover decreased while non-native cover increased to baseline (2008) levels. Clearly, even a one rest year from spring mowing can negate many of the gains made over 3 years of management.

Table 3. Effect of Experimental Treatments, Year 4 Compared with Baseline.

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

Fence Enclosure Comparison

Our experimental design allows for vegetation comparison inside and outside the enclosure, to determine the effect of excluding foot traffic and dog use in portions of the serpentine prairie habitat.

The enclosure fence was built in December 2009. This year 4 report presents a comparison of vegetative cover inside and outside of the enclosure for 3 sets of plots (Figure 13).

In 2012, no appreciable difference in percent cover of bare ground, thatch, or non-native annual grass was observed in the spring mow or control plots. The tree removal data observed maybe a reflection of soil differences and the tree removal treatment. Inside the enclosure, where trees were removed 2 years ago, bare ground is higher, thatch is lower and annual grasses are lower compared to tree removal plots outside of the enclosure. The tree removal inside of the enclosure was more thorough in removing all the duff, while outside of the enclosure, much of the duff remains. Additionally, tree removal plots inside the enclosure are underlain by soils that are more typical of the Prairie with reduced organic matter. The plots outside of the enclosure are characterized by deeper soils with a larger organic fraction. We believe that these two differences are driving the results more than any effect the enclosure has on the habitat. Until minimally the duff is removed, we consider tree removal data to be incomplete.

