Serpentine Prairie Restoration Project

Redwood Regional Park

2015 ANNUAL REPORT: YEAR 7

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. This is the 7th annual report, reporting results from the 2015 year. This report follows the more concise format initiated in the 6th annual report.

The past year was another dry year characterized by record drought. Many areas that were rich in clarkia in 2011 (a wet year) were nearly devoid of the plant in 2012-2015. While most of the core areas remained occupied, the reference plots that are censused annually were reduced to about one fifth of the 2011 peak population numbers. We believe this reduction in population is within a reasonable range of historic variability. We report the Serpentine Prairie macroplot results alongside Presidio macroplot results and note that the population fluctuations seems to be synchronized to a large degree. Differences in annual weather from San Francisco and Oakland are not significant enough to trigger differences in annual clarkia populations.

Our work in 2015 utilizes the 4 years of drought and difficult growing conditions for annuals to help characterize where occupied habitat may persist in light of climate change and prolonged periods of drought. Estimated clarkia in the macroplot is calculated to be 56,920 +/- 14100 individuals. The macroplot estimate is lower than 2014 counts (63,690 +/- 17,461) but the numbers' 25% confidence intervals overlap, indicating that these two numbers are not statistically different. Clarkia polygons were remapped throughout the prairie, minus the macroplot area where analogous distribution data was collected. This 2015 (4-year drought data) is compared with 2007 survey polygons that were collected in more historically typical precipitation years. As expected, many polygons where clarkia was mapped in 2007 are devoid of plants in 2015.

Clarkia collection and dispersal trials continue with some success. Soils and microclimates combined with precipitation play an influential role on the density and occurrence of clarkia in various areas of the Prairie. A soil map that predicts the thickness of the soil for the entire Prairie was completed in 2014 in order to further guide restoration efforts. Using this soils map and known clarkia distribution, 2 relocation areas were seeded in September 2015 with Creekside staff and Golden Hour Restoration Institute volunteers. Habitat in these areas was prepared by raking the ground with McCleods and similar tools and then sowing seeds into recently disturbed soil.

We continue to dedicate a significant portion of this study to 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 were 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 mowing of high quality habitat on Hunt Field, as well other critical habitat areas identified later in this report, 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.

We recommend continuing the following efforts in 2016: 1) strategic mowing in areas of thinner soils with historic clarkia populations (although mowing should not occur in occupied habitat with bolting, or reproductively mature, clarkia) 2) continue a standardized goat grazing trial where grazed sites can be compared with ungrazed, 3) continue to schedule and support volunteer work around weeds, clarkia seed collection, and removal of new tree seedlings in the restored Prairie, and 4) initiate a study that will assess the impact of mowing at two times in the year on annual clarkia survivorship and fecundity.

Introduction: Project History, Ecological Site Description

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.

Plate 1: Clarkia franciscana

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.

A key factor that influences germination, survivorship and flowering in Mediterranean-region annual plants is annual rainfall. Since clarkia flowers in late spring, we hypothesized precipitation in April, May and June may be an important contributor to this plant's survivorship and fecundity. We have been tracking overall rainfall (Oct 1-Sept 30) and spring (April 1-June 30) rainfall (Figure 1). The 100-year average for annual precipitation for this site is 27.63 inches.

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.

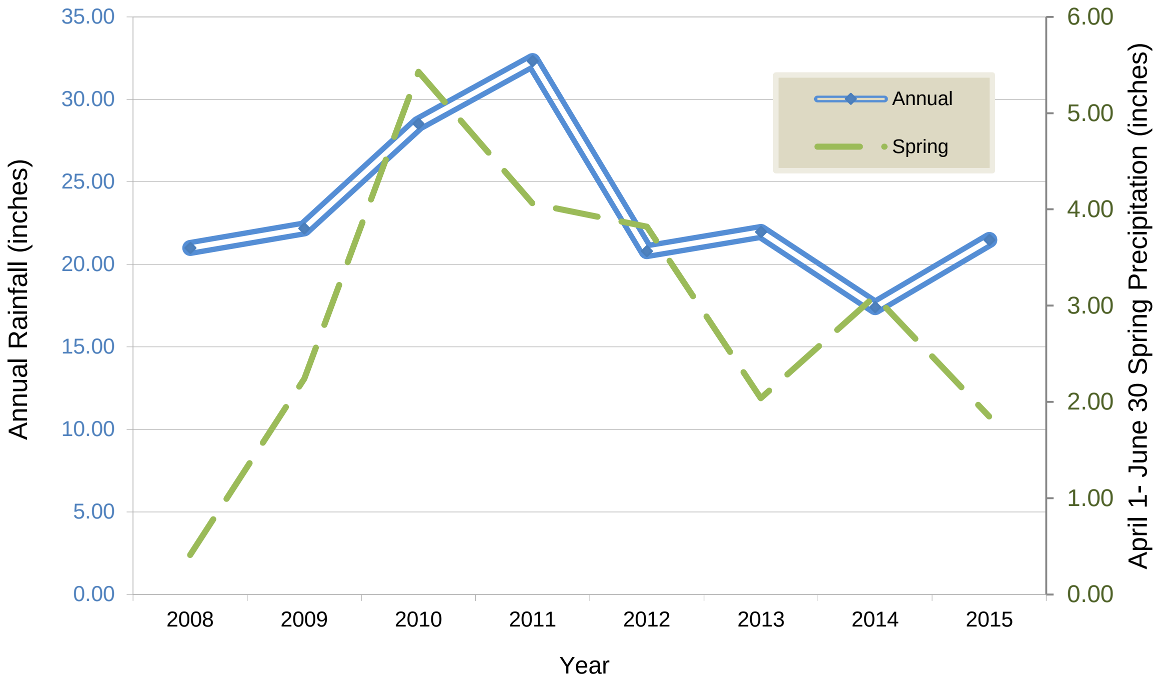


Figure 1: Precipitation at Serpentine Prairie (LAT = 37.8129, LONG = -122.187675)

Methods

Methods for our experimental work are described in full in previous reports (Naumovich et al. 2014). The experimental design consists of 32 permanent plots measuring four treatments: fall rake, spring mow, tree removal, and reference plots which were formerly called "control" (Figure 2). 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.

The Clarkia population of the permanent macroplot (100 x 300 meters) was estimated by selecting twenty 0.5 x 300 meter transects using a restricted random start. Total individuals were counted along each one meter interval. The full method is described in Appendix D of the Serpentine Prairie Restoration Plan (EBRPD 2008).

