Serpentine Prairie Restoration Project
Redwood Regional Park

2014 Annual Report: Year 6

A **Creekside Center for Earth Observation** Project
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March 17, 2015

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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 6th annual report, reporting results from the 2014 year, represents a change in the style of reporting. This report is streamlined in order to more succinctly present results, stewardship tasks, conclusions and future considerations.

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 2012-2014. 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.

Volunteers and EBRPD staff (not counting the time of the project manager, Denise Defreese) invested well over 250 hours in mowing, seed collection, and learning about the prairie and its unique resources. 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 lost after only a single rest year (when mowing was not completed). When we reinitiated mowing, the experimental plots rebounded almost completely to conditions similar to those found after three years of successive mowing (e.g. 2011), characterized as high habitat quality with reduced annual grass cover. 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.

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. 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. Clarkia is typically distributed in thin soils and on a few thick soil lens on northeast facing slopes.

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 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.

We recommend continuing the following efforts in 2015: 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) execute 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.

Introduction: Project History, Ecological Site Description

Plate 1: Clarkia franciscana

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.

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).

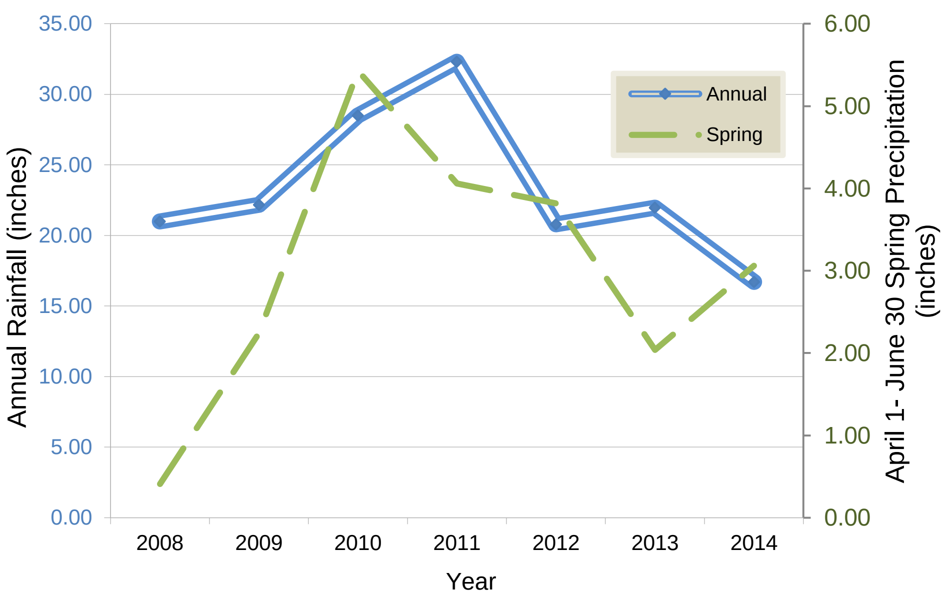

Figure 1: Precipitation at Serpentine Prairie (Annual and Late Spring)

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.

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).