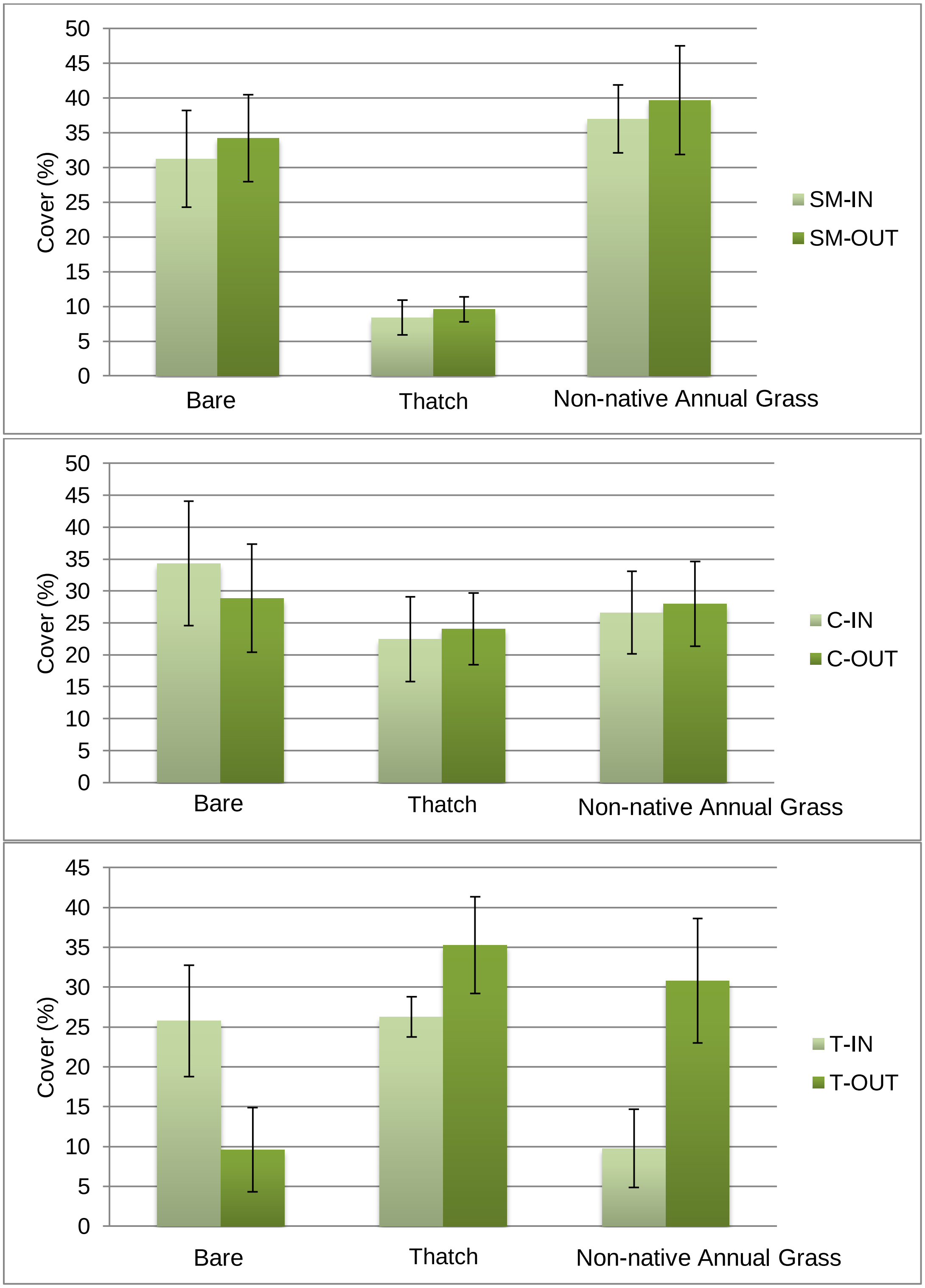


Figure 13: Comparison of 2012 experimental plot data inside and outside the enclosure

Summary Table for Effect of Enclosure Fence on Vegetation

2012 is the first year where we have complete data on the effect of the enclosure fence on vegetation. An experiment this size must progress stepwise, so although experimental plots have been divided on the two sides of the enclosure, the full experimental treatment of these plots was not finished until late 2011. The table presented below presents the first year of data for this experimental study.

We have yet to observe a significant difference between experimental plots inside and outside of the enclosure.

Table 4: Summary of Effects of Enclosure

	Improvement (+) Degradation (-) Neutral/Marginal Change (0) Incomplete Data (INC)			
Species or guild	Control	Fall rake (2011 data)	Spring mow	Tree removal
Bare cover	0	0	0	INC
Thatch cover	0	0	0	INC
Non-native annual grass cover	0	0	0	INC
Total negative effects(-)	0	0	0	INC
Total neutral effects (0)	3	3	3	INC
Total positive effects (+)	0	0	0	INC

Seed Dispersal and Survivorship

Of the 600 seeds that were dispersed on three sites in 2010, 147 (24.5%) survived by May 2011. By 2012, only 85 (14.2%) plants were relocated. Given the low survivorship in the control plots, we believe that this level of survivorship may lead to successful establishment of a new population locus.

Seed survivorship in each of the three 2010 sites varied greatly (Table 5). We observed individuals flowering and early fruit development at each plot in 2011, but in 2012, only the T7-T8 2010 site was well established. The other extant site, Hunt 2010, had comparatively smaller and less hardy plants.

Although seedling survivorship was extremely low for both the 2011 sites (Table 5), we believe those seeds should germinate and flower in a wetter year. We believe that weather is fully responsible for these low survivorship rates. As observed with the tree removal plots, clarkia seed remains viable for at least 20 years. We will monitor all these sites for clarkia in 2013.

Table 5: Seed Dispersal Results for 2010 and 2011

Site	# Seeds sown	# Clarkia surveyed 2011	% Clarkia survivorship 2011	Approx. % flowering 2011	# Clarkia located 2012	% Clarkia from initial seeding
Keyhole 2010	200	26	13	10	0	0
Hunt 2010	200	43	21.5	20	18	9
T7-T8 2010	200	78	39	40	67	33.5
Keyhole 2011	2100	-	-	-	10	<0.01
Pine Removal 2011	2900	-	-	-	5	<0.01

In 2012, we executed a larger seed dispersal experiment in Hunt Field. Approximately 7,000 seeds were scattered in high quality serpentine habitat (as determined by soil and vegetation) over an area of approximately 1.5 acres. This area has been named Greater Hunt 2012 for reference. Additionally, we transferred approximately 1,000 seeds to a second area in Hunt Field near an obvious poison oak thicket. We scraped away about an inch of earth to provide bare ground for the seeds. This small area is on flat ground that is normally heavily dominated by non-native grasses. We call this experimental dispersal treatment area PO 2012. Survivorship results from the large scale Hunt Field dispersal and the new experimental (PO 2012) area will be available in the year 5 report.

Conclusions

The Serpentine Prairie restoration project is well underway, with several results that will guide effective management in the future. We provide these six key conclusions:

Tree removal creates habitat

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 nearly 100-fold 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 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, with a concurrent decrease of clarkia in 2011. 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.