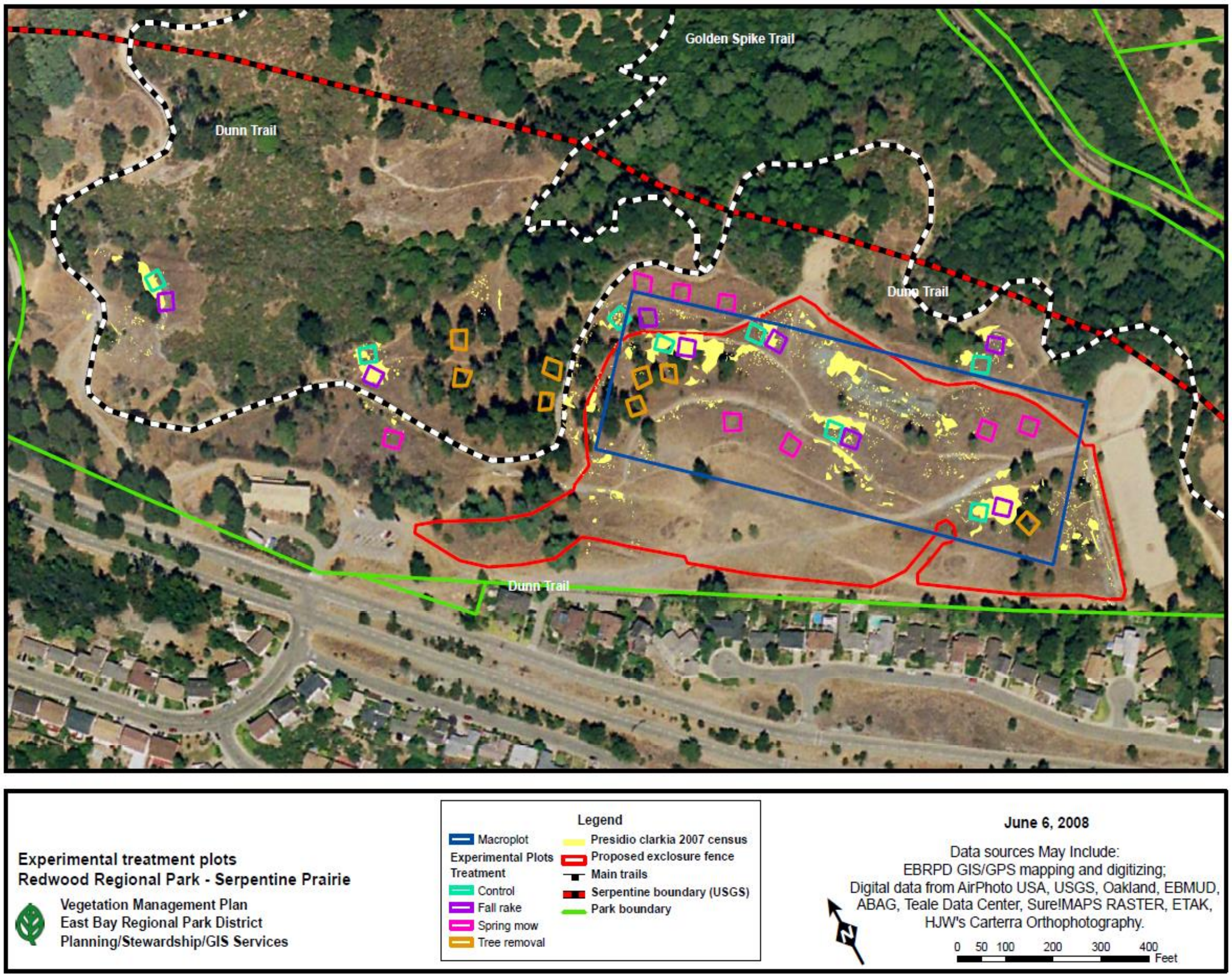


Figure 2: Plot, fence, and trail at Serpentine Prairie (Map by EBRPD, 2008)

Soil Depth Mapping

Soil depth was sampled systematically across the Prairie in the spring 2014 when soils were saturated. A metal stake with depth marks was pounded into the ground in approximately a 20-meter grid. Once the stake impacted solid rock (as determined by reverberation of hammer on stake), a measurement in cm was recorded. The maximum depth the stake could record was 75 cm, therefore samples with a measurement of 75cm have soil depth from 75 cm to several meters. Results were used to create a GIS map. Points were analyzed using a Kriging interpolation method in order to create a surface which approximates the distance to bedrock.

Clarkia re-mapping

Clarkia remapping was conducted during peak flowering over 4 days from late April through May 2015. This remapping effort was strategically conducted at the end of the drought period in order to help identify areas where clarkia refugia may exist in times of climate change and extreme drought.

A 2007 mapping effort completed by Wilde Legard and EBRPD staff was used as a base map for searching for clarkia. All previously mapped areas (outside the macroplot) were visited and clarkia was flagged. Once an area was flagged, a GPS polygon was drawn around any flags that were no more than 20 feet from another flag. A new polygon was initiated if clarkia were found more than 20 feet away from other individuals. All mapping was completed with a Trimble Juno 3B GPS.

Grazing Transects

Six grazing transects were installed in the fall of 2015. These were placed with the aid of EBRPD staff (Denise Defreese) and a local grazing operator who is familiar with the site and will be conducting the work, Brittany Cole Bush of Star Creek Land Stewards, Inc.

We have established six 50 meter transects (Figure 3). The cover photo of this report shows the habitat between transects 5 and 6.

