Serpentine Prairie Restoration Project

Redwood Regional Park

2016 ANNUAL REPORT

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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 following report presents data and information on the 8th full year of ongoing research and management. The Redwood Regional Park – Serpentine Prairie is owned and managed by the East Bay Regional Park District (EBRPD). The Prairie has undergone a dramatic transition over the course of this time period, most notably characterized by the removal of trees from large portion of the project area followed by the restoration of perennial grasslands colonized with an endangered annual forb, Presidio Clarkia (*Clarkia franciscana*).

In 2016, the focus of the project was stewardship activities, research and education. The highlights of stewardship work included the phenologically timed mowing of approximately 3 acres of serpentine grasslands, the execution of a grazing study which mimicked potential grazing impacts on the Presidio clarkia, monitoring of grassland vegetation changes in response to grazing activity, and the translocation of approximately 8,600 Presidio Clarkia seeds to two different locations at the Prairie. 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. We continued the large scale mowing of Hunt Field and surrounding potential habitat areas for Presidio Clarkia. Past results from test plots show substantial habitat benefits of reduced annual grass, increased native forb, and increased bare ground cover after three successive years. This year, 150 clarkia individuals were experimentally cut to 6 inches, emulating a possible grazing method, were tracked through the year to observe survivorship and fecundity. There was no significant difference in Clarkia fruit length or number per plant observed between the clipped plants and the control plants. The macroplot was not completed in the year, as in past, nor was vegetation surveyed in the treatment plots established in 2008. Instead, the project has focused towards on-the-ground improvements.

Current work is focused a few key aspects of the prairie:

- Monitoring of the Presidio Clarkia population
- Increasing the habitat quality and distribution of Presidio Clarkia across the Prairie
- Researching various tools for habitat stewardship that are cost effective and ecologically sensitive
- Increasing awareness of the unique resources of the Serpentine Prairie by creating outreach and service-based learning activities

The following report represents the first year that the Serpentine Prairie project was transferred from Creekside Science to Golden Hour Restoration Institute.

Introduction: Project History, Ecological Site Description

PLATE 1: PRESIDIO CLARKIA

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). The 100-year average for annual precipitation for this site is 27.63 inches.

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1 Presidio clarkia will hereby be referred to as “clarkia” throughout the document. Although another *Clarkia* species does occur just off of the serpentine bedrock (*Clarkia rubicunda*), it is not germane for this report.

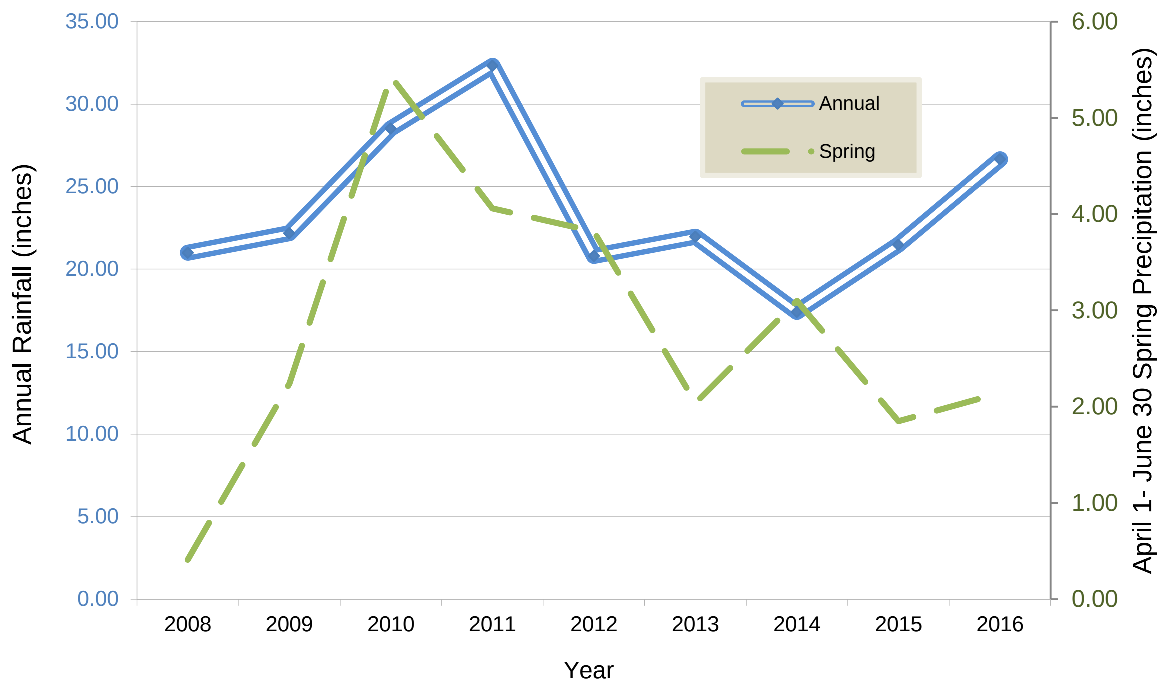

FIGURE 1: PRECIPITATION AT SERPENTINE PRAIRIE (LATITUDE = 37.8129, LONGITUDE = -122.187675)

Methods

Methods for our experimental work are described in full in previous reports (Naumovich et al. 2014). Although all these studies are not active for this report, we are still continuing to provide the methods since the results may be referenced in this report.

Macroplot

A macroplot is a large, permanent plot that is surveyed in order to provide statistically defensible measurements of the population of the Clarkia. The Clarkia population of the permanent macroplot (Figure 2) (100 x 300 meters) was estimated by selecting twenty transects that extend the 300-meter length of the macroplot. Transects are selected in a restricted random start. A 1x0.5m quadrat is then placed along the transect line. Total plants that are identified in each quadrat are recorded, summed and then used to report the macroplot population. The full method is described in Appendix D of the Serpentine Prairie Restoration Plan (EBRPD 2008).

