Serpentine Prairie Restoration Project

Redwood Regional Park

2017 ANNUAL REPORT

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TABLE OF CONTENTS

TABLE OF FIGURES

Cover photo: Hunt Field, May 2017, filled with goldfields and healthy stands of owls clover, purple needle-grass and soap plant.

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 9th 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, and prairies that include newly occupied habitat for the Presidio Clarkia.

In 2017, the focus of the project continued to be stewardship activities, research and education. The highlights of stewardship work included the phenologically timed mowing of approximately 3 acres of serpentine grasslands, and the continuation of a grazing study which was expanded to 4 acres of habitat. 2017 surveys in the study area were not able to detect negative impacts of grazing, while providing a notable benefit for native forb cover.

The macroplot measurement was the lowest in 8 years, which we attribute to the El Nino weather which dropped near-record rainfall on the Prairie. The wet year increased the competitive advantage of the annual grasses. These grasses were abundant and historically high annual grass cover is inversely correlated with native forb cover. Despite lower clarkia numbers, our estimate is well within a healthy historic variability for this population.

Additionally, Golden Hour helped organize 2 volunteer days that included education, seed collection and invasive plant removal for a total of approximately 20 volunteers. The seed collection workshops continue to be well attended and provide a cost-effective and educational manner to complete this portion of the restoration plan.

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 second year that Golden Hour Restoration Institute has served as the lead for this project, in collaboration with District staff.

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. Precipitation for the 2017 water year was reported to be 45.14 inches, which is extraordinarily high for the area, more than 2 standard deviations greater than the 100-year average. The precipitation in the past year is the 4 highest total recorded since 1896.

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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.

We have been tracking overall rainfall (Oct 1-Sept 30) and spring (April 1-June 30) rainfall (Figure 1, source: https://cefa.dri.edu/Westmap/Westmap_home.php?page=timeseries.php)[2]. The 100-year average for annual precipitation for this site is 27.63 inches.

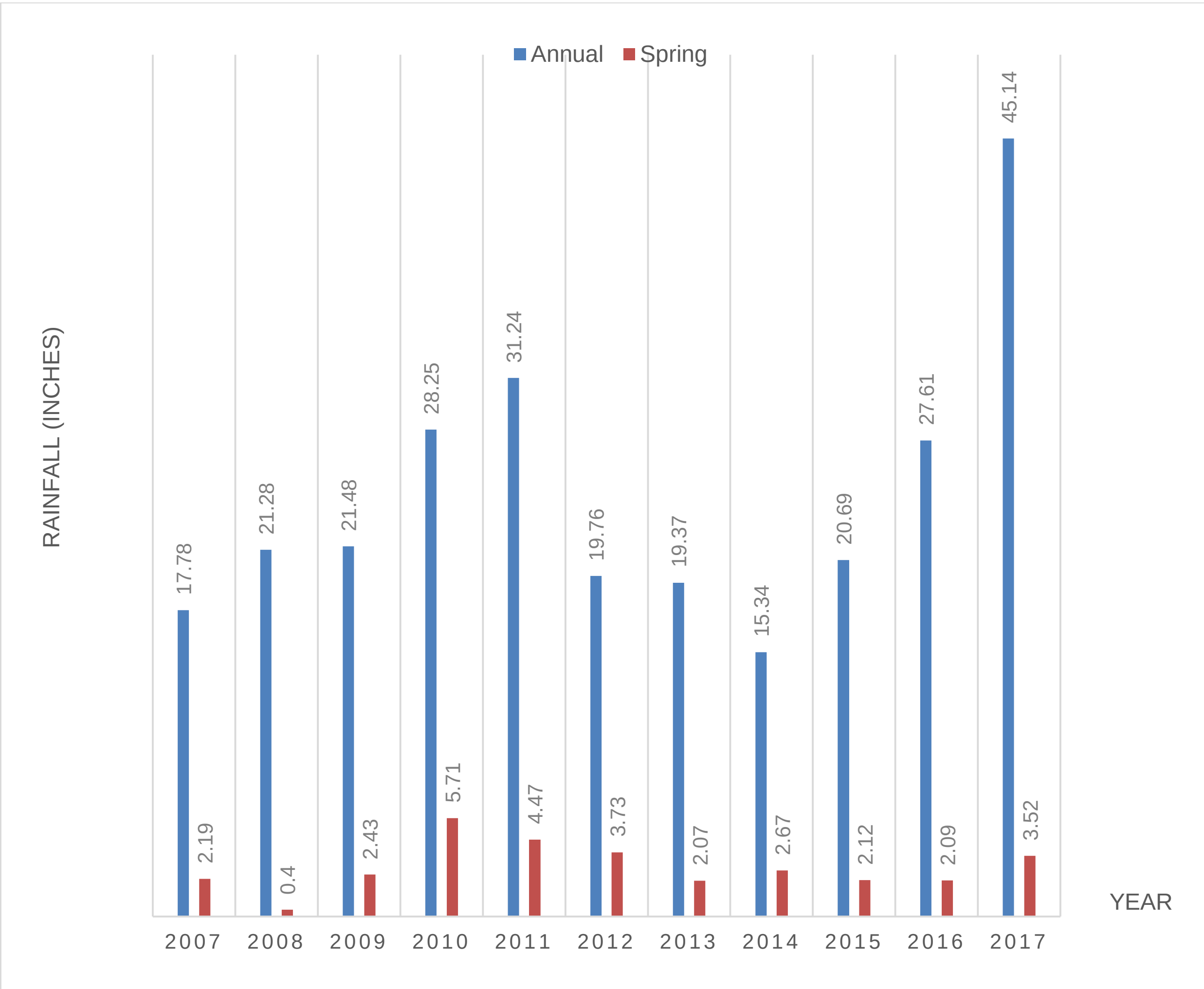

FIGURE 1: PRECIPITATION AT SERPENTINE PRAIRIE (LATITUDE = 37.8020, LONGITUDE = -122.1730)

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[2] The GPS point for our WESTMAP data was updated to latitude of 37.8020 and longitude of -122.1730 which represents a more accurate data point for the Serpentine Prairie. The previous point is was at 37.8129, -122.1877, which is also in the Oakland Hills, but about ½ mile from our site. This update occurred because we believe the pixels and model used by WestMap was updated since this data set was initially mined in 2007.