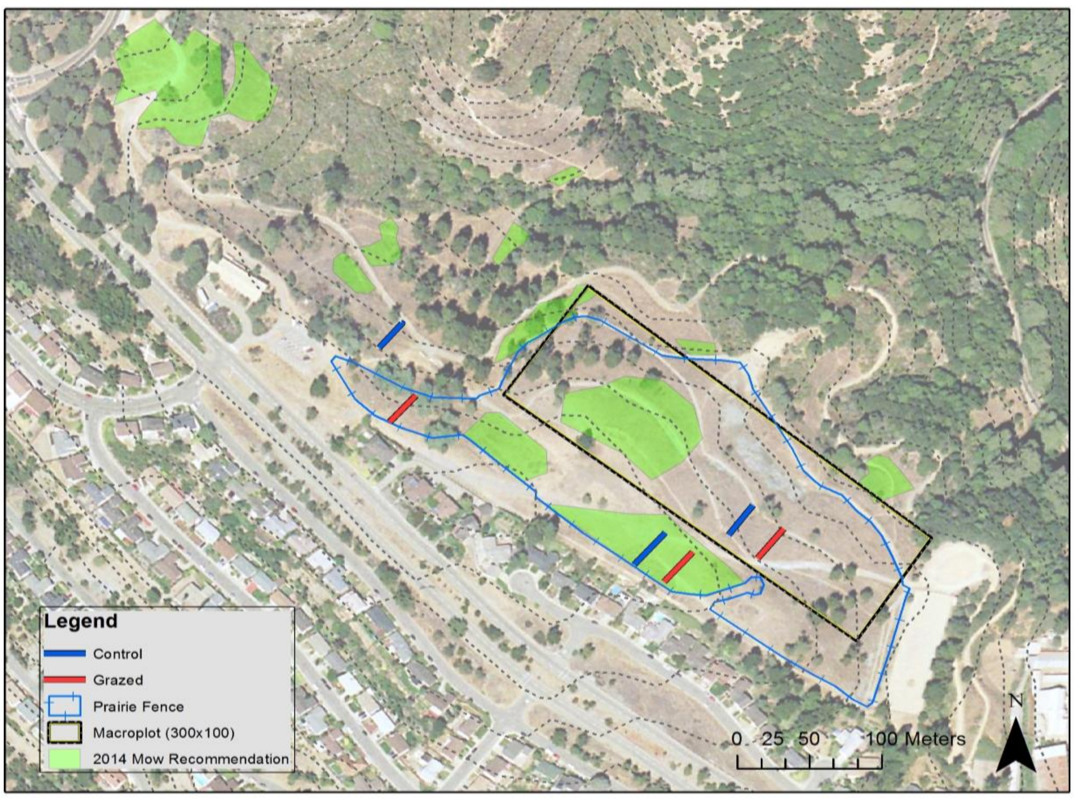


Figure 3: Location of six (6) transects for inspection of grazing effects

Three transects are experimental where goats and sheep will graze, and three are paired controls with similar pretreatment habitat, soils and exposure. We will conduct the following vegetation measurements on an annual basis:

- Read 10 ¼ m^2 square quadrats per 50m transect. Measurements will include vegetation cover, bare ground, litter and abiotics such as rocks. Vegetation will be recorded to the nearest 1% cover. Minimum cover is ½%. Vegetation transects will alternate on either side of the transect, with the back edge ending on a 5m or 0m mark (Figure 4)

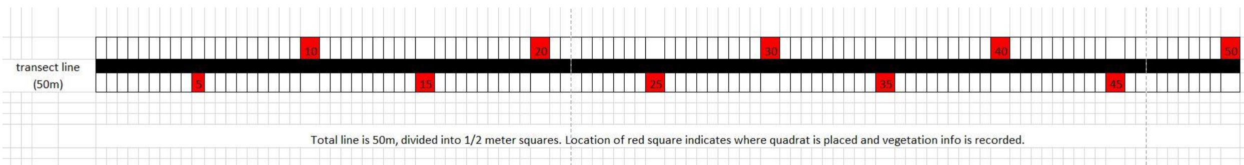


Figure 10: 50 meter transect with quadrat placement locations along line.

- Record all species found within 5 meters of either side of the transect. This is anticipated to allow for observation of any new weeds or plants imported on the grazing animals. Any new species should be quantified by either percent cover, area, or number of individuals allowing for simple tracking of the new plants.
- Photos will be taken every year at the 0 and 50m end of each transect for photomonitoring.

Research Results and Discussion

Clarkia Macroplot

Plate 2: Recording clarkia within the macroplot. Although it was a below-average precipitation year, annual grass net primary productivity (growth) was also lower than typical years. May, 2015.

In 2015, the macroplot recorded clarkia during the fourth year of a multiyear drought (Plate 2). Macroplot surveys were completed in 2015, 2014, and 2009-2011, but not completed in 2012 and 2013 due to funding constraints (Table 1).

This year's macroplot allows us to start cataloging normal population variability of this annual plant in drought conditions. As this report is being completed, the 2015-2016 water years on course to provide about average rainfall (as of February 2016), despite a very strong El Nino event.

In 2015, the macroplot estimate was calculated to be 56,920 ± 14,100. 2015 macroplot numbers were statistically similar to 2009 and 2014 survey results, but still well above 2008 measurements of 15,569. We did notice more clumped plants in this year's distribution of clarkia. This higher variability among transects led to the larger 80% confidence interval. This higher degree of clumped plants may be a result of the drier year, where plants in high quality microsites thrived. Germination appeared similar to past rainfall years, but this has never been quantitatively measured. It will be instructive to track plants in a few permanent plots from germination to seed set to allow us to understand if fertility was impacted in this drier year, of if fewer plants matured to flowering, etc.

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
2014	63,690	17,461
2015	56,920	14,100

We have shown in past reports that Clarkia population in the Reference plots is closely linked with total annual precipitation (Naumovich et al. 2015). With the completion of this 2015 macroplot, we plotted the log of the macroplot estimate against the total annual precipitation and found these two numbers are linearly correlated (R^2=0.81) (Figure 5). We have excluded 2008 macroplot numbers since we were measuring the macroplot population with a slightly different method (full meter quadrats versus half meter quadrats). Notably,2008 was the most unusually dry spring on record, when the Prairie received just 0.41 inches of rain from March 1 through June 30. The regression results when the 2008 data was considered noted a less powerful correlation between annual precipitation and macroplot estimate.