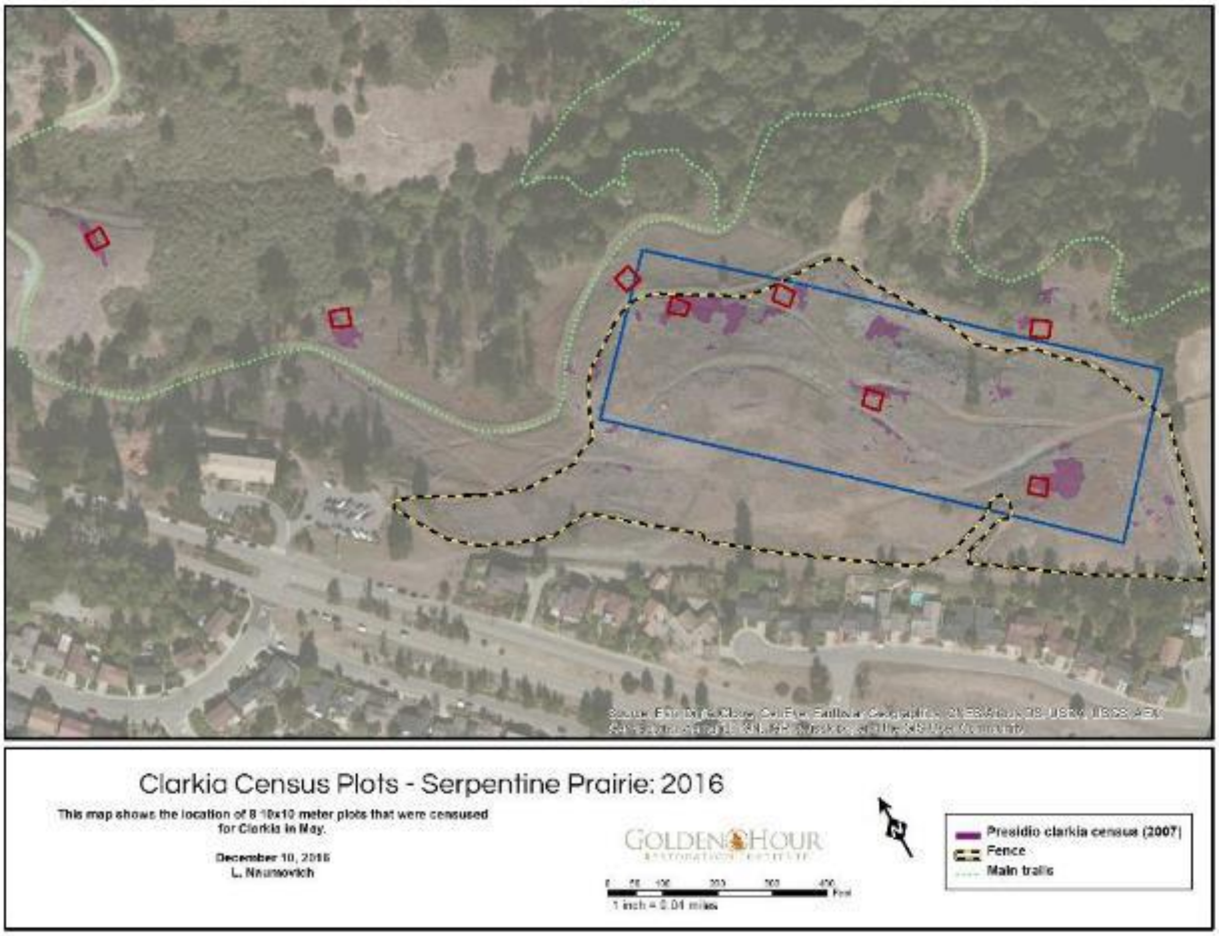

FIGURE 2: MACROPLOT, CLARKIA CENSUS PLOTS, AND TRAILS AT SERPENTINE PRAIRIE (MAP BY EBRPD, 2008)

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 during 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 (data displayed above in Figure 2). 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 gazing transects were installed in the fall of 2015 as three sets of two paired transects. Each pair included a control and a grazed transect. The paired transects were chosen to visually contain with similar pretreatment habitat, soils and exposure. In 2016, only 4 transects (2 pairs) were surveyed because the last pair was substantially different from the other 2 pairs found on and near Hunt Field (Figure 3).

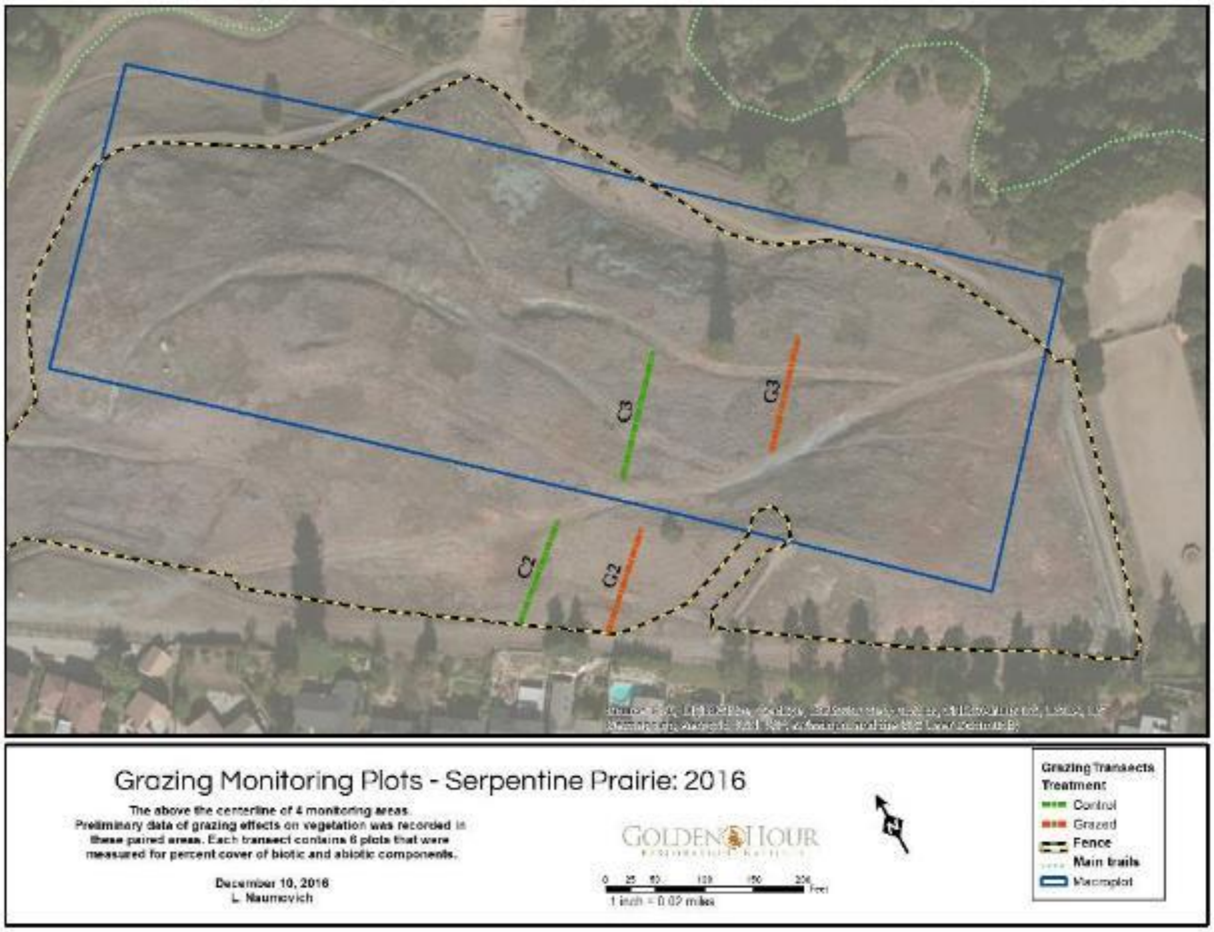

FIGURE 3: GRAZING MONITORING TRANSECTS

These were placed with the aid of EBRPD staff (Denise Defreese) and a local grazing operator who conducted the initial grazing experiments, Brittany Cole Bush of Star Creek Land Stewards, Inc. Ms. Cole was the project manager at the time transects were selected. Ms. Cole was instrumental in helping determine the number and type of grazing animals for this project. Transects were fit into the constraints of the grazing areas, therefore their lengths are not standardized. One pair of transects is 35 meters in length, the second is 30 meters.