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).

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. All previously mapped areas (outside the macroplot) were visited and clarkia was flagged (Figure 2). 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.

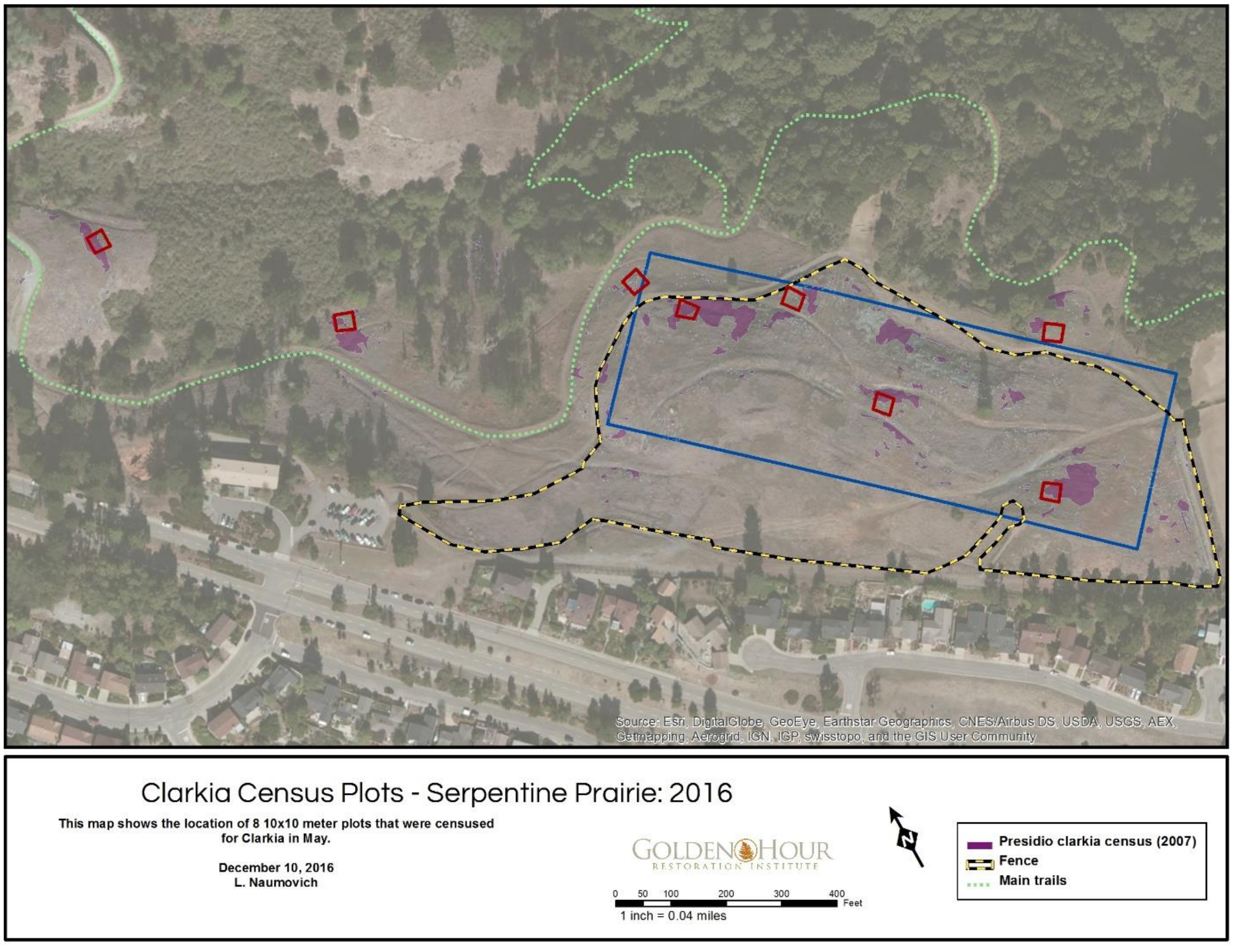

FIGURE 2: CLARKIA CENSUS PLOTS (8 REFERENCE PLOTS), MACROPLOT BOUNDARIES, AND 2007 COMPREHENSIVE MAPPING

Grazing Transects

Six grazing 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 and 2017, 4 transects (2 pairs) were surveyed. The last pair of transects was rejected for two reasons: 1) they were different soil types from the other 2 pairs found on and near Hunt Field and 2) the third pair was outside of the area grazed in '16 and '17, therefore there was no data. (Figure 3).