Spring mowing maintains clarkia habitat

Once clarkia habitat has been created, it requires management to prevent overgrowth of non-native annual grasses and thatch. Spring mowing has emerged as an effective tool for annual management of native serpentine flora. Three successive years of spring mowing provided benefits of increased bare ground, decreased thatch, decreased non-native annual grass, and increased annual forbs. The third successive year of treatment did not appreciably improve habitat conditions.

After allowing for one rest year, without a mowing treatment, many of the benefits of three years of spring mowing were negated, as observed by a decrease in bare and native plant cover in 2012 . Although mow effects were reduced, in most cases, the mow plots were improved from baseline conditions (Figure 14). The seed bank of non-native annual grasses may not have been fully exhausted, thus allowing for non-desirable species to quickly rebound when mowing pressure was removed. Thatch and bare ground increased quickly after only a one year rest from mowing. The 2012 spring mow plots retain higher habitat value for clarkia than baseline conditions, but the reversion to baseline conditions was quicker than anticipated. These observations indicate that annual mowing will be required to maintain habitat quality.

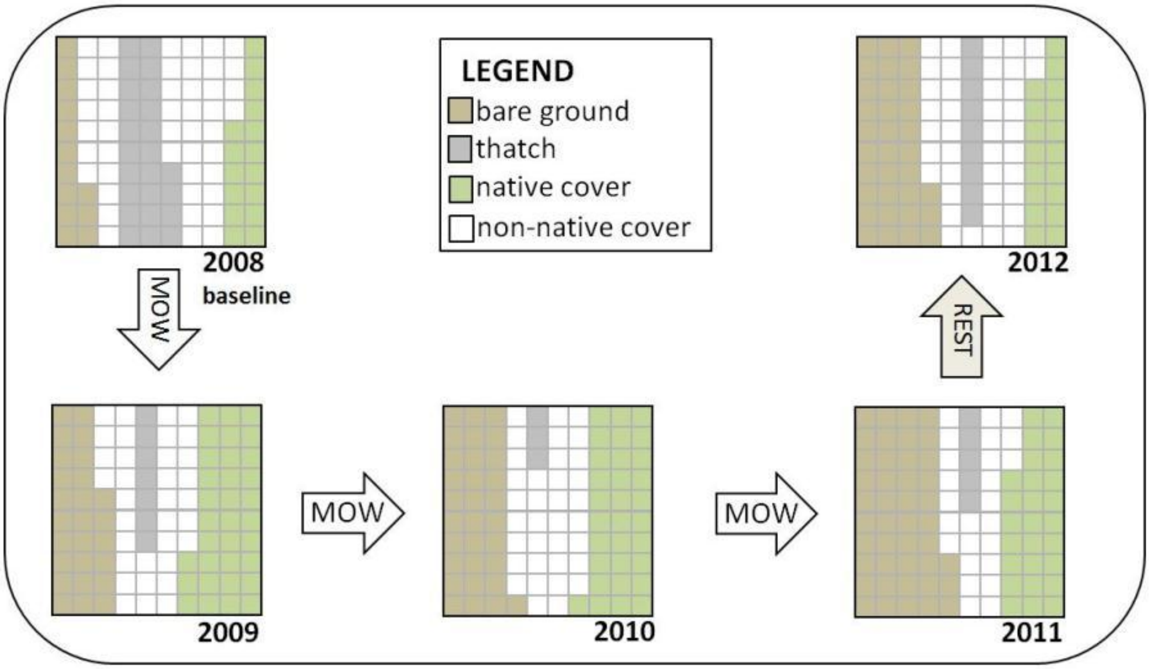


Figure 14: Percent cover of bare, thatch, and native plants in the spring mow plots from 2008 to 2012

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 a total of 3 individuals found in all 8 plots. Direct competition from annual grasses appears to be reducing clarkia germination and/or survivorship.

Annual spring mowing is critical in managing the prairie, to prevent 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.

We believe spring mowing is compatible with low density clarkia-occupied habitat. In 2011, upon inspecting our landscape-scale mow area two months after treatment, we observed 20 clarkia individuals that were mowed accidentally. All of these individuals were found within about 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 overcompensation. 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 do not believe there was a negative net impact on the clarkia, especially in light of the late spring precipitation. High density clarkia-occupied areas should not be mowed to minimize risk and because the clarkia is already doing well in such areas.

Weather affects clarkia survivorship

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. In general, years with higher spring precipitation also had higher clarkia populations. In 2012, the spring precipitation was above average, but clarkia notably declined. We believe that the benefit of the late spring rains was negated by low total precipitation. Both total and spring rainfall need to be considered when predicting clarkia survivorship in any given year. The magnitude of increase and decrease observed at the Prairie continues to parallel observations at the Presidio in San Francisco.