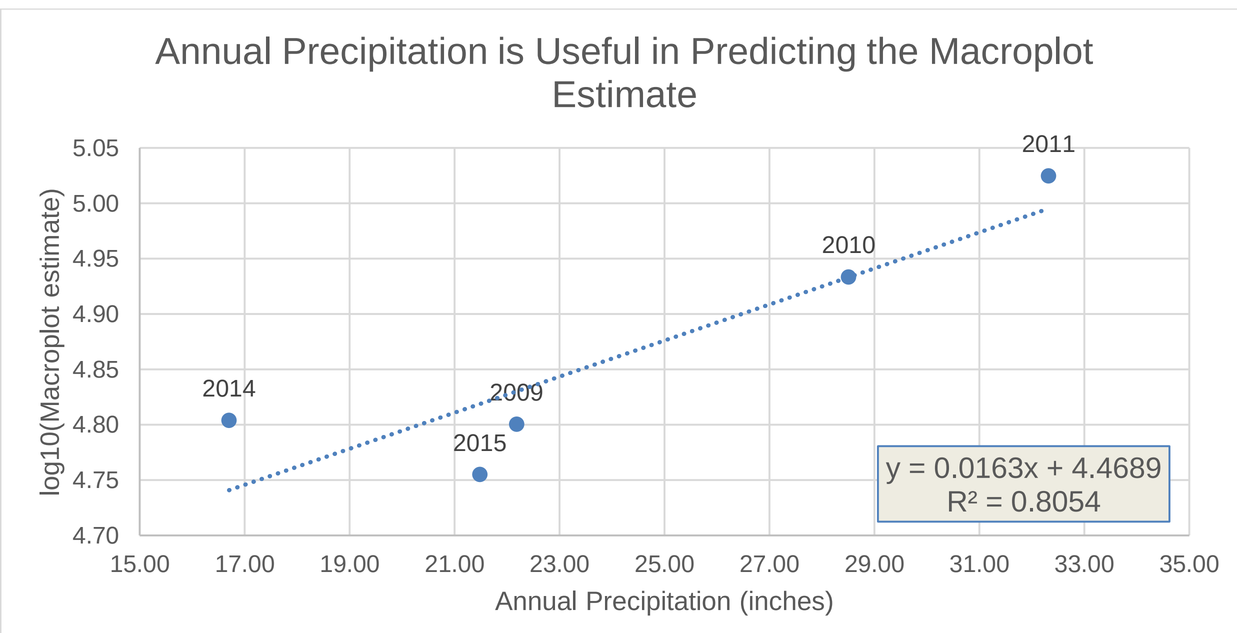
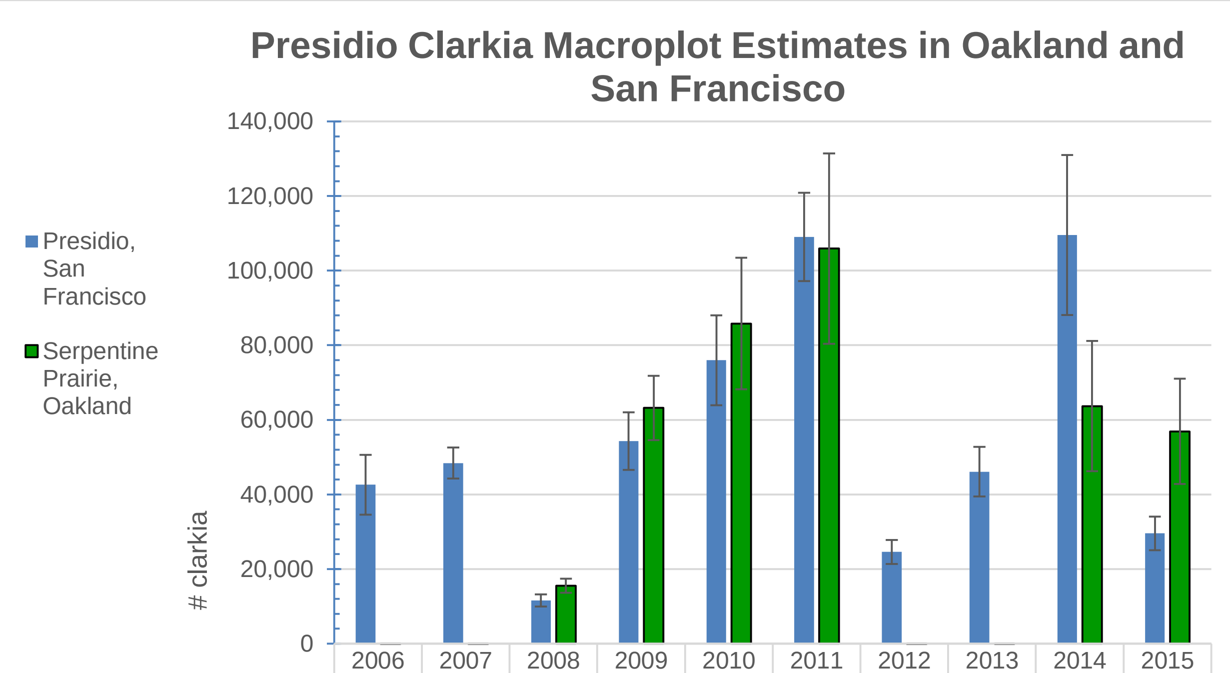


Figure 5: Comparison of annual precipitation at the Prairie to macroplot estimate numbers.

Comparison to San Francisco Presidio Population of Clarkia

Clarkia macroplot data collected at Serpentine Prairie is compared with macroplot data from the Presidio (San Francisco). From 2008 to 2011, the two populations tracked each other very well (Figure 6). Although the two macroplots differ in size, the degree to which they are changing indicates that local climate and environmental conditions were similar. Despite notable differences in the habitat and climate of the two sites, the two distinct populations seem to be going through similar population fluctuations. This observation allows us to hypothesize that differences in climate between San Francisco and Oakland's Redwood Regional Park do not significantly impact clarkia populations year to year.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Presidio, San Francisco	42,617	48,429	11,595	54,322	75,995	109,047	24,589	46,100	109,538	29,560
Serpentine Prairie, Oakland	0	0	15,569	63,210	85,830	105,918	0	0	63,690	56,920

Figure 6: Comparison of Clarkia macroplot estimates from Oakland and San Francisco populations. Zero (0) in 2012 and 2013 indicate the macroplot survey was not completed.

Clarkia re-mapping

In 2015, we departed from our usual census of experimental treatment blocks since we have a fairly rigorous, multi-year dataset which we have moved on from in this year in order to maximize stewardship dollars for adaptive management rather than simply research. Additionally, we are finding notable correlations of clarkia population with overall precipitation. We spent additional time recording detailed polygons of where clarkia is distributed spatially on the Prairie. The 2007 census completed by EBRPD staff shows the entire distribution of clarkia across the Serpentine Prairie. This survey was repeated for all areas except for the macroplot in 2015 (Figure 7).