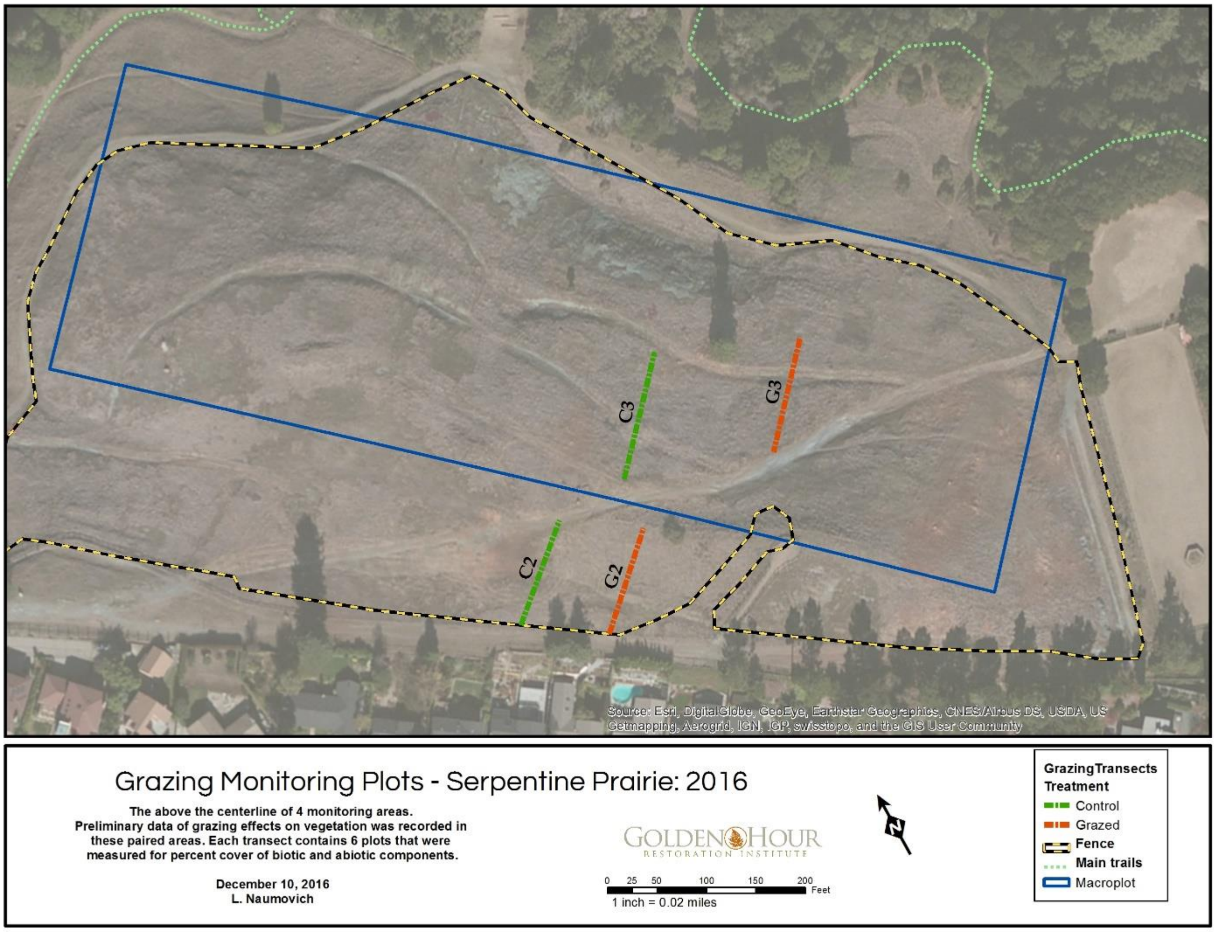

FIGURE 3: GRAZING MONITORING TRANSECTS

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. 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 rocks greater than 2cm in size. Vegetation will be recorded to the nearest 1% cover for any cover greater than 1%. 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 4).

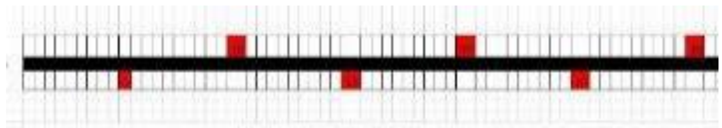

FIGURE 4: 30 METER TRANSECT WITH QUADRAT PLACEMENT LOCATIONS ALONG LINE.

- 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.

Research Results and Discussion

Clarkia Macroplot

The macroplot was completed in 2017 and we have 80% certainty that the population of the macroplot is between 21357 and 32982, with an average value of 27,170 plants. Prior years' data is presented in Table 1[3].

TABLE 1: CLARKIA POPULATION WITHIN THE MACROPLOT, OAKLAND, CA

Year	Population	± Confidence Interval
2008	15,569	1,888
2009	63,210	8,627
2010	85,830	17,607
2011	104,060	27,130
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
2017	27,170	5,812

We present the distribution of clarkia spatially in the macroplot (Figure 5). We also display how this data aligns with the Serpentine Prairie (Figure 6). Each rectangle represents the surveyed count of clarkia along a 100m transect. Note that there are 20 rows of transects which matches our experimental methods that requires a transect within every 5-meter section (e.g. a transect from 0 to 5m, another transect from 6 to 10m, etc.) We have collected macroplot data in a similar manner of the years require information at this level for statistics.

[3] Data for 2011 was slightly updated in this table reflecting what is present in the raw data.

	0-100m	100-200m	200-300m	
5	3	1	36	2017
10	7	46	26	27,170
15	1	0	29	
20	12	28	16	
25	0	51	41	
30	16	41	23	
35	10	49	37	
40	0	73	106	
45	32	73	154	
50	157	199	58	
55	41	117	98	
60	0	17	168	
65	0	8	151	
70	23	46	163	
75	0	81	129	
80	0	110	42	
85	0	20	16	
90	0	129	1	
95	0	16	5	
100	0	11	0	

FIGURE 5: A HOTSPOT MAP OF CLARKIA DISTRIBUTION IN THE 2017 MACROPLOT. BLUE INDICATES COOL AREAS WHERE CLARKIA IS LOW. YELLOW REPRESENTS THE AVERAGE PER TRANSECT (99) THAT ALIGNS WITH OUR RUNNING AVERAGE OF APPROXIMATELY 60,000 CLARKIA OVER THE ENTIRE MACROPLOT AREA. RED INDICATES HOT AREAS WHERE CLARKIA IS ABUNDANT APPROXIMATELY TWO TIMES THE AVERAGE AND MORE.