We will conduct the following vegetation measurements on an annual basis:

- Read 6 ¼ m^2 square quadrats per 30m 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 0.1% indicating that a very small individual (usually an annual) was located. Vegetation transects will alternate on either side of the transect, with the back edge ending on a 5m or 0m mark (Figure 3).

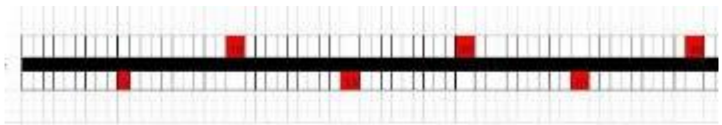

FIGURE 4: 30 METER TRANSECT WITH QUADRAT PLACEMENT LOCATIONS ALONG LINE.

- 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.

Clipping Experiment

A pilot experiment to observe the impact of grazing and mowing was initiated in 2016. This experiment was designed to test the impact of cutting Clarkia during the spring. Patches of plants (where plant density was < 10 plants/m^2) were identified in the Hunt field area (Figure 5). Each of these patches was randomly assigned to be a treatment or control plot. Individual plants were labeled with a roofing nail (Plate 2). Plants in the control plots were left unmanaged for the year. Plants in experimental plots were clipped to 6 inches and then observed. Plants that were not 6 inches tall were not clipped. This clipping height is intended to emulate an achievable mowing and grazing height under highly controlled conditions.

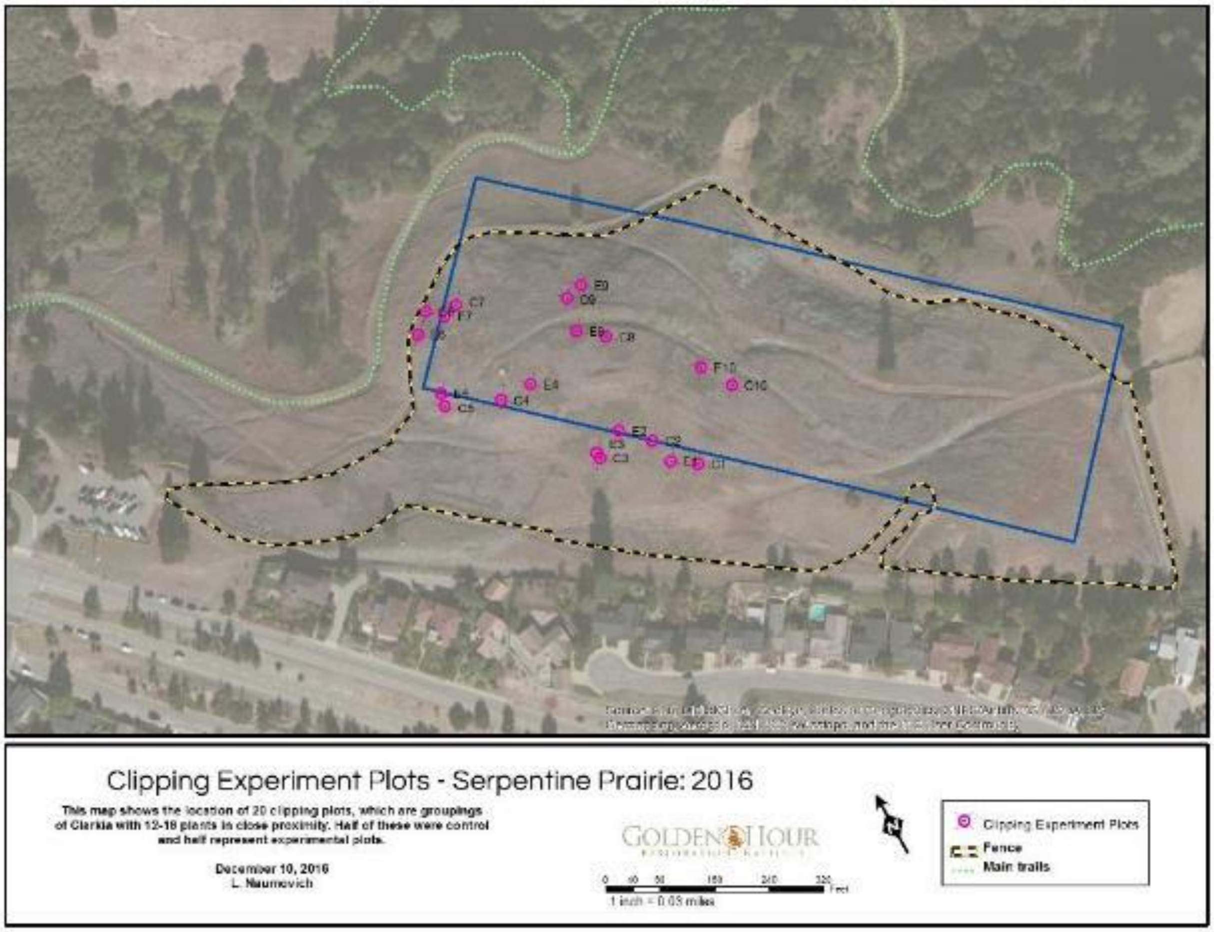

FIGURE 5: CLIPPING EXPERIMENT AREAS

In August, once the annual plants had all naturally senesced, plots were revisited. For each plant, the following information was recorded:

I. Fruiting – Did the plant produce fruits (Y/N)
II. Number of fruits per plant (discrete integer)
III. Length of fruit (measurement in mm) from attachment point (where pedicle begins to become enlarged) to tip of fruit.

PLATE 2: CLIP PLOTS WITH PINK MARKER IN CENTER

Research Results and Discussion

Clarkia Macroplot

In 2015, the macroplot was not scheduled or completed. Prior years' data is presented in Table 1. Although this measurement provides useful information, it comes at a high cost of approximately 80 researcher hours. We hope the macroplot can be completed every other 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
2013	N/A	N/A
2014	63,690	17,461
2015	56,920	14,100
2016	N/A	N/A

Although the macroplot was not completed, we can match the recorded annual precipitation to the population-precipitation model for Clarkia (Figure 6). Based on this model, we expect the macroplot population in 2016 was about 80,068. Since this was calculated and not measured, we cannot assign a confidence interval to this number.