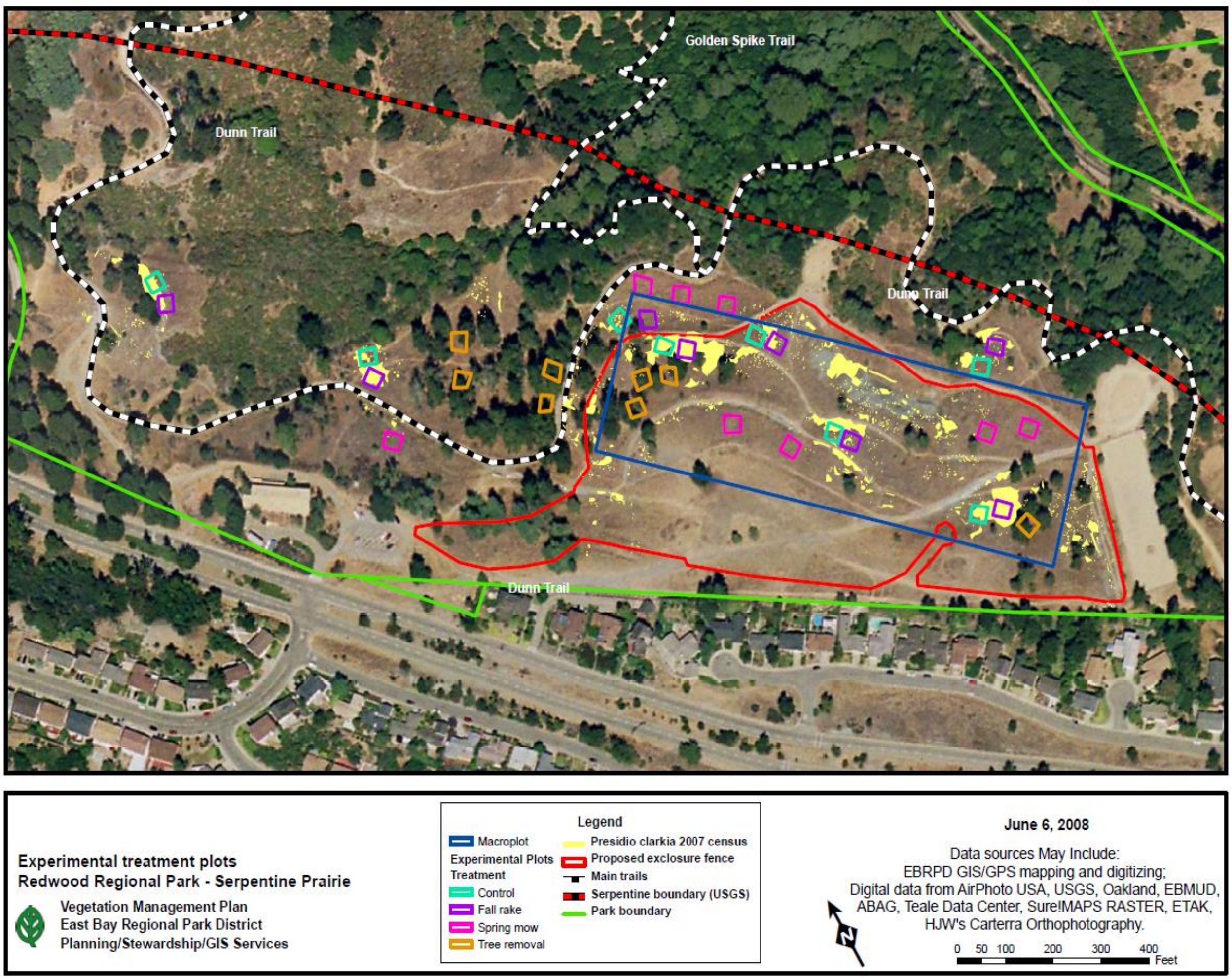

Figure 2: Plot locations

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.

Research Results and Discussion

Clarkia Macroplot

In 2014, the macroplot was reinitiated in the 3rd year of a multiyear drought (Plate 2). Macroplot surveys were 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 2014-2015 water year appears to be another drought year and thus may further test population variability in multi-year drought conditions. In 2014, macroplot numbers were similar to 2009 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.

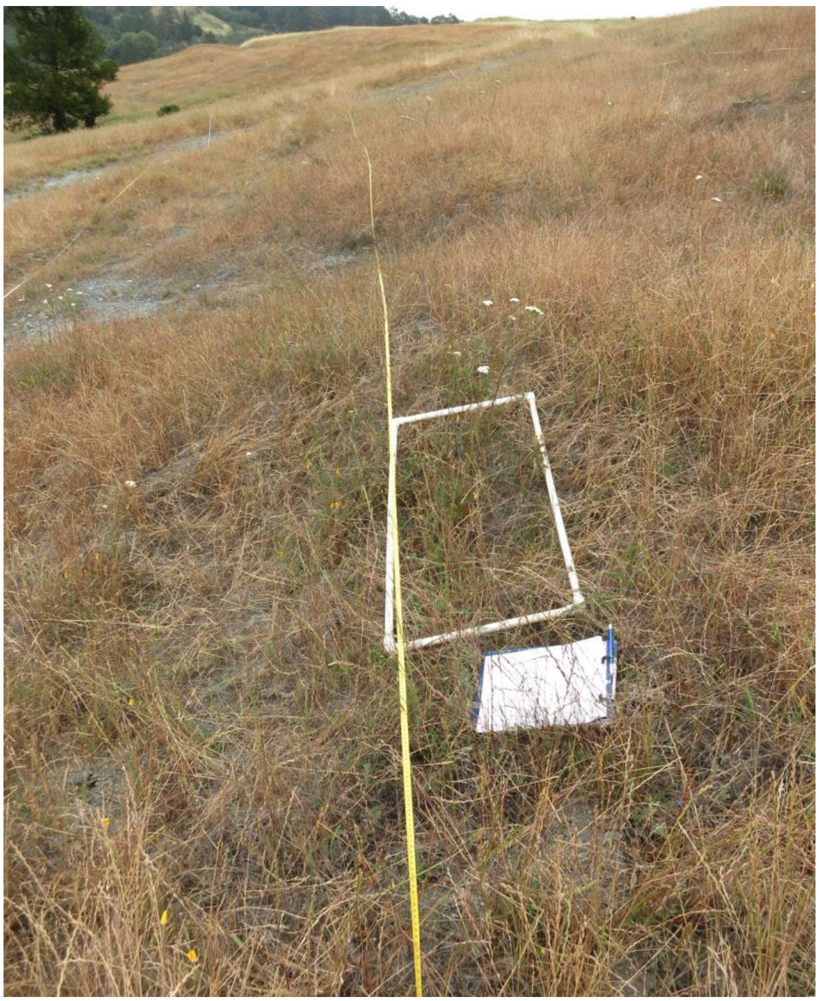

Plate 2: Recording clarkia within the macroplot

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

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 3). Although the two macroplots differ in size, the degree to which they are changing indicates that local climate and environmental conditions were similar.