In past years, we located new, passively recruiting colonies of clarkia in areas where it had not been located before. No new colonies were located this year, likely because clarkia survivorship was so low throughout the prairie.

Enclosure effects are not evident

No notable differences in vegetation composition were observed between the enclosed plots and the non-enclosed plots for the second year. We expected that thatch might increase and bare ground decrease in the enclosure area because of the reduced foot traffic. In fact, pocket gophers were found to be very active and regularly create surface soil disturbance. This native rodent may be critical in helping maintain bare areas and helping unearth formerly buried seeds.

Clarkia seed dispersal has benefits

Survivorship from seed dispersed on site is disappointing, excepting the T7-T8 2010 dispersal polygon. Of the 5,000 seeds that were dispersed in 2011, only 15 plants were located, a survivorship rate of less than 0.0001. This level of survivorship is well below expectations, but we believe the weather prohibited better establishment. We will continue to track 2010, 2011 and 2012 dispersal sites in year 5.

Appropriate disturbance benefits clarkia

Clarkia has been observed in areas with disturbance. Tree removal plots, where we've observed an increase in clarkia from 15 individuals in 2008 to 1183 individuals in 2012, are testament that disturbance can positively increase clarkia population. In the case of the tree removal plots, duff and leaf litter was removed by raking which exposed bare soil. We believe that clarkia seed buried under the organic layer germinated and flourished because trees were removed in concert with duff removal.

Initial conversations with agency officials about the restoration of the prairie cautioned mowing could impact the population. Our results show that clarkia survived in mow plots after an appropriately timed mow treatment in spring. Additionally, our 2011 in Hunt Field mow accidently cut 20 clarkia individuals. Those individuals were flagged and tracked through the year, wherein we observed many of these cut plants flowering, and in some cases, flowering vigorously with multiple inflorescence stalks.

Anecdotally, we have also observed clarkia germinating on bare ground that was recently disturbed by gophers. The recently turned soils is often free of any plants other than clarkia. This indicates less competition for these clarkia individuals. We have observed these plants also flower vigorously, forming large seed capsules.

This collection of results and anecdotal information leads us to conclude that well-timed, appropriate disturbance can benefit the clarkia population at the Prairie. Researching more about types of disturbance and timing of events may help develop another tool for clarkia conservation.

Year 5 Proposals

The tree removal treatments have been completed, and we shift focus from creating new clarkia habitat to managing it.

The number of positive results created by spring mowing is encouraging. We recommend trying to continue fostering the collaboration with Civicorps if they are willing to agree to be flexible on their spring scheduling. It is critical for any land manager to be responsive to ecological cues in order for effective management. EBRPD staff and Creekside staff are critical in overseeing the spring mowing and ensuring that the progress made in 2011 and 2012 is not lost.

We also recommend targeting additional areas for mowing, especially in tree removal areas. This follow up may ameliorate the spike 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 and relatively high precipitation, high grass growth years are inevitable.

Experimental plots should be monitored again to determine effects on clarkia and vegetation composition after tree removal, enclosure installation, and spring mowing. In 2013 we will begin to see how quickly the spring mow effect will be reinstated after a rest year where many non-native annual grasses recolonized the experimental area quickly. Because mowing the entire habitat is not financially feasible, and could create take issues, we will investigate the effects of mowing every other year

We hope to complete the clarkia macroplot survey, which provides a statistically robust estimate of the population. The GPS-mapped site distribution of clarkia illustrates how the population changes spatially over time, and should also be repeated. This invaluable information allows us to quantitatively gauge management progress and ensure that the population at Serpentine Prairie is not underperforming compared to the Presidio.

In year 5 we will also monitor survivorship of nearly 13,000 clarkia seeds dispersed from 2010 through 2012. We hope that clarkia numbers will recover with a wetter year, and more of the dispersed seeds will germinate. The scrape treatment may also produce some interesting results in terms of how well clarkia establishes on bare soil. We anticipate that monitoring dispersal areas may require a larger percentage of time than previously allocated.

We believe that disturbance is important in the germination and possibly even survivorship of clarkia individuals. Research around type, timing, and degree of disturbance may reveal important information about clarkia. We hope to entertain discussions with appropriate agencies about utilizing disturbance in managing clarkia at the Prairie.

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.

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