

# **COYOTE CEANOTHUS (*C. FERRISIAE*) MITIGATION PROJECT**

**Annual Report for 2020 and Lessons Learned  
From Five Years of Planting in the Introduction Site**



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## EXECUTIVE SUMMARY

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Coyote ceanothus (*Ceanothus ferrisiae*), a covered species under the Santa Clara Valley Habitat Plan (Habitat Plan), is a critically endangered chaparral shrub restricted to three extant occurrences on serpentine soils in Morgan Hill, CA. Projected impacts to the largest occurrence of Coyote ceanothus from the planned seismic retrofit of Anderson Dam and subsequent dam maintenance, along with a conservation strategy for the species, are outlined in the Habitat Plan. The Santa Clara Valley Water District (Valley Water) began implementation of a mitigation and recovery strategy in 2009 for Coyote ceanothus to compensate for impacts to the species from the accelerated timeline of Anderson Dam activities.

The creation of a new population of Coyote ceanothus by Valley Water in a candidate introduction site on Coyote Ridge began in 2014. After the first year of planting at the site inadvertently introduced *Phytophthora cactorum*, a lethal water mold plant pathogen, full remediation ensued and was complete by 2018. Planting of both container plants and via direct seeding of Coyote ceanothus at the site, utilizing new phytosanitary procedures, resumed in a limited capacity in 2015 and has accelerated since with planting of Coyote ceanothus at the site annually. This report presents results of the 2020 monitoring effort of plants installed from 2015 through 2019.

Four test plots incorporating planted Coyote ceanothus into different pre-existing vegetation communities or 'test plots' (Chaparral Edge, Pine, Upper Sage, and Lower Sage) were established to examine whether Coyote ceanothus performed differentially in various habitats mimicking the extant occurrences of the species. Similarly, the planting of both container material and direct seeding, which is the result of phytosanitary concerns, has allowed an examination of whether Coyote ceanothus establishes better from planted container material or from seed. Planting annually allows development of structural complexity in the created occurrence and increases the amount of genetic diversity and resilience.

Results for 2020 indicate a germination success of direct seeded basins ranging from 52% to 63% in the different test plots averaged over five years of direct seeding. Survival success was consistently higher for container plants than direct seeded plants across plant age and test plot. Direct seeded plants had the lowest survival rate in the Lower Sage plot (26.7% survival one year after planting and 10% survival four years after planting) due to extreme herbivory of young seedlings. Cover provided by adjacent sagebrush (*Artemisia californica*) likely facilitated a higher density of small herbivore pressure in this plot. The highest survival rate for both direct seeded plants and container plants was seen consistently over time in the Pine plot, with an 85% survival rate for direct seeded plants and a 90% survival rate for container plants, by Year 4. Survival amongst container plants was similar across test plots and changed little as plants aged. Average health and vigor scores were consistently higher for container plants than for direct seeded plants, and the highest health and vigor scores for both container plants and direct seeded plants were seen in the Pine plot (2.40 for direct seeded plants and 2.450 for container plants, out of a highest possible score of 3).

Flowering of planted Coyote ceanothus in the introduction site was first documented in 2019, with very limited fruit production that year. In 2020 plants flowered in all four test plots. The first flowering typically occurs as early as two to three years after planting, with container plants more likely to flower than direct seeded plants. Ten percent of direct seeded plants had flowered by age four or five, while 29.2% of container plants had flowered by age two or three.

In 2020, 22% of container plants three to four years old produced fruit. Direct seeded plants appear to lag behind container plants by a year, in time to first fruit production.

The higher overall success of Coyote ceanothus in the Pine plot is possibly due to the shelter and some shading provided by overstory grey pines (*Pinus sabiniana*), as well as protection from the prevailing NW winds on the ridge. Planted Coyote ceanothus appear to experience annual drought stress in the late summer months, evidenced by yellowing and chlorotic foliage, and some leaf drop on the older stems. Plant stress is seen less frequently in the Pine plot. The most stressed plants in the introduction site appear to be intermediate in age and have been weaned from irrigation (plants are irrigated for 2-3 years), relying only on annual precipitation, and appear in more exposed and windy portions of the introduction site. All the plantings put on new, healthy foliage in the winter months after adequate rainfall. Future plant installation will occur adjacent the Pine plot and shelter provided by the foothill pine woodland at the east end of the introduction site. While the introduction site does appear to fall within the limits of water availability needs and microclimate suitability for Coyote ceanothus, it is in the upper limit and higher elevation range of the summer marine layer, which has shown to be important in enhancing water availability for coastal chaparral shrubs. This may have implications for long-term persistence of Coyote ceanothus in the face of a changing and warming climate, and for this reason we believe that any additional introduction or population creation efforts for the species should occur on the west side of the valley near the Llagas occurrence, where the climate is more mesic (and population genetic diversity is highest).