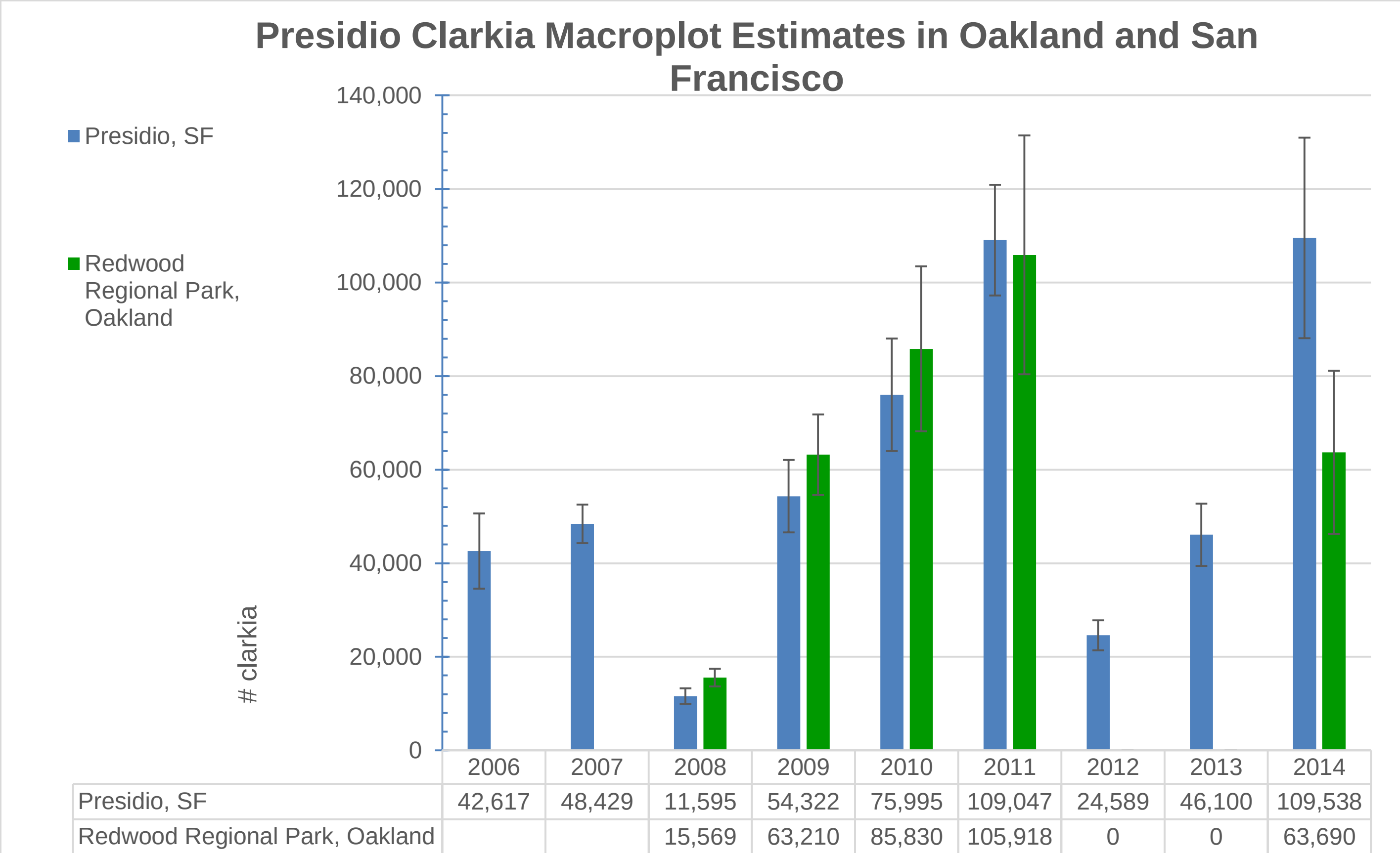

Figure 3: Comparison of Clarkia macroplot estimates from Oakland and San Francisco populations. Zero (0) in 2012 and 2013 indicate no data since the macroplot survey was not completed.

Clarkia Census

Clarkia individuals are annually censused in the experimental plots (Table 2). Baseline data are shown in 2008. Reference plots declined in 2014, while tree removal plots contained similar numbers of clarkia. Removal of trees has restored occupied habitat that was lost decades ago, and these numbers contribute to the stabilization of the overall population at the Prairie.

Table 2: Total clarkia individuals per treatment

	2008	2009	2010	2011	2012	2013	2014
Reference	1,229	3,030	5,728	11,130	2,268	2,301	1,592
Fall rake[2]	1,238	3,254	935	2,317	N/A	N/A	N/A
Spring mow[3]	0	24	2	41	3	28	13
Tree removal	15	184	810	621	1183	728	797

Over the course of our study, total rainfall and clarkia populations proved to be well correlated, with total precipitation explaining about 75% of the variance (Pearsons correlated $r^2 = 0.75$) (Figure 4). 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 ($r^2 = 0.52$).