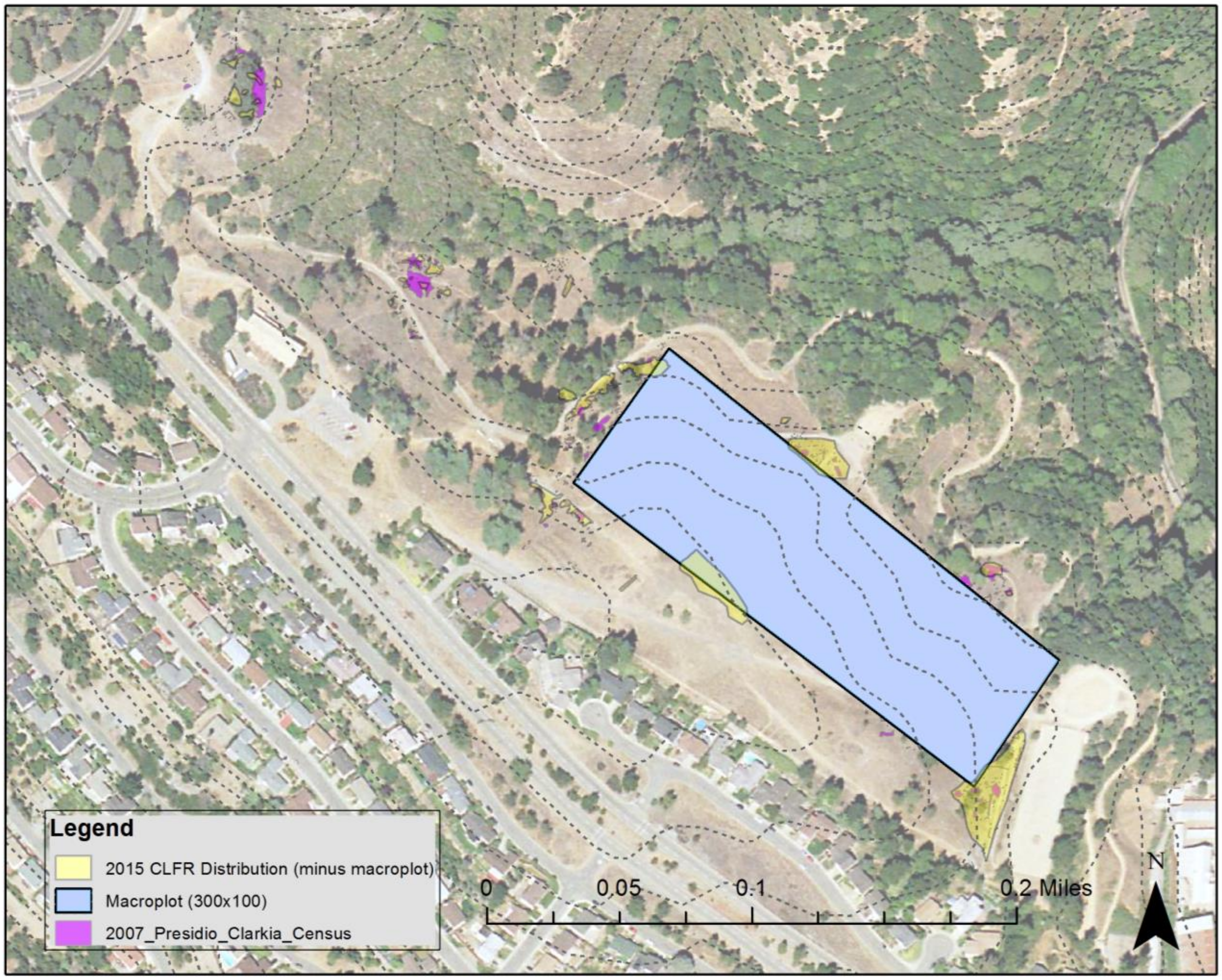


Figure 7: 2007 and 2015 census map of clarkia at Serpentine Prairie.

Notable areas of clarkia exist immediately around the edges of the macroplot, as expected, since the rectangular form of the macroplot was optimized to cover the majority of the occupied habitat when it was designed in 2008. Notable essential refugia also exist on hot south facing slopes, the northwest-most polygons (top left of map) and the southern-most polygon (located in the bottom right corner of the map) (Figure 8). These areas continued to be occupied by clarkia despite conditions that would seem to be difficult for seedling survival. Note that no dispersal areas are included because *de facto* they did not exist during the 2007 survey.