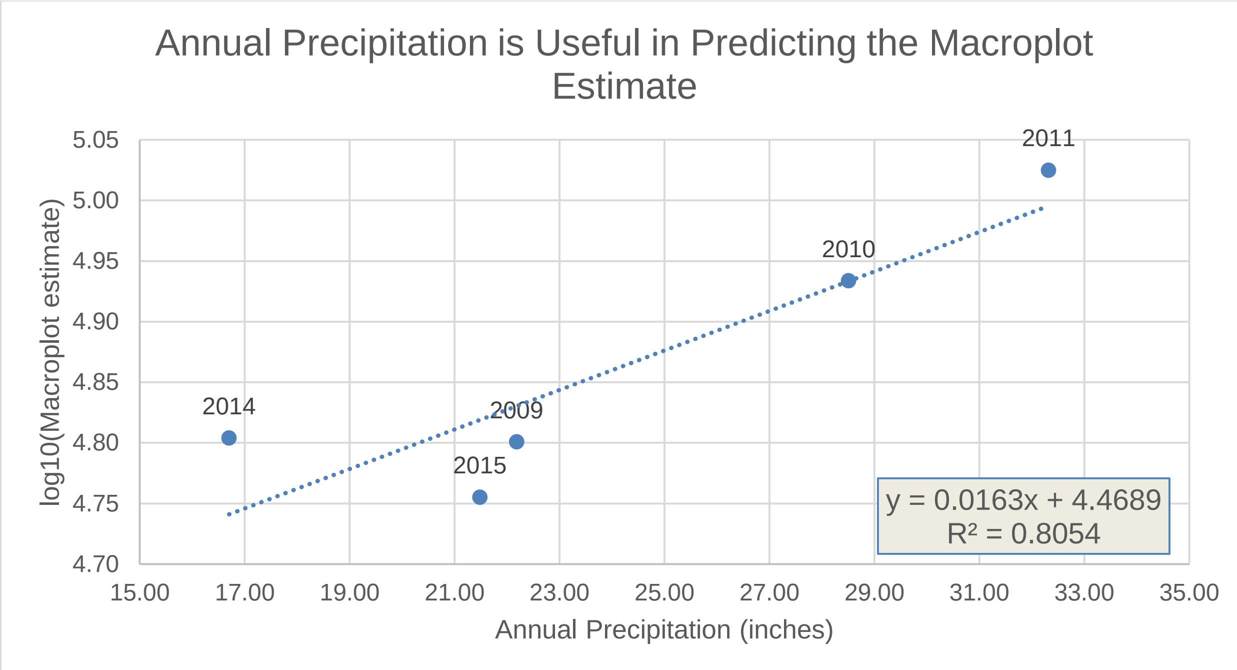

FIGURE 6: COMPARISON OF ANNUAL PRECIPITATION AT THE PRAIRIE TO MACROPLOT ESTIMATE NUMBERS.

Clarkia Census in Reference Plots

Clarkia were censused in 8 reference (control) plots at peak bloom when Clarkia were most easily observed. This year was marked by an increase in the total Clarkia counted versus 2014 (Table 2). These numbers are only about 30% of the 2011 high point.

TABLE 2: CLARKIA CENSUS COUNTS IN 8 REFERENCE PLOTS

	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Count of Clarkia (800 m^2) survey area	1,229	3,030	5,728	11,130	2,268	2,301	1,592	N/A	3,301

Notably, the C1 plot located at the northern end of the Prairie has shown declining numbers of Clarkia. It is possible that this area had a large seed flush when the mature trees were removed during the original Prairie restoration work in 2010, and the “flushing effect” is now minimal 7 years later.

Another notable decline from the beginning of monitoring is reference plot C8 located in the southeastern extreme of the Prairie. There has been a steady decline over the years and no Clarkia were found in this location in 2016. In 2016, Clarkia was observed in cooler, wetter locations about 10 meters from this plot, near the edge of the oak woodland.

Clipping Experiment

A total of 300 plants were observed during the 2016 spring and summer. Experimental design called for a total of 150 plants to be clipped (or cut) to 6 inches, which is a reasonable height for mowing and/or residual grass height after a low density/quick graze of an area by cattle or sheep. In fact, some plants did not total 6", and therefore these plants were not cut. This represented approximately 75% of plants. About 25% of the plants randomly selected were too short to be clipped. We did regularly observe plants that were clipped and displayed compensatory growth (Plate 3 and the report cover).

PLATE 3: CLIPPED CLARKIA WITH 3 MATURE FRUITS IN SEPTEMBER. THE RED ARROW POINTS TO THE MAIN STEM THAT WAS CUT, WHICH IS WITHIN CM OF THE CENTRAL FRUIT.

We conducted a number of measurements and presented the two numbers that best represent fecundity: average number of fruits per plant and average length of fruits. The first measurement, average number of fruits per plant (counting plants with no fruits) allows us to determine if fruit production was impacted with clipping.

Control plots contained an average of 1.1 fruits per plant, while experimentally clipped plots contained 1.0 fruits per plant (Figure 7). A two-tailed t-test analysis reported a p value of 0.60 indicating that these results are likely the result of chance. With the given dataset, it is reasonable to conclude that the spring clipping of plants in 2016 did not have a significant impact on overall total number of fruits produced.

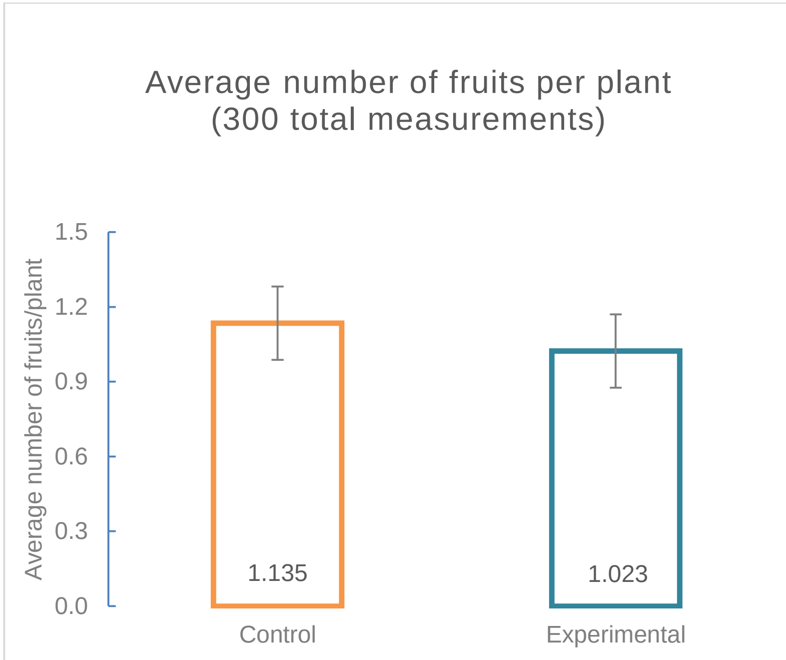

FIGURE 7: MEANS ARE PRESENTED FOR THE TEN EXPERIMENTAL GROUPS. ERROR BARS REPRESENT THE STANDARD ERROR OF MEAN.

The second experimental calculation measured whether fruit quality (length) is impacted by clipping. Fruits from control plants had an average length of 19.7 mm while fruits from experimental plants had an average length of 16.8 mm (Figure 8). Again, the experimental measurement is lower than the control, but it was not found to be statistically significant. A two-tailed t-test P value of 0.428 was calculated indicating the difference between these two groups is not statistically significant. With the given dataset, it is reasonable to conclude that the spring clipping of plants in 2016 did not have a significant impact on length of fruits produced.

It is important to note that experimental numbers were trending lower, therefore, clipping may have long term impacts on the population if mowing or grazing during the Clarkia growth season is repeated year after year.