[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. Clarkia have since passively colonized.

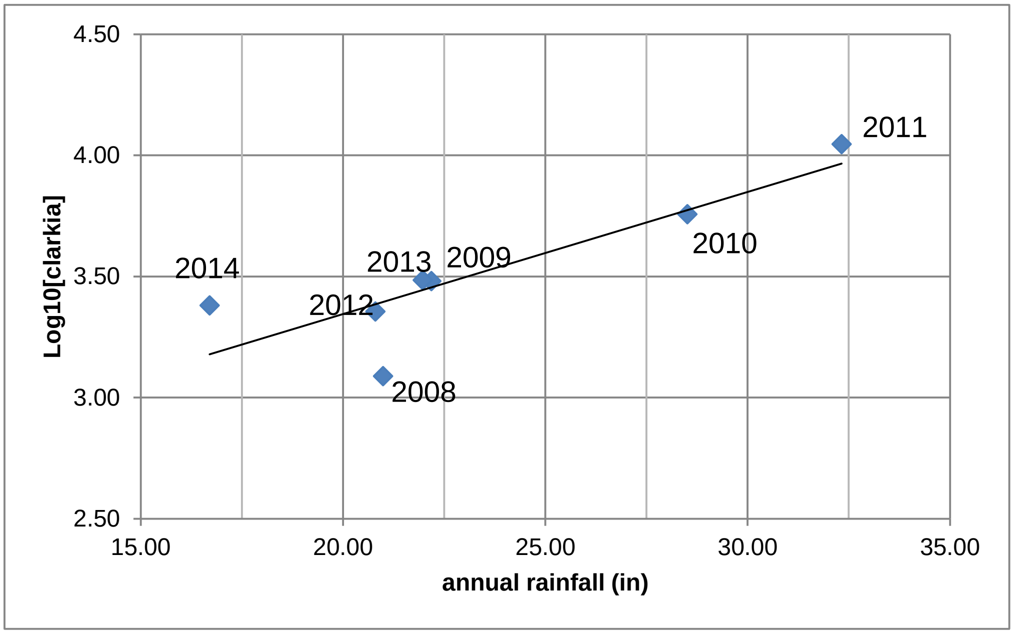

Figure 4: Regression analysis of log transformed clarkia population in reference plots and total annual precipitation

Clarkia continues to germinate and reproduce in spring mow plots. We expect that although spring mowing is improving the habitat quality for annual forbs, the initial low numbers of clarkia preclude large increases. While the clarkia have passively recruited into the plots, the ongoing low numbers suggest they may be poor dispersers. Actively moving seeds into mowed areas may be needed to see larger increases.

Tree removal numbers stayed stable. We believe that the ground disturbance from tree removal may have stimulated clarkia germination in 2010 and 2012, years when the Prairie had active tree removal projects. This was the first year the "post-tree removal decline" was not observed indicating that the populations may be stabilizing in the tree removal plots.

Experimental Plot Data

Baseline data collected in 2008 are compared with 2014 data for four guilds that provide a snapshot of how the experimental treatments affected native annual forbs, non-native annual grasses, bare ground, and perennial grasses (Figure 5). 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.