FIGURE 6: SPATIAL REPRESENTATION OF CLARKIA DENSITY IN THE MACROPLOT IN 2017 (AS PRESENTED IN FIGURE 5). AS ABOVE, "COOLER" COLORS INDICATE LOWER CLARKIA COUNTS. MACROPLOT DATA IS OVERLAID ON 2007 CLARKIA CENSUS POLYGONS (PINK).

Through the 2015 year, annual precipitation has been closely correlated ($y = 0.0163x + 4.4689$ $R^2 = 0.8054$) with the macroplot measurement (Figure 7). The El Nino rainfall of 2017 is well off the existing model and impacts the correlation. In fact, we wouldn't expect a linear relationship in extreme events, so the 2017 wet year data is not presented below. Our first approximation of a model that would consider temperature extremes would not be linear, but rather a threshold model, wherein clarkia population estimates fall to a certain base level once a precipitation threshold has been reached (Figure 8).

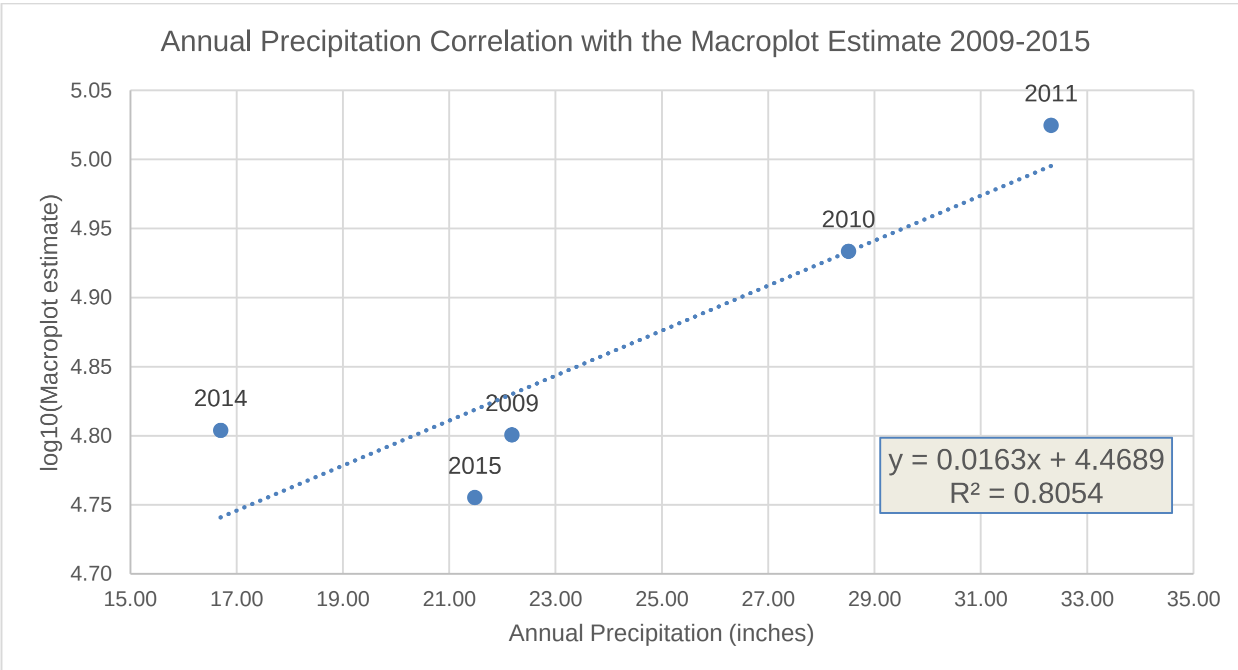

FIGURE 7: COMPARISON OF ANNUAL PRECIPITATION AT THE PRAIRIE TO MACROPLOT ESTIMATE NUMBERS.

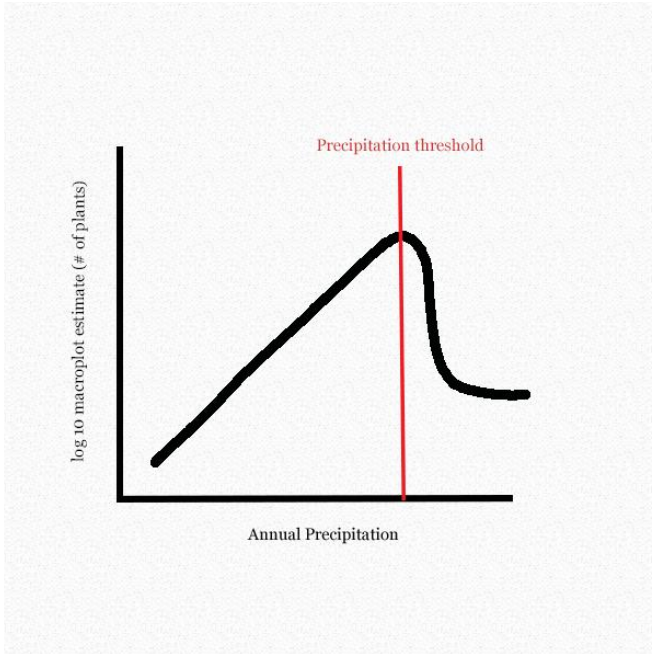

FIGURE 8: THEORETICAL MODEL FOR RELATING PRECIPITATION TO CLARKIA POPULATION

Although the macroplot measurement provides statistically defensible information, it comes at a high cost of approximately 80 researcher hours. We believe that the cost and value of having 80% certainty may not be best use of management dollars.