Most importantly, this data does not take into account the related beneficial effects of grazing: reduced thatch, increased bare ground, reduced non-native annual grass cover, that may provide a net positive effect even though fecundity measures are slightly trending downward with clipping.

We would recommend continued experimentation and close monitoring of grazing as a management tool at the Serpentine Prairie.

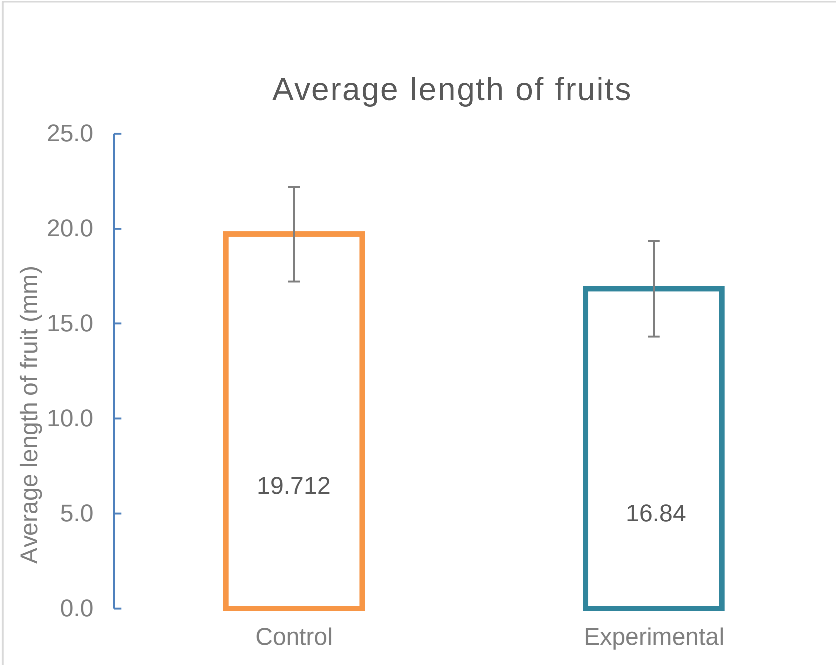

FIGURE 8: MEANS ARE PRESENTED FOR THE TEN EXPERIMENTAL GROUPS. ERROR BARS REPRESENT THE STANDARD ERROR OF MEAN.

Grazing experimental data is presented in the Stewardship Section in order to allow for the reporting of actions, followed by the representative monitoring.

Stewardship Results and Discussion

Completed Land Management and Monitoring Tasks: 2008-2016

Tasks completed by Golden Hour Restoration Institute and Creekside Center for Earth Observation from 2008 to 2016 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. Currently only the reference plots are regularly being surveyed.

- 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 once all the initial tree removal was completed. This technique is most useful the year in which tree removal is conducted so no take occurs.

- 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. The macroplot was skipped in 2016.

- 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. Four transects were read in 2016 and we will likely reposition the remaining two in 2017.

- In 2010-2016, collection of clarkia seed on site by methods specified by CDFW and USFWS. Seed was redistributed on site each year in potential, unoccupied habitat. In 2016, we achieved our highest total of relocated seed.

- 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 2016, 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 2014-2016.

- 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 2016, 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 4). Each location was surveyed for presence of clarkia and if found, plants were flagged and avoided. A total of 2.02 acres were mowed

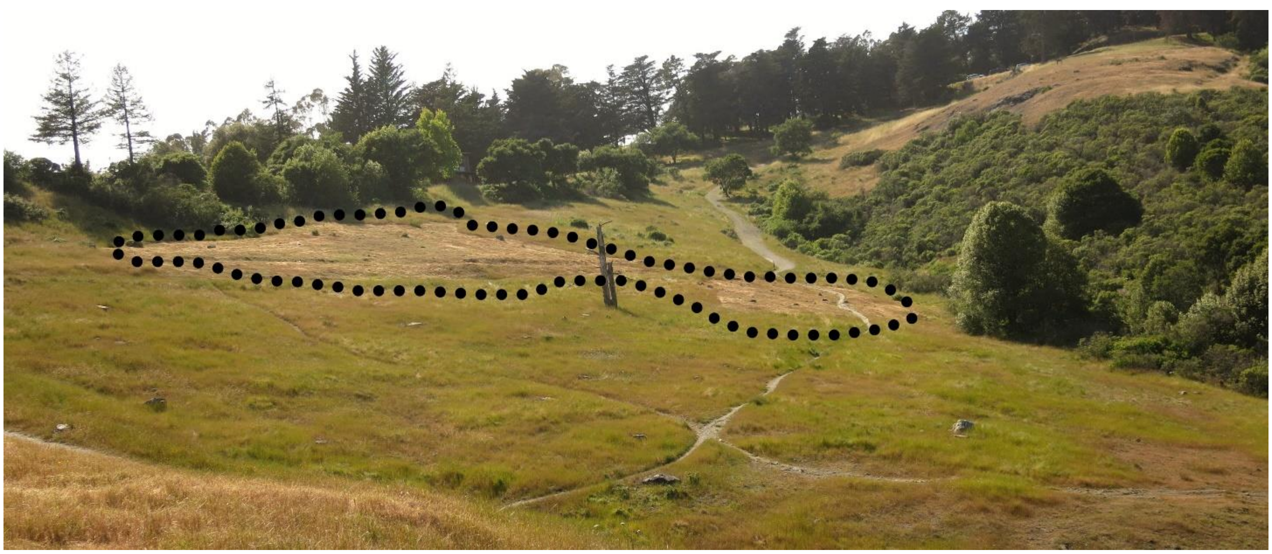

PLATE 4: SPRING MOWING ON THE NORTHERN END OF THE SERPENTINE PRAIRIE, APRIL 2015. BLACK DOTTED AREA SHOWS LOCATION OF A PORTION OF THE SPRING MOWING.

in 2016. As more clarkia is relocated, mowing becomes more and more tricky since clarkia is starting to popup in area where it was previously safe to mow without additional inspection.

Prioritizing mow areas is essential for ensuring that funding is spent effectively: this was completed in 2015 and 2016 (Figure 9). Although the entire grasslands area will respond to well-timed mowing, we recommend targeting areas 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.