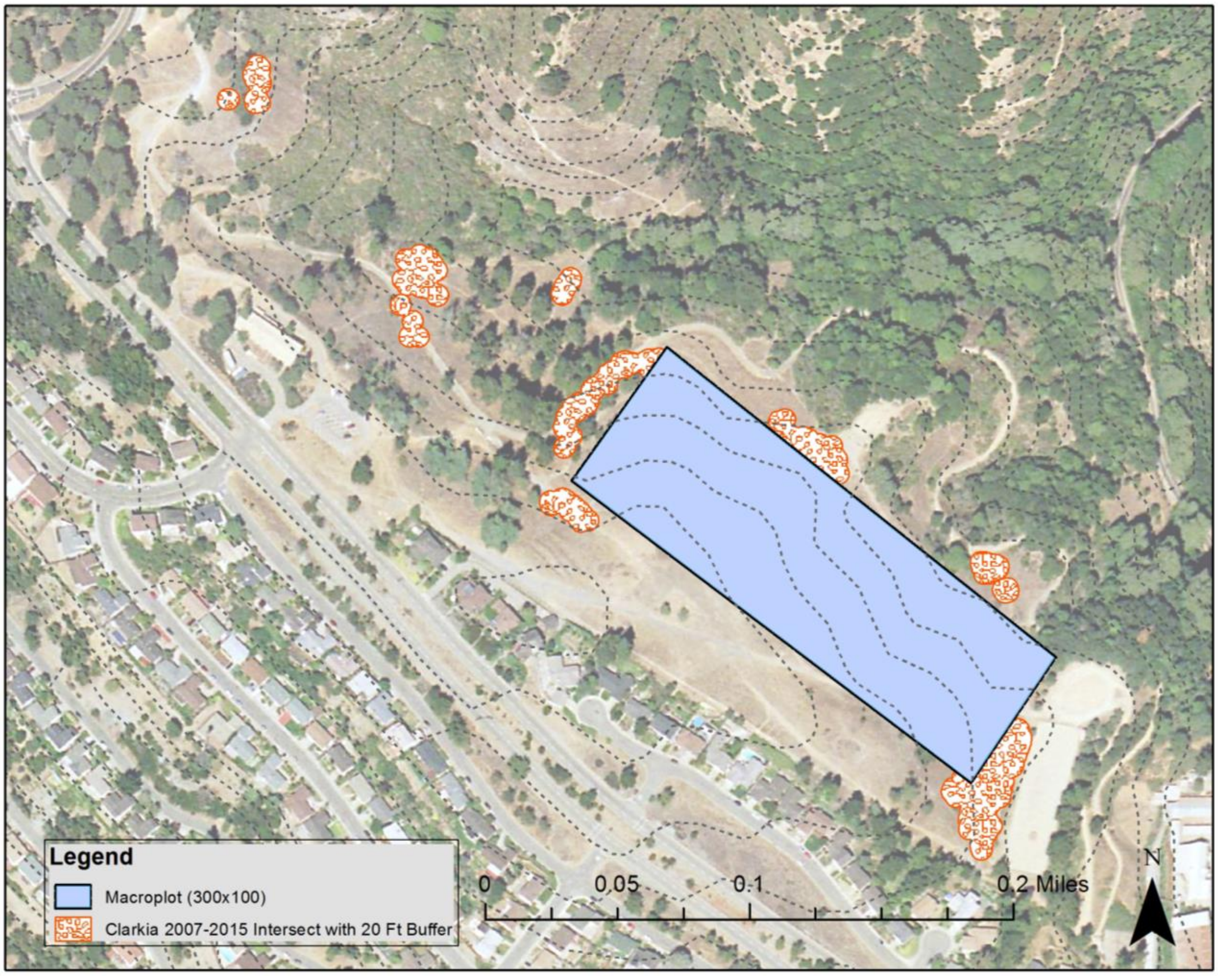


Figure 8: Essential clarkia refugia area where clarkia was mapped in two drought years: 2007 and 2015. The macroplot area is all considered essential refugia due to the concentration of clarkia present.

Stewardship Results

Completed Land Management and Monitoring Tasks: 2008-2015

Tasks completed by Creekside Center for Earth Observation from 2008 to 2015 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 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. This task was discontinued in 2015.

- 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. This task was discontinued in 2015.

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

- From 2008 to 2011 and again in 2014 and 2015, 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 2011 and again in 2014, helping staff study and evaluated a proposal to implement seasonal sheep grazing at the Serpentine Prairie. The first proposal was extremely costly and ultimately rejected. A second proposal is being investigated. Sheep and goat grazing was piloted in the summer of 2014 and 2015.

- In 2015, six grazing transects were established in order to determine effects of grazing on plant composition and help monitor for possible import of novel weeds and native plant material (seeds) from grazing animals, by surveying for novel flora around the transect. Transects will be read in 2016.

- 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. This task was discontinued in 2012.

- Mowing approximately 3 acres on the Prairie in 2012 thru 2015, 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.

- Designing and leading a workshop on seed collection and dispersal techniques for EBRPD staff and others in 2014 and 2015.

- Completed a soil depth measure in 2014 and subsequent GIS map across the entire habitat in order to better understand soil depth and how that contributes to clarkia distribution.

- 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.

Large Scale Mowing by Creekside Science Biologists

In 2012 thru 2014, 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. Areas with high habitat potential were mowed in April 2015 (Plate 3). Each location was surveyed for presence of clarkia and if found, plants were flagged and avoided. A total of 2.75 acres were mowed in 2015.

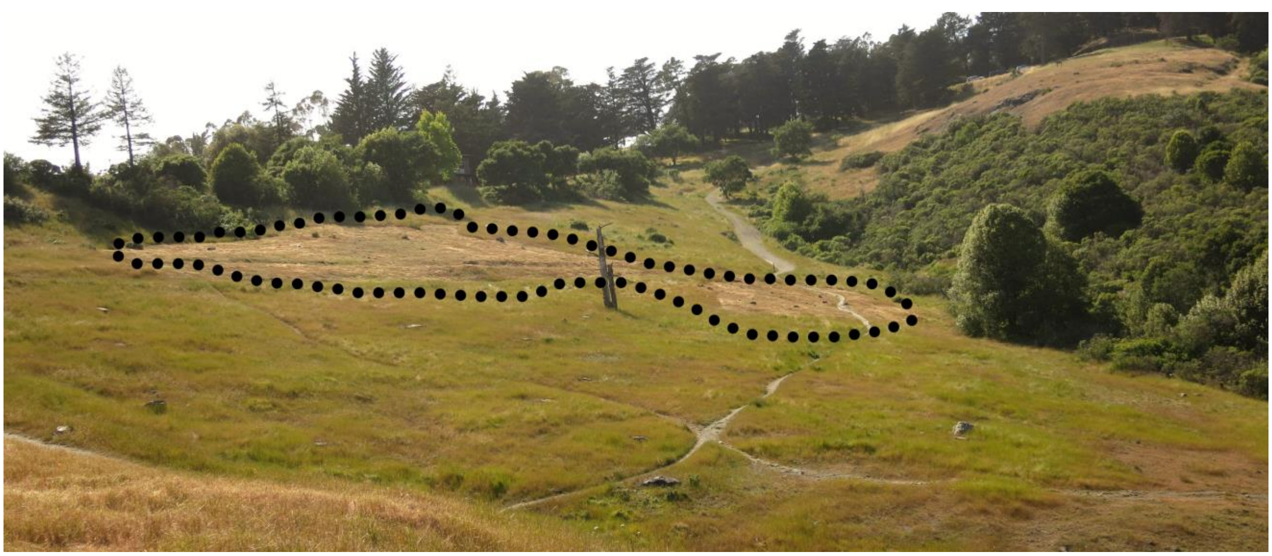


Plate 3: Spring mowing on the northern end of the Serpentine Prairie, April 2015

Prioritizing mow areas is essential for ensuring that funding is spent effectively: this was completed in 2015. Although the entire grasslands area will respond to well-timed mowing, we recommend targeting areas (Figure 9) with thinner soils around known populations of clarkia buffering some of the larger habitat areas, allowing seed to naturally disperse into high quality habitat. Since clarkia seed seems to disperse only very locally (no known wind, ant, or bird movement of seed), areas downhill of occupied patches should be targeted. Mowing must always be completed with an eye on phenological timing of the clarkia in order to ensure there is no take, although anecdotal evidence points to the fact that an early season mow causes tiller growth in clarkia increasing the number of fruits per plant. This observation needs further scientific evaluation.