One recommendation is to consider retooling the macroplot method. We believe that decreasing the size of the macroplot by 1/3, making it a 100m by 100m square, would allow for the work to be finished in about 1/3 of the time (30 researcher hours). We recommend sampling 25 transects (one random line every 4 meters). This would greatly reduce our effort and still provide reliable numbers for qualitative analysis of data. In addition, we believe that a smaller portion of the Prairie would be trampled and impacted every year with monitoring activities. We hope to discuss this with EBRPD staff.

Another proposal is to move towards simply completing the census blocks. Although we consider the macroplot to be extremely valuable, we've also found that a complete census of 800 m^2 of high quality reference habitat (eight 10x10 meter plots in selected locations) can serve as a fairly reliable surrogate. For additional discussion see the *Clarkia Census in Reference Plots* section that follows.

Clarkia Census in Reference Plots

Clarkia were censused in 8 reference (control) plots at peak bloom when plants were most easily detected. 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	2017
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	2,676

Notably, the R1 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 R8 located in the southeastern extreme of the Prairie. This plot is characterized by thin soils near the serpentine contact zone. A redwood stands over a portion of this plot. R8 contained 72 plants in the 2011 survey, which were reduced to measurements of 0 or 1plant in subsequent years. In 2017,18 plants were located in this area, which likely serves as a clarkia refugia in wet years.

Stewardship Results and Discussion

Completed Land Management and Monitoring Tasks: 2008-2017

Tasks completed by Golden Hour Restoration Institute and Creekside Center for Earth Observation from 2008 to 2017 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, and 2017 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 2012, 2013 and 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 and continues to be used with caution in 2016-2017.

- 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 2017.

- In 2010-2017, 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 2017, 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 2014-2017.

- 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.

- Hand removal of *Vicia sativa* and other legumes from the Prairie that abound in wet years. We believe that we can effectively reduce these populations by treating them aggressively in wet years. This was completed in 2017.

- Weeding/mowing and removal of Cal-IPC moderate and high ranked invasive plants with volunteer effort. This was formally continued in 2017, although it was completed in previous years by EBCNPS volunteer effort.

- 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 2015, Creekside staff worked alongside EBRPD employees mowing nearly 3 acres of non-native grassland adjacent to occupied clarkia habitat. This portion of the project has been completed by Golden Hour since the transition.

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 May of 2017,

PLATE 2: SPRING MOWING ON THE NORTHERN END OF THE SERPENTINE PRAIRIE: MAY 3, 2017. FLAGS INDICATE AREAS NEAR CLARKIA THAT ARE TO BE AVOIDED.

specifically timed for greatest reduction in Italian ryegrass, *Festuca perennis* (Plate 4). Each location was surveyed for presence of clarkia and if found, plants were flagged and avoided. A total of 2 acres were mowed in 2017. Since it was a wet year, mowing occurred later than usual with a higher density of cover. Higher precipitation years reduce mowing rates because the grasses are taller (requiring more mulch cuts, and searching for clarkia is more time consuming (pre-mow surveys). 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 through 2017 (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.