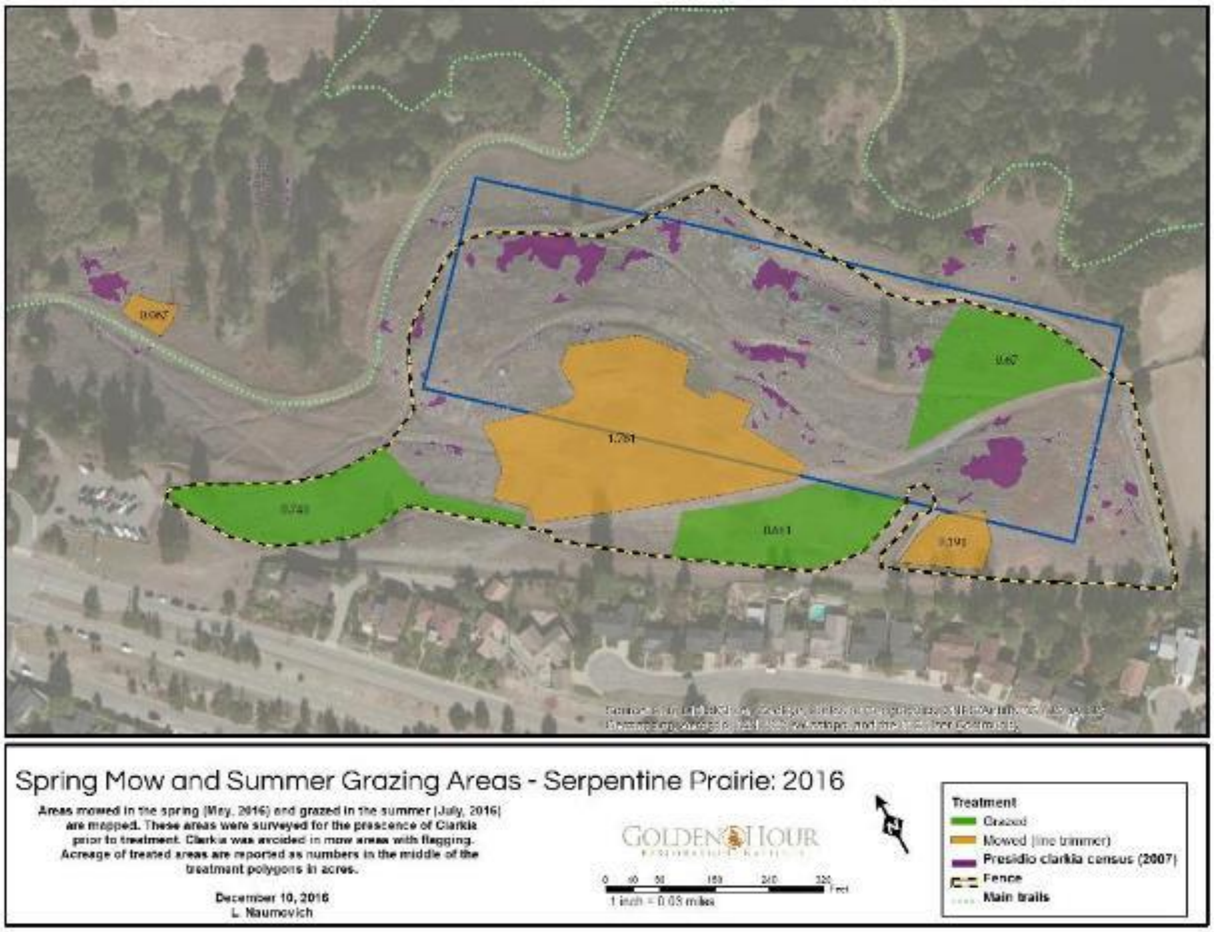

FIGURE 9: MOW AND GRAZE AREAS, 2016.

Grazing Trial

A grazing trial was initiated in summer of 2014 when an opportunity arose to work with a local, sensitive environmental grazing company: Star Creek Ranch. 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 (Plates 5-7).

PLATE 5: GRAZING TRIAL AT HUNT FIELD SHOWING ANIMALS ON SITE IN THE SOUTHEASTERN PADDOCK, JULY 2016 (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.

PLATE 6: A VIEW OF THE GRAZED SITES ON SEPTEMBER 6TH, 2016. THE RESIDUAL DRY MATTER (RDM) WAS INSPECTED AND STILL PROVIDES EFFECTIVE COVER AGAINST EROSION WHILE PRODUCING POCKETS OF BARE GROUND FOR ANNUAL FORB RECRUITMENT.

PLATE 7: TRANSECT C3 (NOTE YELLOW TAPE). THE GREEN AREA WITH WILDFLOWERS ON THE RIGHT IS AN AREA THAT WAS MOWED IN APRIL 2016. PHOTO: JUNE 2016.

Careful planning and timing of grazing was essential to ensure that Clarkia will not be negatively impacted by this practice, and the results of our fall grazing have been significant and notable. Significant benefits of grazing (conditions that improve the habitat per our goals) included grazed plots showing an increase in bare ground, a decrease in non-native annual grass, an increase in annual native forb cover, and an increase in total native species (Native Count) (Figure 10, next page). Unintended consequences of grazing include the decrease in native perennial grass cover: we do not believe the data represents a valid change in the actual number of perennial grasses, but rather reflects a decline in cover associated with thatch and dead material that was accumulated around mature bunchgrasses. Our experimental design is not sensitive enough to differentiate these two processes, but based on discussion with staff and other grazing professionals, we are not alarmed by this decline in cover.

Overall, the results of grazing have been beneficial. One invasive plant, rose clover (*Trifolium hirtum)*, was previously only observed in small pockets and along old trails. This species now occurs in slightly higher densities and distribution in the grazed areas. This plant could easily be distributed by animal activity since seeds are mature at the time of grazing and they easily adhere to animal fur. Rose clover should be monitored mowing forward. Fennel and French broom have notably declined in the grazed areas, especially the area near the Prairie outlook on Hunt Field.