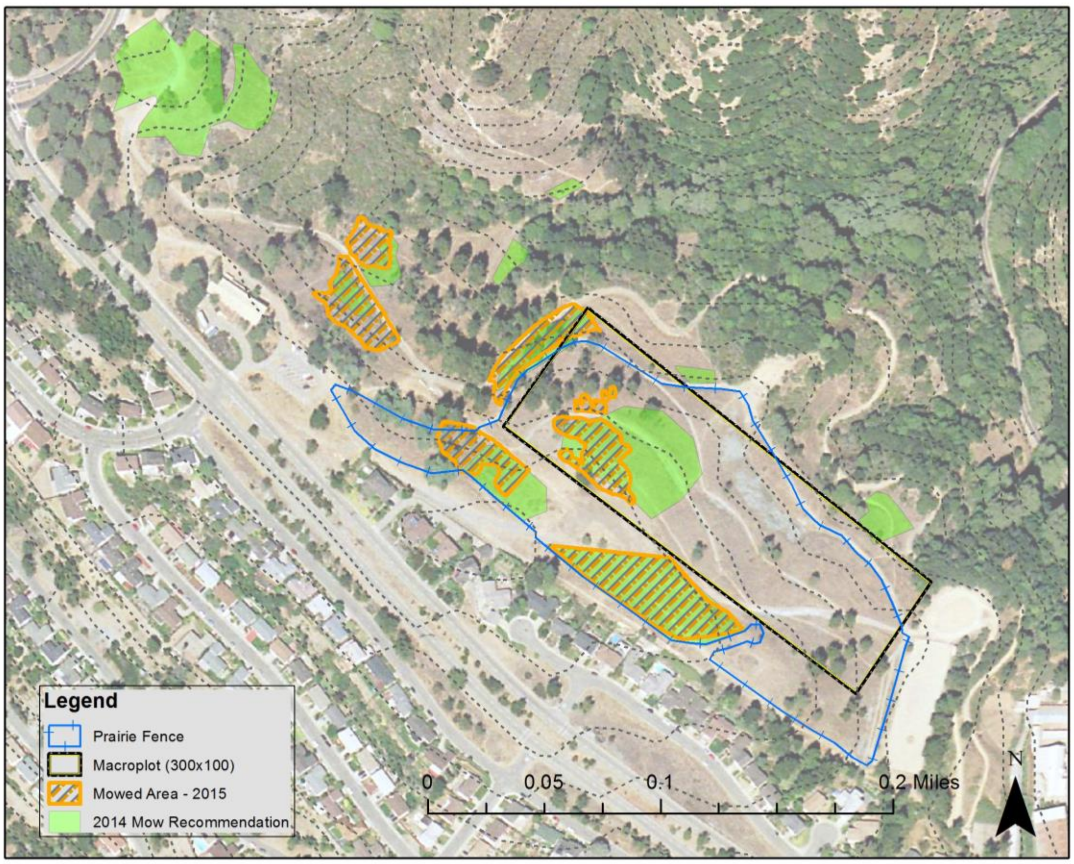


Figure 9: Recommended areas from year 6 annual report (2014) for mowing consideration and areas that were mowed in spring 2015.

Grazing Trial

A grazing trial was initiated in summer of 2014 when an opportunity arose to work with a local, sensitive environmental grazing company. A mix of sheep and goats were delegated to target areas free of clarkia, where thatch and non-native annual grass cover was high. Goats and sheep were only kept onsite for three days, wherein we observed significant biomass reduction (Plate 4).

Plate 4: Grazing trial at Hunt Field showing animals on site, July 2014 (top) and May 2015 (bottom) grazed and ungrazed habitat edge.

A mix of goats and sheep may be the most optimal grazing arrangement in order to reduce duff and grasses (non-native seed set) while maintaining bare ground. Additionally, the animals help create a ground level disturbance that may maintain habitat for forbs. As observed in the tree removal plots, the 2012 scrape, and the 2011 skidder areas, disturbance seems to greatly increase clarkia numbers.

Careful planning and timing of grazing will be essential. We recommend a trial that will compare grazed and ungrazed areas for vegetation cover and bare ground to ensure this treatment is advisable for areas where native forbs are well established. It is unclear whether we can use this as a blanket technique for the entire Prairie, but experimentation and monitoring can help answer these research questions.

Seed Collection and Dispersal

In September 2015, 2 Creekside staff and 2 Golden Hour Restoration Institute volunteers worked to collect seed and disperse it into two areas which are located close to occupied high quality habitat. Soils were scarified with a McCloeds and rakes (Plate 6) allowing for better seed to soil contact. Seeds were approximately divided into two groups of 2,000 and hand broadcast into the soil (Figure 8). Staff walked on the newly seeded area effectively tamping the seeds into the ground. Staff and volunteers collected approximately 4000 seeds from mature Presidio clarkia plants and dispersed all seeds on-site in the same workday.

Plate 3: Soil preparation for clarkia seeding, September 2015.