Additional lessons learned from five years of planting and maintaining the introduction site for population establishment of Coyote ceanothus include fine-tuning of the irrigation system in a harsh environment, application of a topical spray to reduce herbivory pressure on seedlings and young plants, ever better phytosanitary methods for growing plants in a nursery environment, and further exploration of possible *Frankia* microsymbiont-facilitated Nitrogen fixation. We continue to believe that planting via direct seeding and container plants is important to the overall success of the population creation effort and increases both genetic diversity and long-term successful establishment of plants at the site, and that over time, there will be less difference between planting methods.

# 1. INTRODUCTION

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Coyote ceanothus (*Ceanothus ferrisiae*; CEFE; Federally Endangered, CRPR 1.B) is a chaparral shrub in the buckthorn family (Rhamnaceae) restricted to serpentine soils and endemic to Santa Clara County, CA. Limited to only three occurrences within an approximate three-mile radius of Anderson Reservoir (a total area of less than 15 km<sup>2</sup>) in Morgan Hill, CA (Figures 1 and 2), it is a covered species under the Santa Clara Valley Habitat Plan (Habitat Plan). Projected impacts to the species are clearly defined in Chapter 4 of the Habitat Plan, and a conservation strategy for recovery of the species is outlined in Chapter 5 (ICF 2012). Impacts to the largest occurrence of CEFE at Anderson Dam (Appendix A, Photo 1) due to the Anderson Dam Seismic Retrofit Project (ADSRP) and subsequent dam maintenance are required to be offset by the protection or creation of one population within five years of impact, with the additional requirement of protection of five total occurrences (populations)\* within the 50-year permit term of the Habitat Plan. Impacts from the ADSRP are limited to 3,650 individuals or 5% of the population, whichever is less.

Due to the accelerated timeline of the ADSRP, and the first impacts to CEFE which occurred in 2015, the Santa Clara Valley Water District (Valley Water) initiated the process of creating a new population of CEFE on a mitigation property owned by Valley Water (the Coyote Ridge Preserve). Located on the serpentine ridge line known as Coyote Ridge, the site selected is situated to the northwest of and above Anderson Reservoir (Figure 3).

Implementation of the conservation and recovery strategy for CEFE outlined in the Habitat Plan includes a number of tasks, many of which have already been completed by Valley Water. These tasks are outlined and summarized in previous reports (SCVWD 2018; Fiedler, J. letter to Ryan Olah, August 16, 2013), and include work conducted by Valley Water and partners over a five-year period (2009-2104) which laid the foundation for the development of an Occurrence Plan for creation of a new population of CEFE on Coyote Ridge (SCVWD 2018). These completed tasks include the following:

- A population genetics study of all three known CEFE occurrences (Honeycutt 2012; Potter 2012)
- A study of soil relationships and rhizosphere fixation of N-nodulating *Frankia*, a soil actinomycete (Battenberg and Berry 2014; Battenberg et al. 2017)
- A study of late dry season water availability in extant occurrences and microclimate suitability of the proposed introduction site (Vasey 2014)
- Collection and evaluation of detailed natural history and demographic data on known occurrences (Hillman, unpublished data; SCVWD 2018)
- A pilot planting project using different methods of establishment (direct seeding and container plant installation; SCVWD 2018)

The pilot planting project began in 2014 and concluded in 2017. Results of the pilot project are outlined in the 2017 report (SCVWD 2018).

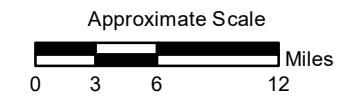
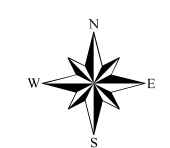
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\* The terms “occurrence” and “population” are used interchangeably throughout the report.