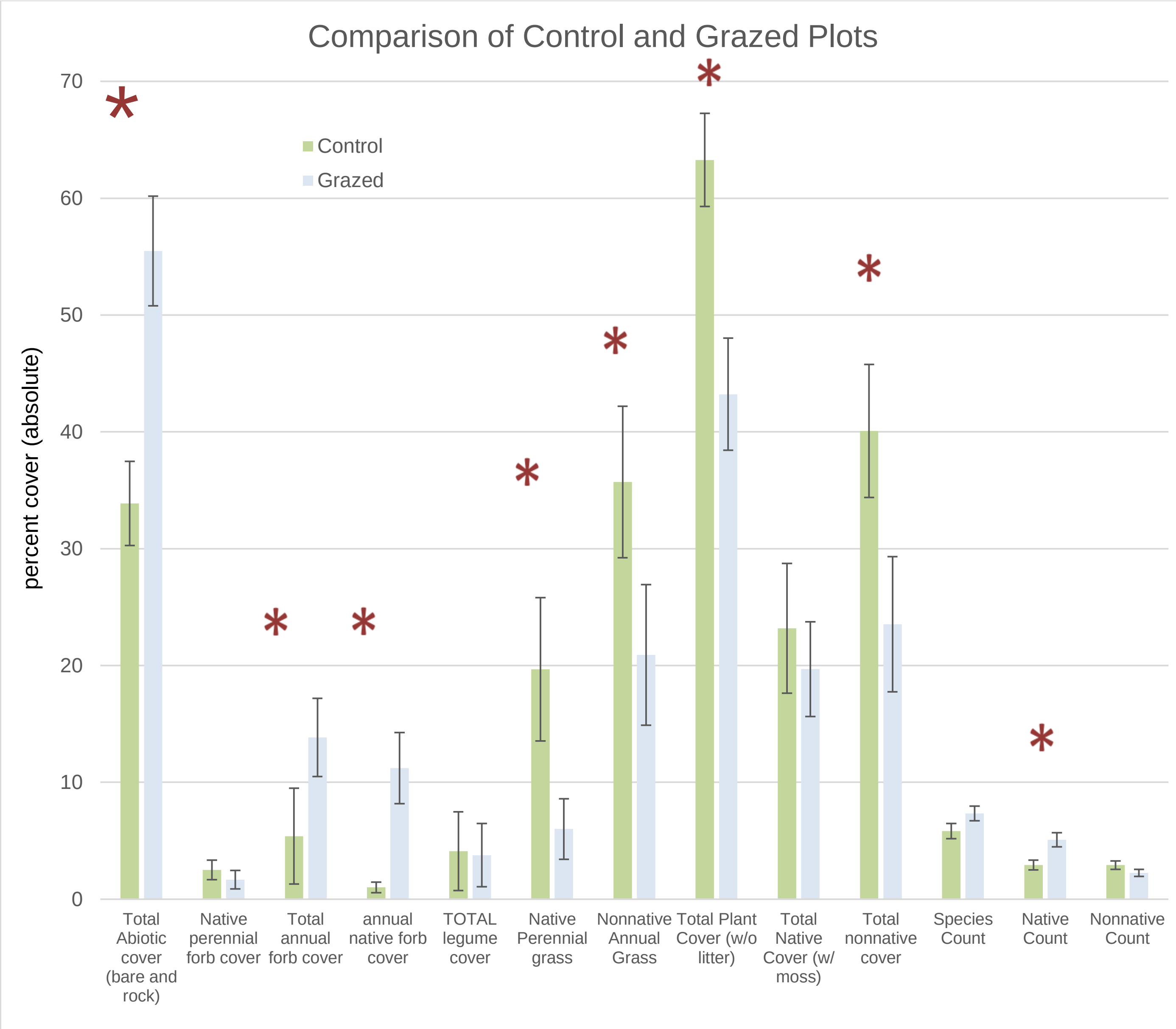

FIGURE 10: COMPARISON OF QUADRAT COVER DATA OF GRAZED VS. UNGRAZED AREAS. ERROR BARS REPRESENT THE STANDARD ERROR OF MEAN. RED STARS DENOTE PAIRED DATA THAT IS SIGNIFICANTLY DIFFERENT. THIS DATA IS PRESENTED IN APPENDIX A.

Seed Collection and Dispersal

In August 2016, EBRPD staff, Golden Hour staff and volunteers worked to collect seed and disperse it into two areas which are located close to occupied high quality habitat.

Golden Hour staff conducted class on rare plant collection and the value of the Serpentine Prairie restoration project was presented to all the staff and volunteers to help raise awareness about this project and to make people more familiar with rare plant rules and regulations, as well as seed collection techniques in general.

Seeds were approximately divided into two groups: 1) a large relocation site near a former spring mow plot that responded well to mowing (8,000 seeds) and 2) a second experimental site just north of the Serpentine Prairie proper where serpentine-influenced soils exist (600 seeds) (Figure 12). These two locations should be counted and monitored for 1-2 years to measure establishment success. Soils were scarified with a rakes to allow for better soil-seed contact in the fall.

PLATE 8: VOLUNTEERS AND EBRPD STAFF COLLECTING SEED AT THE NORTHERN END OF THE SERPENTINE PRAIRIE.

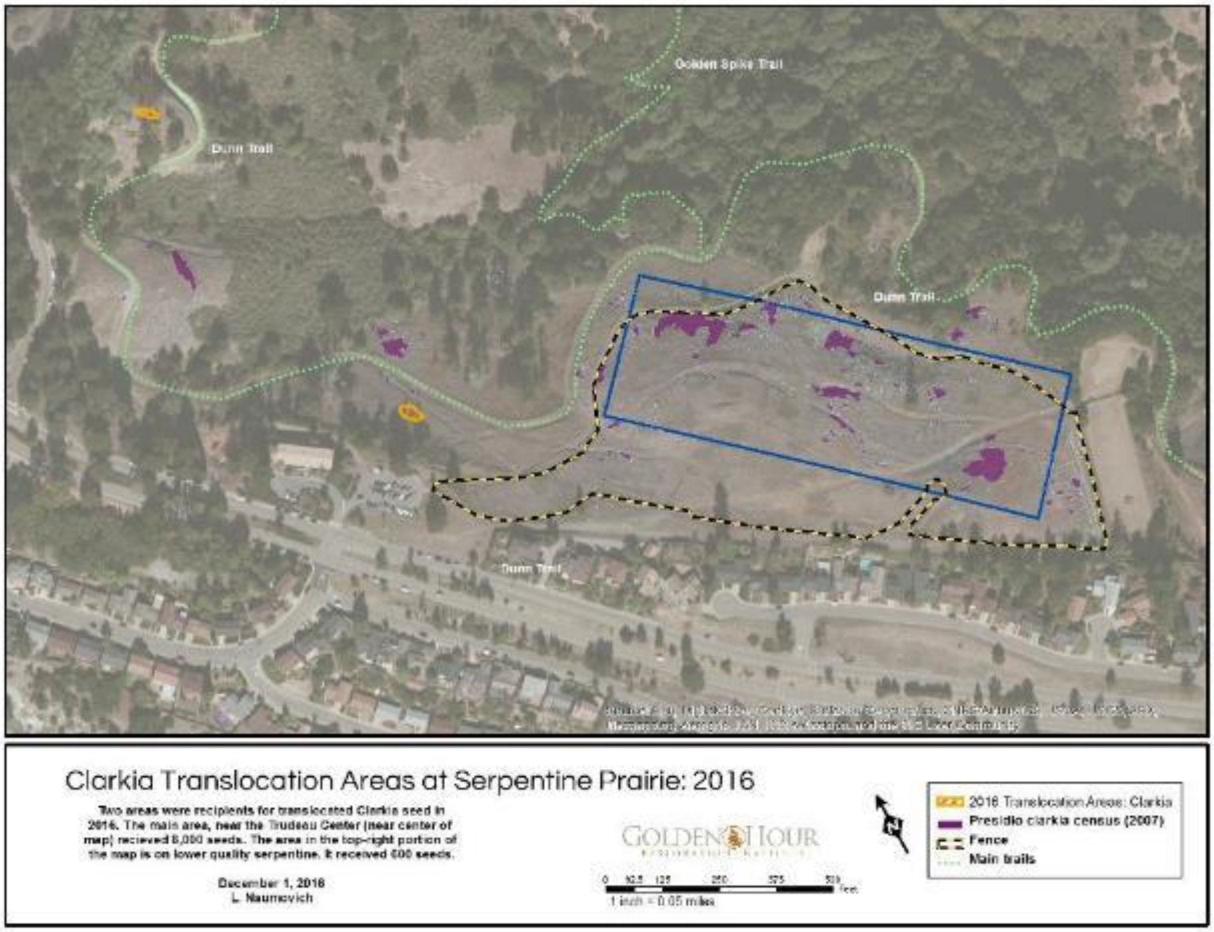

FIGURE 11: CLARKIA TRANSLOCATION AREAS, 2016.

Conclusions 2008-2016

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.
As we observe areas that once flourished with Clarkia go into decline in terms of number and vigor of population, we question whether a light scrape/soil disturbance might revitalize plant populations. At the same time, we think it is valuable to maintain a seed bank and since we believe that seeds may be viable for up to 30 years, we're not overly concerned with years with lower population numbers, as long as we don't continually loose >25% of the population.