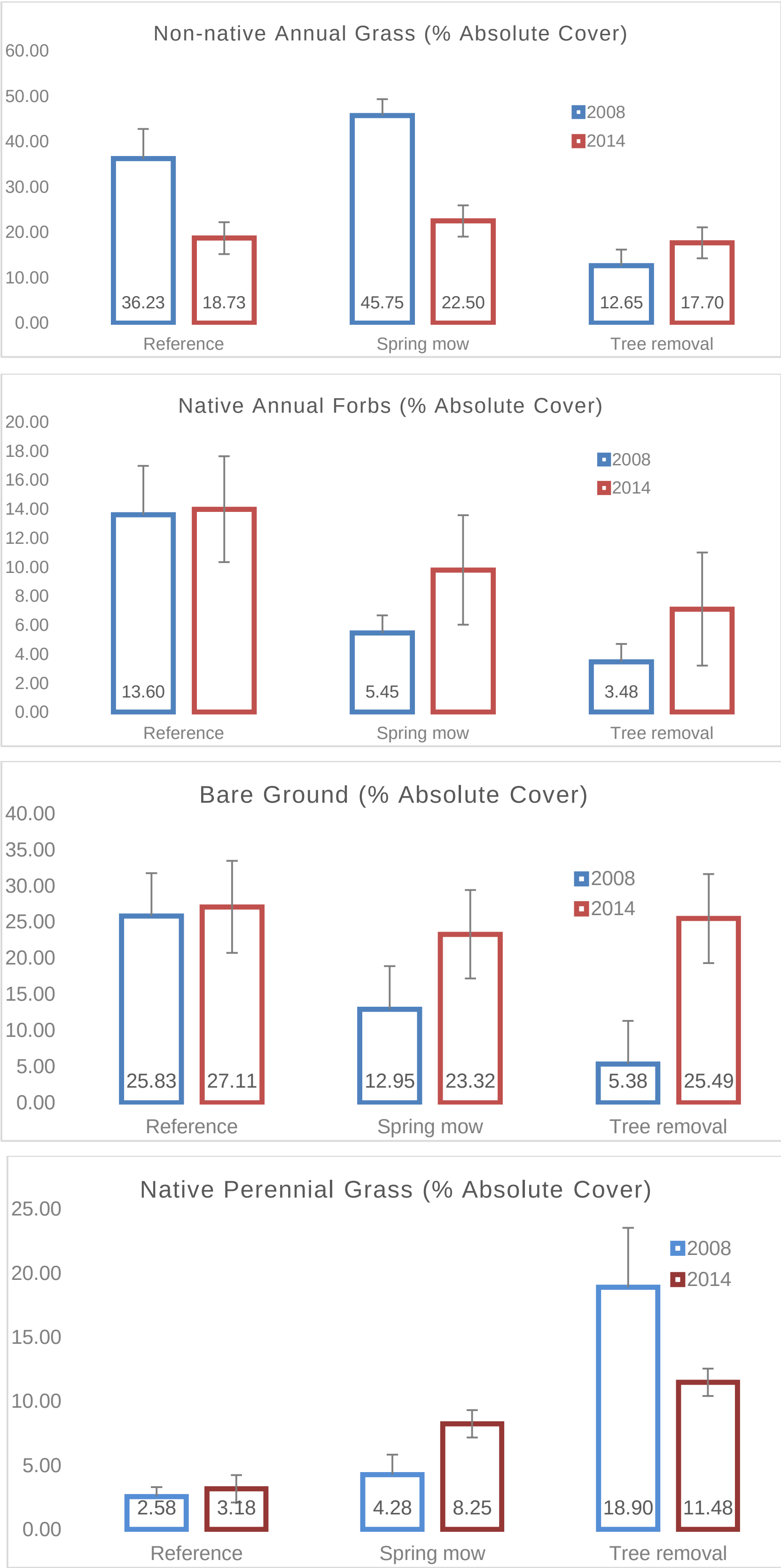

Figure 5: Vegetation changes from 2008 to 2014 at the Serpentine Prairie. All data is presented with a 90% confidence interval.

Reduction of non-native annual grass was the objective of timely mowing. Our results over the entire study indicate that mowing effectively reduced non-native annual grass cover by about 50%. The niches that were once occupied by non-native annual grasses were converted to a mix of predominantly bare ground, annual forbs and native perennial grasses. Each of these three guilds are considered beneficial to both clarkia habitat and establishing a resilient, healthy native prairie. Tree removal plots continued to harbor low non-native grass cover, while annual forbs and bare ground increased, although it was at the cost of native perennial grasses that likely benefited from the cooler, shady tree canopy.

Photographs from each treatment type were randomly selected and presented below (Plate 3). The goal is to restore vegetation to reference plot conditions where the native forbs and grasses persist with low cover of non-native annuals. Visual inspection indicates that results from the spring mow treatment has produced habitat similar to reference plots, whereas the tree removal plots contained higher grass cover for this subset of plots.



Plate 3: Plots from top left (R5 reference), top right (S5 spring mow), bottom (T2 tree removal)

Soil Depth Mapping

A soil depth map was created for the Serpentine Prairie grassland area, including non-occupied sites (Figure 6). Soil depth seems to correlate well with clarkia distribution on flat and warmer slopes: thinner soils were more likely to be occupied than thick soils. Notably, northeast facing slopes, which are often cooler, had some deeper soils where clarkia is thriving. These sites may become especially important in dry years when water is limited, competition may be lower, and late season annuals can tap into a deeper profile of serpentine soil.

This map helps highlight new areas where soil depth is optimal for clarkia growth. Clarkia seems to be regularly associated with the following soils and slopes:

1. On flat, west, and south facing slopes, clarkia is well correlated with thinner soils (< 30 cm).
2. North-facing, cooler slopes often have considerable clarkia populations in deeper soils (>50cm).

Optimal soil areas that may be targeted for future seed translocation.. 2015 clarkia dispersal should target soils that are representative of where the plants are observed now. This map can also provide guidance for reconsidering mowing and clarkia dispersal into thicker soils such as those directly west of the Trudeau Center and parking lot.