Figure 1. Location of Coyote Ceanothus in Santa Clara County, CA



**Legend**  
● Study Area

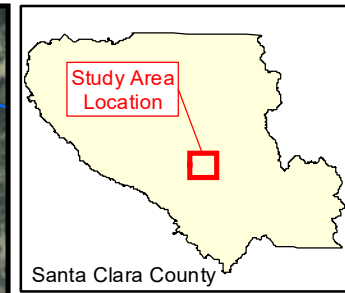




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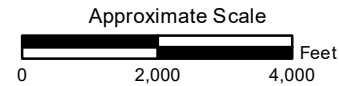
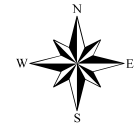
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Figure 2. Coyote Ceanothus CNDDDB Mapped Occurrences and Introduction Site



- Legend**
-  Coyote Ceanothus Introduction Site
  -  Coyote Ceanothus CNDDDB Occurrences

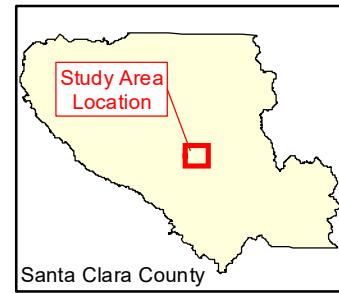


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Figure 3. Introduction Site and Test Plots Located within the Coyote Ridge Preserve

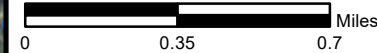


**Legend**

- Test Plots
- ⬭ Coyote Ceanothus Introduction Site
- ⬭ Coyote Ridge Preserve Property



Approximate Scale



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An additional completed task includes full remediation of the site after the initial planting effort in 2014 inadvertently introduced *Phytophthora cactorum*, a lethal water mold (oomycete), to the site on infected container stock (Swiecki & Bernhardt 2014a, 2015a, 2015b). After removal of all the infected plant stock in fall of 2014, remediation of the *Phytophthora* plant pathogen at the site began and was successfully completed in the introduction site in 2018, four years after the infestation was first documented (Swiecki & Bernhardt 2015c, 2018b). As has been previously reported, remediation was accomplished via two methods. First, a soil solarization method was utilized where multiple layers of greenhouse plastic were staked down over infected basins (Appendix A, Photo 2), effectively heating the soil to a high enough temperature via solar radiation to kill the pathogen (Swiecki & Bernhardt 2014b). In shady areas, a second method was employed where insitu solarization was ineffective. This additional method involved the construction of specialized solar ovens, which were installed at the site in sunny areas (Appendix A, Photo 3; Swiecki & Bernhardt 2018a). Contaminated soil was carefully removed from each planting basin and transferred to a solar oven where soil was 'baked' to a high temperature to kill the pathogen. After baking, the remediated soil was returned to the original planting basin. Subsequent testing revealed the effectiveness of both techniques.

This report presents the results of the 2020 annual monitoring effort and evaluation of planting years 2015-2019.

## 2. MONITORING METHODS

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The introduction site design has historically been comprised of four test plots located in different preexisting vegetation communities (SCVWD 2018). Test plots were fenced in four different vegetation communities within the larger introduction site (Table 1; Figure 4) and planting of CEFE interspersed within the vegetation communities occurred annually in the fenced plots via both direct seeding and container plant installation. The purpose of the test plots was to see if CEFE performed better when associated with different functional vegetation communities, rather than planted in a simple monoculture. By 2019 the four test plots had largely reached capacity and subsequent planting has occurred in the larger introduction site.

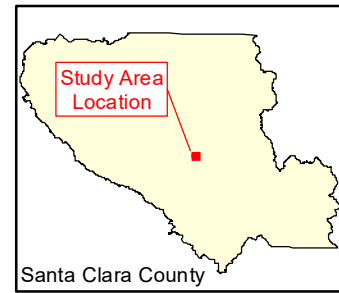
**TABLE 1. Four Test Plots in the Introduction Site and Dominant Vegetation Type**

Test Plot Name	Dominant Vegetation Type
Chaparral Edge	Mixed serpentine chaparral at the edge of serpentine grassland
Pine	Foothill pine woodland
Upper Sage	California sagebrush scrub (Northern coastal scrub/Diablan sage scrub)
Lower Sage	California sagebrush scrub (Northern coastal scrub/Diablan sage scrub)

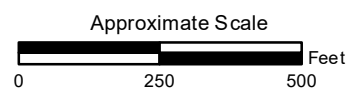
### 2.1 NURSERY METHOD AND PLANT INSTALLATION

Plants were installed annually at the site in order to mimic natural recruitment and establish multiple age classes in the created population, which increases population structural complexity and diversity as well as safeguarding against future stochastic events. This experimental approach is especially important for extremely rare taxa such as CEFE, which have a limited number of extant populations and typically have never before been the focus of a population creation effort.