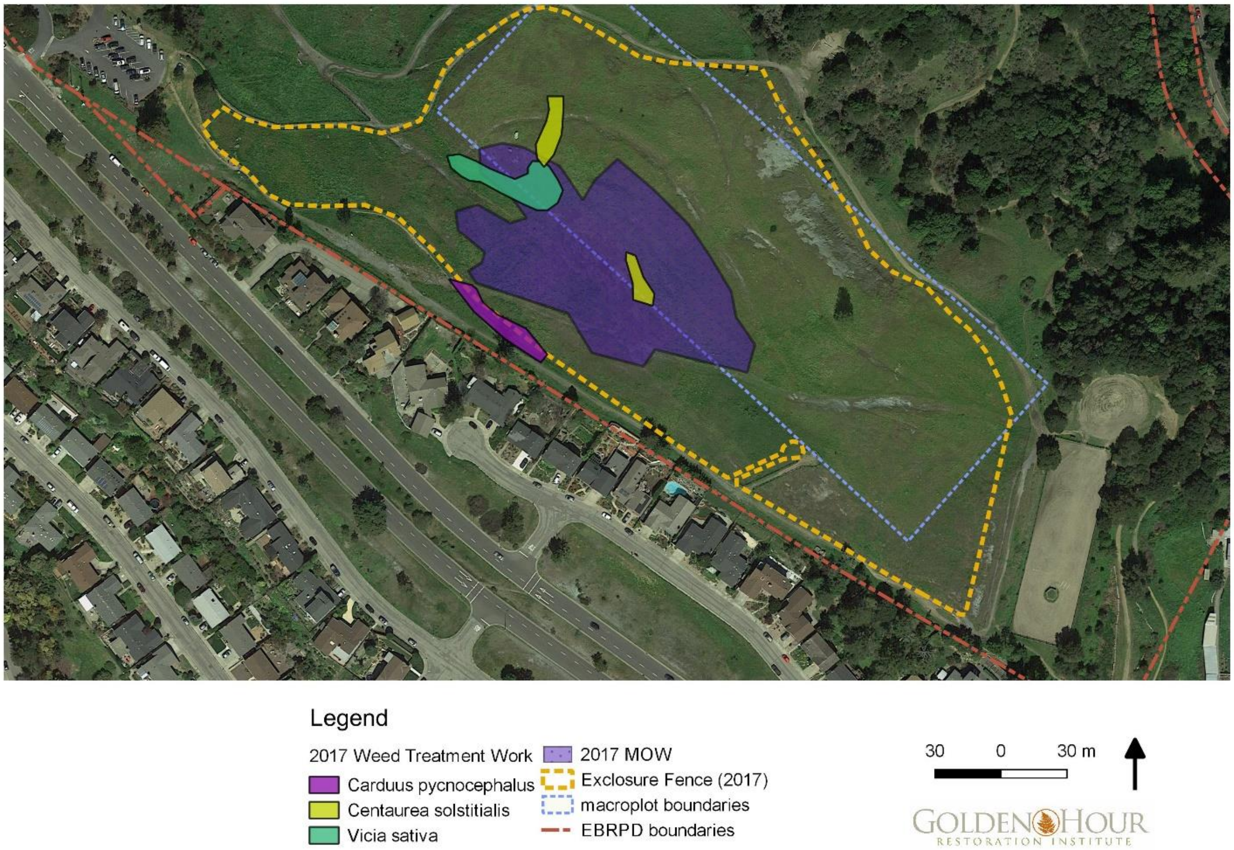

FIGURE 9: MOW AND WEED TREATMENT AREAS, 2017. AN ADDITIONAL AREA NEAR THE NORTH END WAS ALSO MOWED AS USUAL (SEE PLATE 2), BUT IS NOT CONTAINED IN THIS FIGURE.

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).

We've continued working with Star Creek Ranch through 2017. The results to date have been extremely positive including an increase in bare ground and a decrease in litter, both abiotic factors that are positively correlated with high quality habitat. No new weeds or invasives were noted in 2017 despite our spring detection surveys. The area grazed in summer (August) 2017 was mapped after the treatment was finished (Figure 10).

FIGURE 10: GRAZED AREAS: 2017

PLATE 3: 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 4: 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. THIS AREA WAS DISCONTINUED FOR 2017 BECAUSE WE BELIEVE THERE ARE BETTER TARGETED GRAZING AREAS GIVEN THE EL NINO EVENT OF 2017.

PLATE 5: 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.

Comparison of photo-monitoring points from May 2017 visually reveals that the grazed transect has lower biomass, an abundance of shorter forbs, and more apparent native bunchgrasses such as *Stipa* (Plate 8). C3 and G3 are located to the NE of Hunt Field on a north-facing slope, below where the C2 and G2 transects are located.

PLATE 8: MAY 12, 2017 - TRANSECTS C3 (TOP) & G3 (BOTTOM).

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 a significant decrease in non-native annual grass, non-native cover, along with significant increases for total annual forb cover (15x), and species count (Figure 11, next page).

We do not believe the data represents a significant ecological change in the cover of perennial grass simply because grazed grasses typically have smaller culm sizes the year after grazing, while the total number of culms likely will not change significantly. 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.