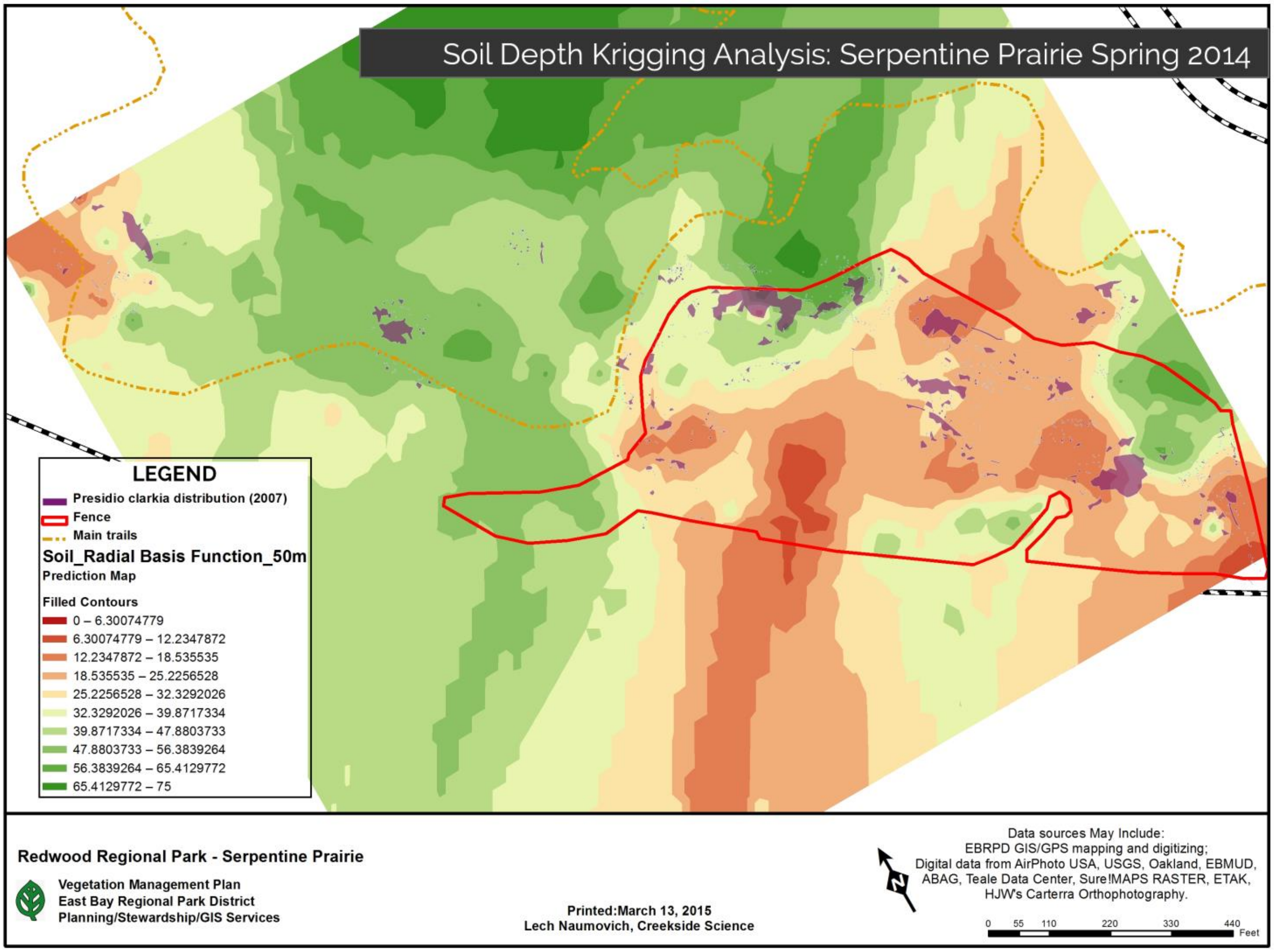

Figure 6: Soil depth analysis of Serpentine Prairie. Approximately 70% of clarkia polygons occur on soils from a depth of 6-40 cm, as denoted by the orange to yellow color range.

Stewardship Results

Completed Land Management and Monitoring Tasks: 2008-2014

Tasks completed by Creekside Center for Earth Observation from 2008 to 2014 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. This technique was discontinued.

- From 2008 to 2011 and again in 2014, 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.

- 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 thru 2014, 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 in 2014.

- 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 Collaboration with EBRPD Staff

Plate 4: Spring mowing on the northern end of the Serpentine Prairie, April 2014

In 2012 thru 2014, Creekside staff worked alongside EBRPD employees mowing nearly 3 acres of non-native grassland adjacent to occupied clarkia habitat (Plate 3). Trained contractors can mow swaths of high density non-native grasses while minimizing impact to native perennials and desirable forbs. Most areas mowed in 2014 were also mowed in 2011-2013. With limited resources, we feel it is important to concentrate efforts in areas that have already been treated in order to maintain habitat improvements.

Prioritizing mow areas is essential for ensuring that funding is spent effectively. Although the entire grasslands area will respond to well-timed mowing, we recommend targeting areas (Figure 7) 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.