2. Restoring and maintaining occupied clarkia habitat will require regular stewardship input. Our 2015 report mapped key areas that seem to be especially responsive to stewardship (Figure 15). 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.

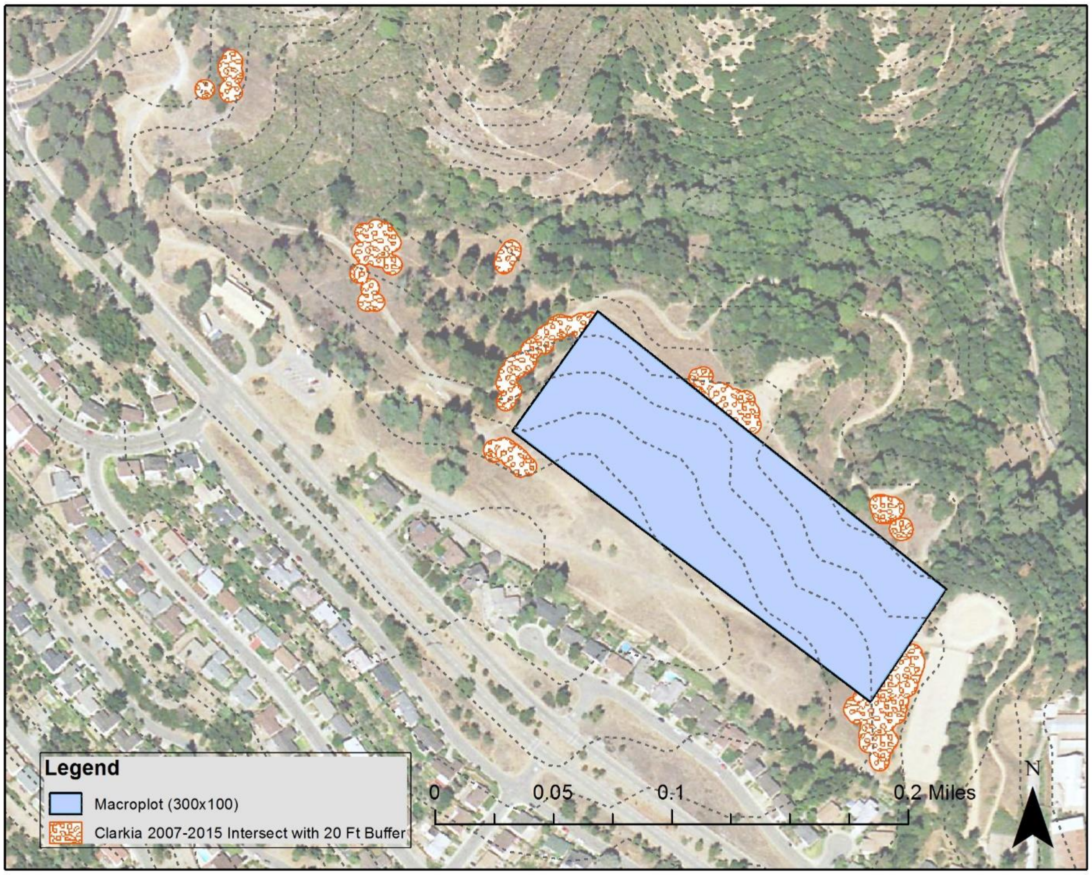

FIGURE 12: ESSENTIAL CLARKIA REFUGIA AREA WHERE CLARKIA WAS MAPPED IN TWO DROUGHT YEARS: 2007 AND 2015. THE MACROPLOT AREA IS ALL CONSIDERED ESSENTIAL REFUGIA DUE TO THE CONCENTRATION OF CLARKIA PRESENT.

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.

In 2016, we conducted a field experiment with 300 plants. No statistical difference between number of fruits per plant and average fruit length were measured in the small colonies of Clarkia clipped to 6 inches and control plants. Timing and height of mowing are extremely important factors to consider. This results may help explain why Clarkia persists on the Chadbourne median strip (Oakland) despite the annual mowing of this population. More research should be conducted and CDFW should be notified before large scale mowing of any Clarkia occupied area is conducted.

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. Clarkia macroplot numbers can reasonably be extrapolated from total annual precipitation, although we caution using numbers at extremes – e.g. very wet years or very dry years.

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. Almost always, bare soils seemed to have a higher number of plants in year 2 after translocation.

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.

FIGURE 13: RESULTS OF TREE REMOVAL WORK CONDUCTED BY EBRPD OVER THE COURSE OF THE LAST 10 YEARS.

Proposals for Next Year (Year 9)

We recommend continuing the following efforts in 2017: 1) strategic mowing in areas of thinner soils with historic clarkia populations 2) continue a standardized goat grazing trial where grazed sites can be compared with ungrazed, 3) reinitiate the macroplot measurements at the Prairie, 4) schedule formal volunteer work days around weeds, tree establishment and clarkia seed collection, 5) update the management plan to reflect advances in knowledge and stewardship practices.

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.

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 continued to target additional areas for mowing, especially in tree removal areas, and areas in the macroplot. 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. In 2016, we raked an area and deposited a very high density of seeds (about 100 per square meter). We would like to see how we do with higher seeding rates. In addition, it will be important to follow up and see what kind of germination occurs in the second seeded site as that could serve as an important population extension if successful.

We recommend resampling the clarkia macroplot in 2017, 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 2017.

As we enter our 10th year of this project, we believe it would be extremely valuable to update the management plan with all this new information and research. Since the majority of the research work is likely completed, and we have had some great success with various techniques, this could serve as an important template for the restoration of rare grassland annuals.

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Appendix A: Grazing Tabular Data, 2016

SD is Standard Deviation, SEM is Standard Error of Mean.

	Total Cover	*Total Abiotic cover (bare and rock)*	*Native perennial forb cover*	*Total annual forb cover*	*annual native forb cover*	*TOTAL legume cover*	*Native Perennial grass*	*Nonnative Annual Grass*	*Total Plant Cover (w/o litter)*	*Total **Native** Cover (w/ moss)*	*Total nonnative cover*	*Species Count*	*Native Count*	*Nonnative Count*
Control	97.16	33.88	2.51	5.38	1.01	4.10	19.68	35.71	63.28	23.19	40.08	5.83	2.92	2.92
SD	2.39	12.48	2.90	14.21	1.59	11.67	21.25	22.48	13.82	19.25	19.71	2.25	1.44	1.24
SEM	0.69	3.60	0.84	4.10	0.46	3.37	6.13	6.49	3.99	5.56	5.69	0.65	0.42	0.36
Grazed	98.71	55.48	1.67	13.84	11.22	3.77	6.00	20.91	43.23	19.69	23.53	7.33	5.08	2.25
SD*	3.52	16.26	2.73	11.63	10.57	9.35	8.94	20.83	16.60	14.07	20.02	2.19	2.07	1.06
SEM	1.02	4.69	0.79	3.36	3.05	2.70	2.58	6.01	4.79	4.06	5.78	0.63	0.60	0.30