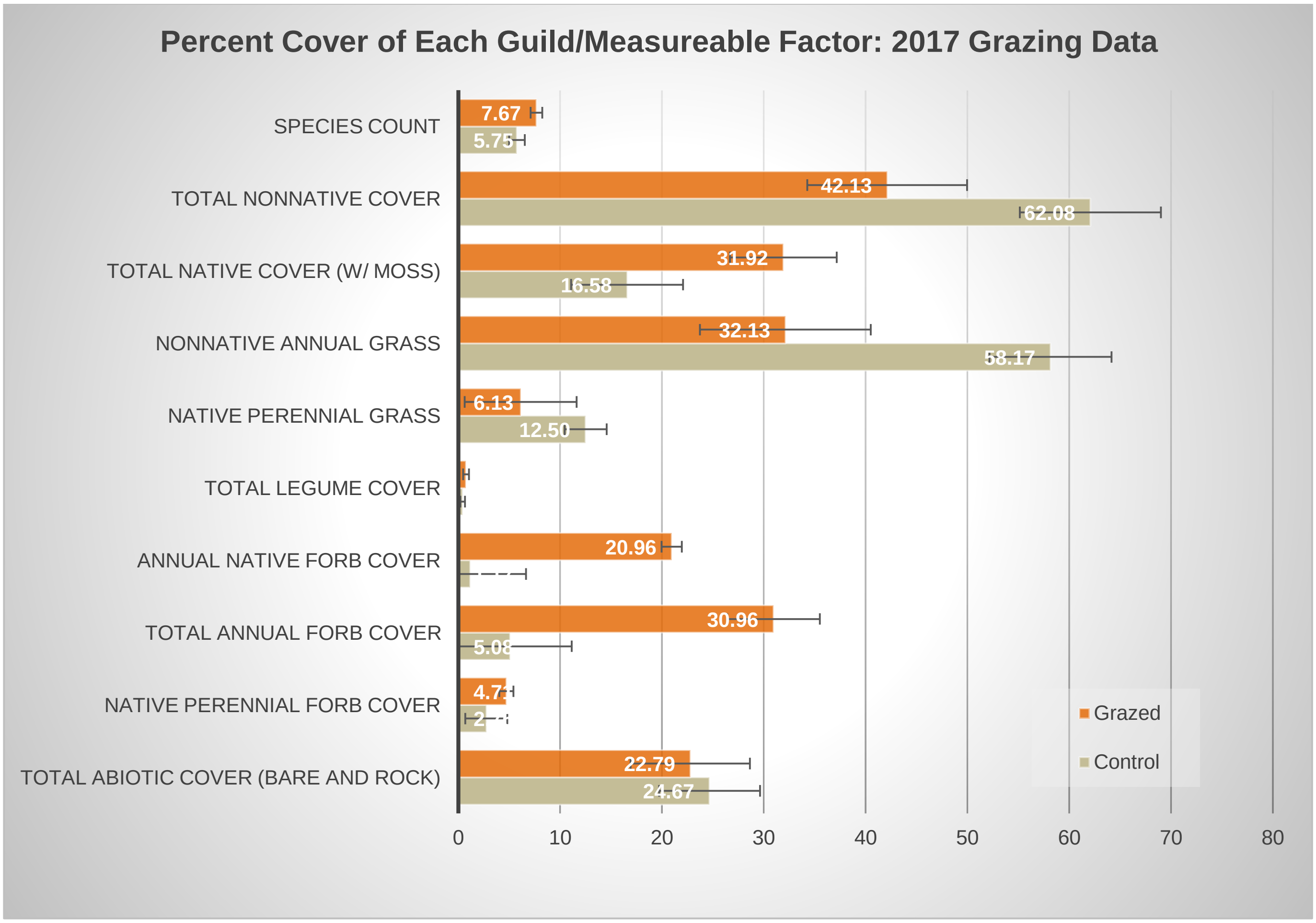

FIGURE 11: COMPARISON OF QUADRAT COVER DATA OF GRAZED VS. UNGRAZED AREAS. ERROR BARS REPRESENT THE STANDARD ERROR OF MEAN. RED STARS DENOTE PAIRED DATA THAT IS SIGNIFICANTLY DIFFERENT. THIS DATA IS PRESENTED IN APPENDIX A.

Seed Collection and Dispersal

In August 2017, 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. We created a handout, conducted a short presentation, and then utilized the volunteers to aid in the seed collection, cleaning, weighing, and dispersal (Plate 9). This year, we used the volunteers to carefully clean seed in order to use a mass-based estimate of clarkia seed collection effort. We cleaned 0.10 grams of seed and counted a total of 366 seeds. We estimate a 10% error based on the scale and therefore provide the first report of how many seeds are in 1 gram of cleaned material: 3,660 ± 366 seeds/gram. We estimate that we collected and dispersed approximately 11,126 ± 1,112 seeds this year.

PLATE 9: VOLUNTEERS AND EBRPD STAFF COLLECTING SEED ON AUGUST 16, 2017 AT THE NORTHWESTERN CORNER OF THE MACROPLOT.

Seeds were all distributed back into Hunt field in locations where past translocations (Figure 12) have been successful. We are working to produce a seed bank in this area and continue to recolonize this area that was devoid of clarkia at the time of the 2007 EBRPD census.

FIGURE 12: CLARKIA TRANSLOCATION AREAS, 2017.

Conclusions 2008-2017

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.

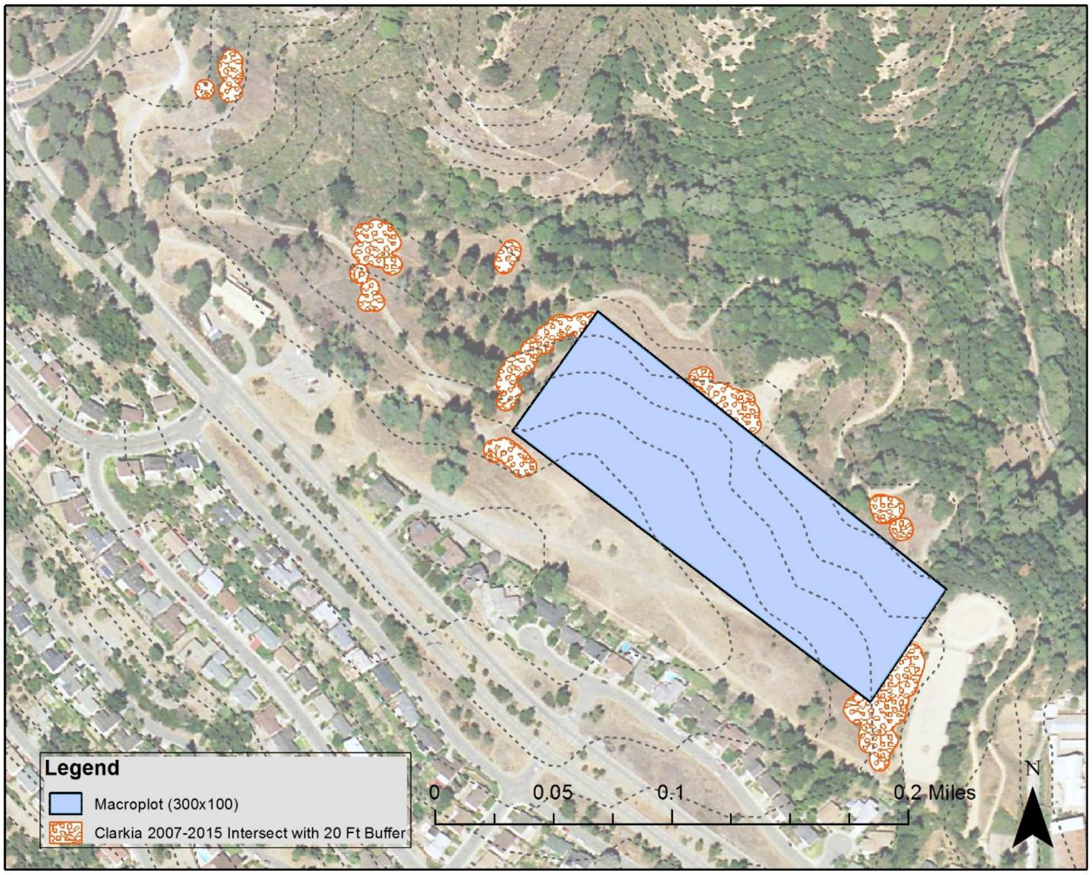

FIGURE 13: ESSENTIAL CLARKIA REFUGIA AREA WHERE CLARKIA WAS MAPPED IN TWO DROUGHT YEARS: 2007 AND 2015. THE MACROPLOT AREA IS ALL CONSIDERED ESSENTIAL REFUGIA DUE TO THE CONCENTRATION OF CLARKIA PRESENT.