Presidio Clarkia Recommended Mow Areas

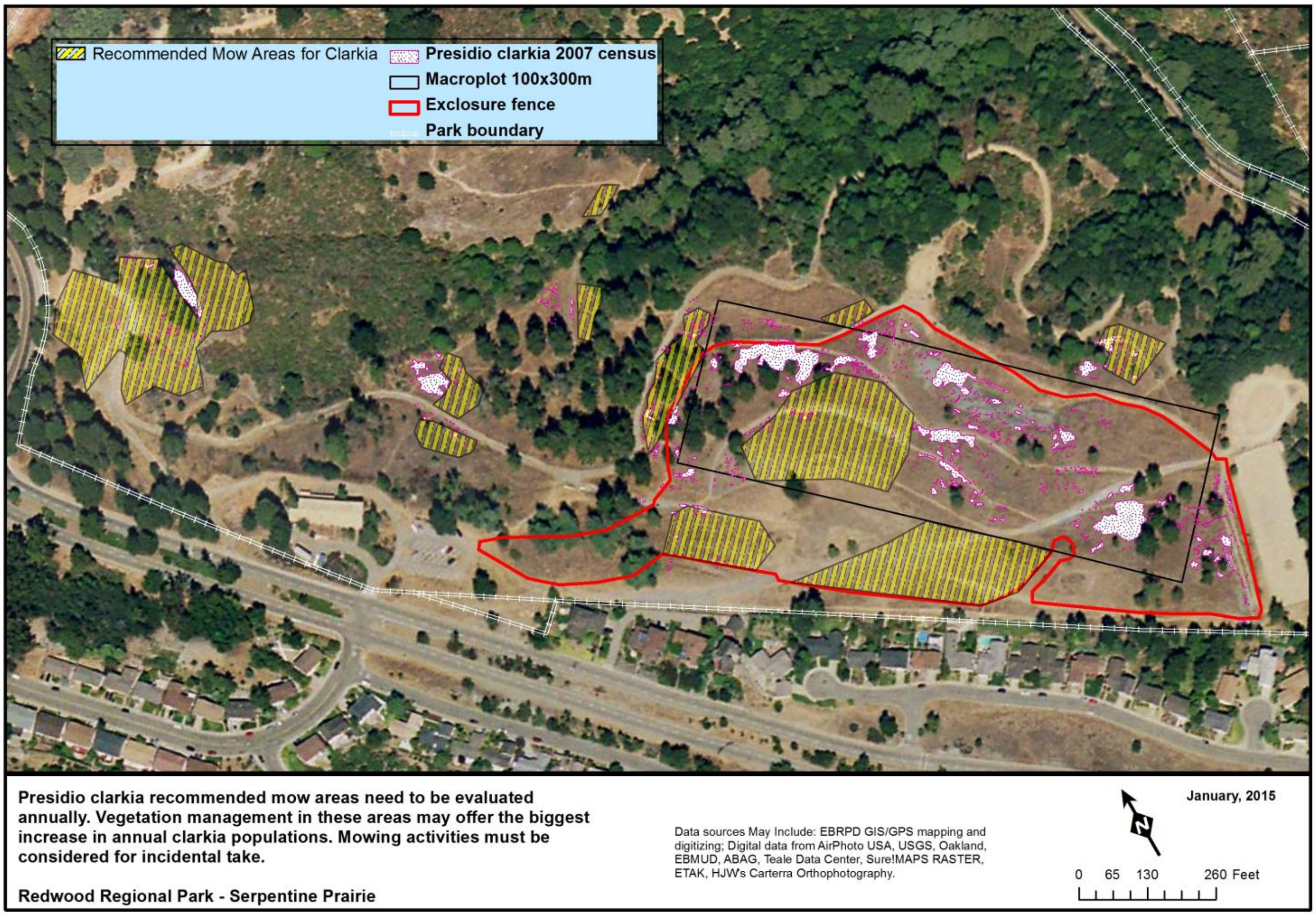

Figure 7: Recommended areas for mowing consideration that will likely benefit the population of Presidio Clarkia at the Serpentine Prairie. Mowing needs to follow all DFG and DFW regulations.

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 5).

Plate 5: Grazing trial at Hunt Field, July 2014.

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 2014, Creekside staff lead a workshop aimed at training EBRPD staff on seed collection and dispersal methods for clarkia. Workshop participants collected approximately 3000 seeds from mature Presidio clarkia plants and transferred them to Hunt Field where soils were lightly raked to allow for better soil-seed contact. No more than 5% of seeds from any given plant were collected to minimize impact to the existing population. Seeds were sown immediately so no seeds were removed from the Prairie.

Three sites where seeds have been dispersed are considered successful. Overall survivorship across the site varies from 0 to 82.5%. Survivorship rates in the Presidio are around 20% (Stringer, personal communication). Our results varied based on which of the three techniques we used:

1) large scale (1000 m^2) broadcast seeding with no soil disturbance,
2) seeding of a hand-scraped area (100 m^2) globally removing all thatch and organic matter regardless of growing plants,

3) seeding of a hand-scraped area (0.5-2 m^2) disturbing top soil with a variety of techniques including rakes, light hand tools, and scuffs caused by feet – creating a smaller scale heterogenous,disturbance among desirable plants.

Technique 1 was used at 3 sites. They have 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, which is too shallow at this site. A minimum amount of soil (3 cm) is needed for seed germination and establishment. We do not recommend continuing this technique.