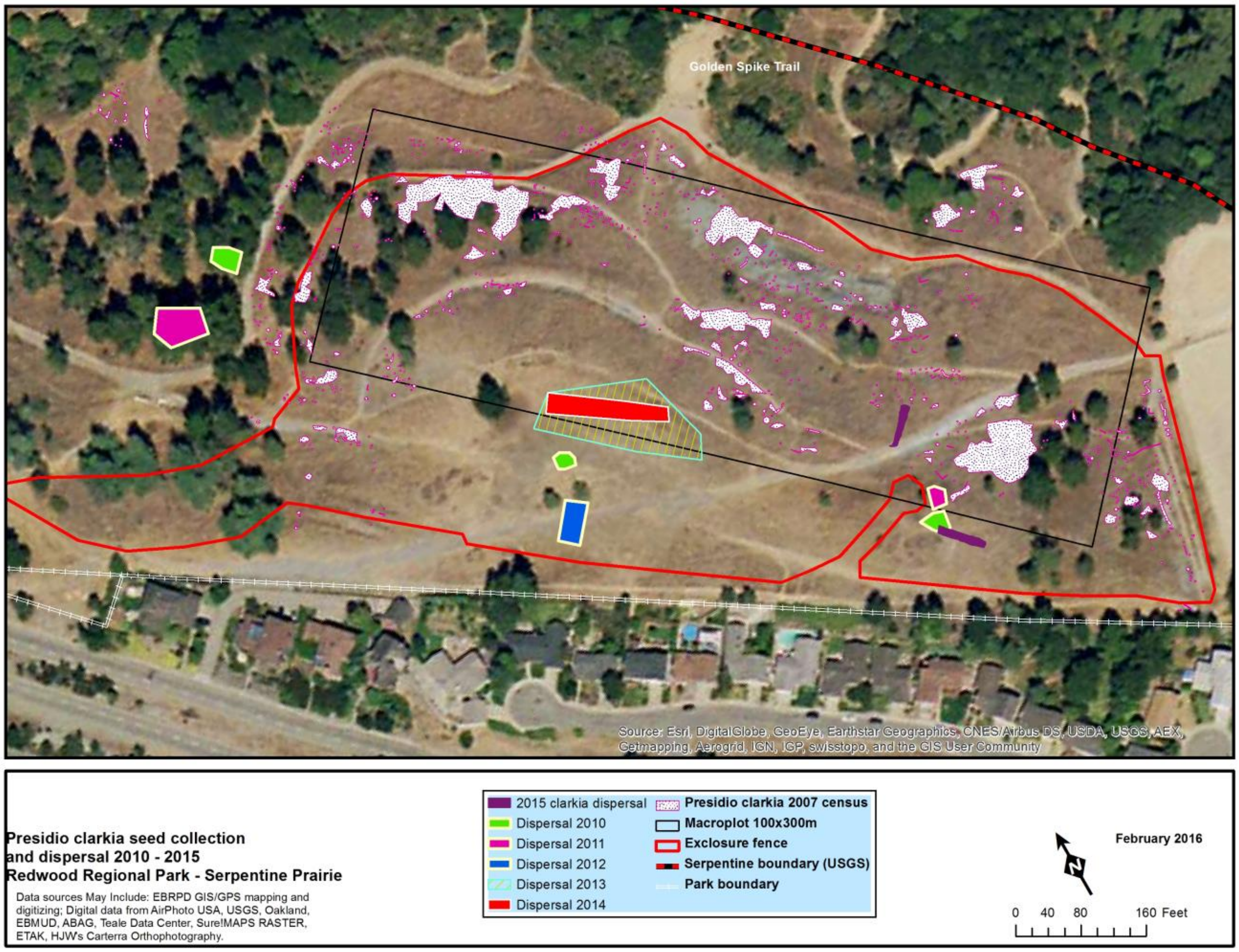


Figure 8: Seed dispersal map of 2015 seeds and past year's dispersal efforts.

Plate 7: Reduction of tree cover has greatly increased native prairie habitat at Redwood Regional Park.

Conclusions Years 2008-2015

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 (Plate 7, previous page). 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. Unfortunately most tree removal is complete in the core habitat, although there may be peripheral areas to consider for grassland restoration.

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. 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 non-native annual grass 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.

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). Spring mowing in low density clarkia-occupied areas will likely increase clarkia numbers.

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 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 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 (>50 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 ($r^2 = 0.9$). Increasing clarkia numbers and total occupied area through restoration and seed dispersal creates a population that is more resilient to drought and other climatic extremes.

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 in drier years.

7. Natural variation in the prairie soils and habitats make this site uniquely qualified for maintaining Presidio clarkia over the long term, through both wet years and drought years alike. One of the keys to management is ensuring that a topographic diversity of grasslands is maintained – hot south facing slopes, as well as cooler, deeper north faces soils and slopes.

Year 8 Proposals

The tree removal treatments have been completed and vegetation analysis is complete for mowing as a treatment tool. Therefore, we shift focus to managing clarkia habitat in the most ecologically sensitive and cost effective manner. Removal of any remnant duff and creation of bare ground generally creates a flush of clarkia plants the following spring. In addition, there are areas of lower quality serpentine, just north of the Prairie proper which have undergone tree removal and could contribute to the habitat diversity of the Prairie ecosystem.

The number of positive results created by spring mowing is encouraging. It is the single best and reliable tool for maintaining the Prairie right now. We recommend collaborating with Civicorps if they are flexible on their spring scheduling. It is critical for any land manager to be responsive to ecological cues for effective management. The appropriate mowing window is generally within two weeks in spring, with the timeframe moving by as much as a month from year to year. Mowing too late or too early may negate the entire benefit, and managers must track the year's phenology and schedule treatment when appropriate. EBRPD and Creekside staff are critical in overseeing the spring mowing and ensuring that the progress made in 2011 thru 2014 is not lost.

Targeted, well-managed grazing may be as effective as mowing in maintaining the quality of Prairie. We highly recommend continuing with the grazer and installing some monitoring plots to observe grazing effects on the Prairie, eventually with the goal of extending the grazing into clarkia-occupied areas.

We also 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 resampling the clarkia macroplot in 2016, which provides a statistically robust estimate of the population. In this record multi-year drought, 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. This is recommended but not essential for 2016.

We do not recommend implementing a monitoring program specifically designed to compare vegetation inside and outside the exclosure. Although this was once considered useful, the exclosure seems to not be a major factor contributing to, or against, prairie health.

We have anecdotally observed an increase in fruits on clarkia that have been accidentally mowed during our mowing (see 2012 and 2013 annual reports). This compensatory growth was intriguing and we would like to evaluate mowing (simulated grazing) as it effects plant survivorship and fecundity. Other studies have shown beneficial growth with simulated grazing (Maschinski and Whitham 1989). We recommend considering two small scale pilot studies: 1) tracking clarkia individuals from germination to fruiting especially with an eye on mortality and seed production, and 2) a pilot study following individuals which have been topped (mowed at the same time as we recommend for annual grass control) in order to assess mortality and seed production.

References

Bay Area Open Space Council. 2011. The Conservation Lands Network: San Francisco Bay Area Upland Habitat Goals Project Report. Berkeley, CA.

Naumovich, Lech, Niederer, Christal, and S. B. Weiss. 2015. Serpentine Prairie Restoration Project, Redwood Regional Park. Year 7. Creekside Center for Earth Observation. Menlo Park, CA. Submitted to East Bay Park District.

Creekside Center for Earth Observation. 2014. Serpentine Prairie Restoration Project, Redwood Regional Park. Year 6. Creekside Center for Earth Observation. Menlo Park, CA. Submitted to East Bay Park District.

Creekside Center for Earth Observation. 2013. Serpentine Prairie Restoration Project, Redwood Regional Park. Year 5. Creekside Center for Earth Observation. Menlo Park, CA. Submitted to East Bay Park District.

Creekside Center for Earth Observation. 2012. Serpentine Prairie Restoration Project, Redwood Regional Park. Year 4. Creekside Center for Earth Observation. Menlo Park, CA. Submitted to East Bay Park District.

Creekside Center for Earth Observation. 2008. Serpentine Prairie Restoration Project, Redwood Regional Park. Creekside Center for Earth Observation. Menlo Park, CA. Submitted to East Bay Park District.

East Bay Regional Park District (EBRPD). 2008. Serpentine Prairie Restoration Plan. Oakland, California.

Maschinski, J., and T. G. Whitham. 1989. The continuum of plant responses to herbivory: the influence of plant association, nutrient availability, and timing. The American Naturalist 134:1–19.

Sotoyome Resource Conservation District. 2010. The Grazing Handbook. Santa Rosa, California.

Stringer, Lew. 2011. Personal Communication. October, 2011.

U.S. Fish and Wildlife Service. 1998. Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area (in PDF). Portland, Oregon.

Weiss, S.B. 2002. Final report on NFWF grant for habitat restoration at Edgewood Natural Preserve, San Mateo County, CA.

Westmap. 2015. Climate Analysis and Mapping Tool. Accessed on January 15, 2016. http://www.cefa.dri.edu/Westmap/Westmap_home.php