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 ($r^2 = 0.9$) except in very wet years when precipitation is greater than 2-3 standard deviations of average. In this past El Nino year, precipitation was within 0.5" of the 1998 El Nino year.

   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.

   In 2017 we observed the 4th highest precipitation ever recorded at the Prairie. The El Nino year dumped over 45 inches of rain, which is more than two standard deviations above average (27.6 inches). Our previous models would predict that the clarkia population increased in the macroplot in 2017, but in fact we observed a notable decrease in the macroplot, likely due to the increase in non-native annual cover. To be fair, we completely expected a threshold response above a particular precipitation threshold, but this was the first such empirical evidence.

   We took this opportunity to compare where there had been changes in clarkia distribution in the macroplot. In the below figure, we compare 2017 (El Nino) to 2011 (an above average precipitation year at 31 inches). The 2011 year macroplot had the highest macroplot count to date. Notably, most of the macroplot area declined in count (red bars), but there is a portion of the site (the northwestern corner) where clarkia numbers were higher than in 2011 (blue bars). This figure illustrates how important it is to have habitat heterogeneity for annual species conservation over multiple years and climate scenarios.

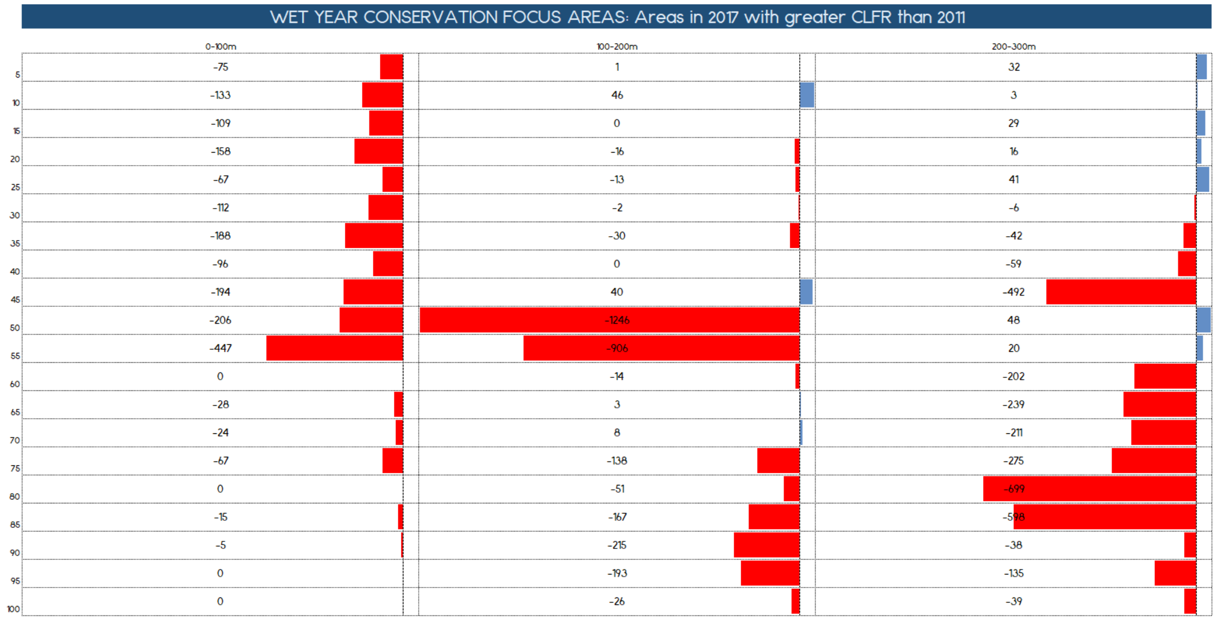

FIGURE 14: CHANGES IN DISTRIBUTION OF CLARKIA FROM 2011 TO 2017

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

Proposals for Next Year (Year 10)

We recommend continuing the following efforts in 2018: 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, but continue to adaptively alter different grazing rates (i.e. some paddocks could be 2-3 acres with the same number of animals), 3) continue the macroplot measurements at the Prairie, but consider a modified technique, 4) schedule 3-4 formal volunteer work days around weeds, tree establishment and clarkia seed collection, 5) finalize the update of 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. Seedling trees regularly colonize the Prairie and a concerted effort to remove these trees is vital to maintaining the grassland habitat.

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.

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 2018, which provides a statistically robust estimate of the population. As we compare data over the years, the macroplot is the single most robust representation of the population and how it has changed annually. We would like to discuss a “modified” macroplot measurement where we sample one 100m x 100m block instead of the entire 300m x 100m block. This would denote a change in methods for this measurement technique.

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. We are well underway with this document and hope to finalize it in 2018.

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Appendix A: Grazing Tabular Data, 2017

SEM is Standard Error of Mean.

Significant Differences in **bold.**

	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 **Native** Cover (w/ moss)*	*Total nonnative cover*	*Species Count*
Control	24.67	2.75	**5.08**	**1.17**	0.42	12.50	**58.17**	**16.58**	**62.08**	**5.75**
Grazed	22.79	4.71	**30.96**	**20.96**	0.75	6.13	**32.13**	**31.92**	**42.13**	**7.67**
Control (SEM)	5.86	0.69	4.55	1	0.29	5.5	8.4	5.25	7.85	0.58
Grazed (SEM)	4.96	2.07	6.04	5.47	0.22	2.07	6	5.5	6.93	0.76