Technique 2 was used at a 2012 site and the results continue to be promising. Clarkia continues to occupy the PO2012 site with roughly 15% of the original seeded number (150 plants) observed in May 2014. Unfortunately since this site has deeper soils, annual grasses have already moved in and established within the scrape area. This technique may be ideal for slightly thinner soils where tree duff or a light organic layer exists.

Technique 3 was used in both earlier trials, and in 2014seed trials. The sites were disturbed, but not as harshly as with heavy equipment or shovel blades removing 1-2 inches of soil. All plants and material was pulled back but no major soil movement occurred. Since we've had two very dry years, germination was very low in all 2014 sites and we hope to have better numbers in 2015. All dispersal effort for 2014 was concentrated in a smaller area of the 2012 dispersal polygon where soils are thin. Numbers for dispersal trials will be reported in the 2015 annual report.

Plate 6: EBRPD staff and volunteers translocating clarkia seed, 2014.

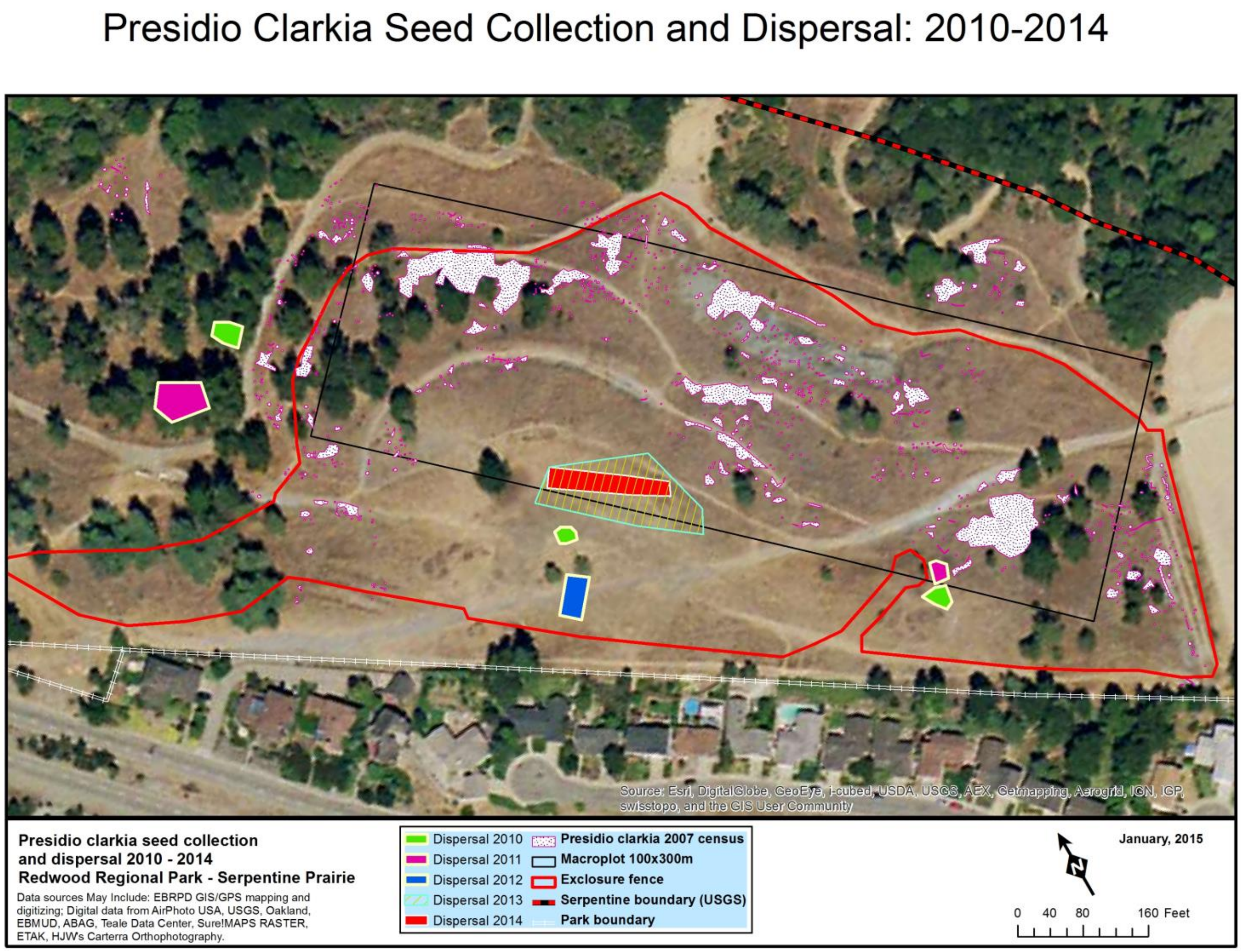

Figure 8: Seed dispersal map. 2014 seeds were dispersed in the 2012 polygon after little survivorship was observed in 2013 and 2014.

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

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 (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 (Figure 12). 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 7 Proposals

The tree removal treatments have been completed, and we shift focus from creating new clarkia habitat to managing it. 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 mowingin 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 2015, 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.

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 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 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.

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