Figure 4. Test Plot Locations within the Coyote Ceanothus Population Introduction Site



- Legend**
- Test Plots
- Grey Pine
  - Lower Sagebrush Chaparral
  - Serpentine Chaparral / Grassland Edge
  - Upper Sagebrush Chaparral
  - Water Tank
  - Coyote Ceanothus Introduction Site



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In fall and winter of 2019, annual planting of CEFE occurred via direct seeding as well as installation of contract-grown container plants. Seed used for all planting years was from annual seed collection of CEFE from the Anderson Dam population. For the direct seeding of CEFE in the field, the following pre-treatment was employed by the nursery (D. Benner, personal communication, January 12, 2021). Water was heated to approximately 190 degrees F, then poured over seeds until they were completely submerged by a volume of water approximately four times the volume of seed. After the seeds soaked for 24 hours, the excess water was poured off and the seeds then surface sterilized with a 0.5% sodium hypochlorite (bleach) rinse for one minute, followed by six rinses with distilled water.

For the 2019 container grown plants, seed treatment prior to sowing in the nursery was as outlined above, except that a 3% hydrogen peroxide rinse was used instead of a 0.5% bleach solution. After treatment, the seeds were put into cold stratification (50 degrees F) for one month, then sown into flats in June 2019 and potted up into D40 containers approximately one month later.

For the 2020 installed plants (both container grown and direct seeding), the method was as outlined above except all seed treatments utilized the 3% hydrogen peroxide solution rather than bleach.

The installation of 200 CEFE container plants at the introduction site occurred during the week of November 25, 2019, while direct seeding into basins (4 seeds of pre-treated CEFE in each basin; see treatment protocol above) occurred on December 17, 2019 (Appendix A, Photos 4-6). The 200 container plants were planted in the larger site area between the Chaparral Edge and Pine test plots, while 30 direct seeded basins were installed in the Chaparral Edge plot and 30 direct seeded basins were installed in the Pine plot. All planting followed strict phytosanitary precautions as outlined at [www.calphytos.org](http://www.calphytos.org).

This installation of basins in 2019 completes the planting in the four test plots (Pine, Chaparral Edge, Lower Sage, and Upper Sage), and 2019 marked the first year that basins were installed and planted in the larger fenced introduction site which encompasses the test plots. Beginning in 2015 and by the end of 2019, a total of 781 basins had been created and planted with CEFE.

On December 16, 2020, 200 container plants were installed in the larger introduction site area adjacent to the Pine subplot where *Ceanothus* plantings have historically performed the best. On December 30, an additional 61 basins were direct seeded, for a total installation of 261 new planting basins in 2020. This brought the current total of created and planted basins at the population creation site to 1,042, as of December 2020. (Note that this does not indicate the current number of surviving CEFE at the site, due to some mortality and the design of direct seeded basins often having multiple surviving individuals).

The annual monitoring results presented here do not include an assessment of the winter 2020 planted stock.

## **2.2 IRRIGATION SCHEDULE**

Plants were watered via three water tanks installed at the site (Figure 4) with irrigation infrastructure to individual basins, on timers and fed by head pressure/gravity (except the Upper Sage test plot where there is a solar-powered booster pump to augment water flow at grade). The 2020 irrigation schedule for direct seeded and container plants is below in Table 2. New container plants are watered for two years. New direct seeded basins are watered for

three years. Irrigation is ceased in winter months, typically from December through April. Occasionally supplemental watering is given during dry winters or during a late start to the rainy season.

**TABLE 2. Irrigation Schedule in 2020**

Year Since Planted	Planting via Direct Seeding	Planting via Containers
Year 1 (First Year)	0.5 gal 3x/week	1.5 gal 1x/week
Year 2	1.0 gal 1x/week	0.6 gal 1x/week
Year 3	0.6 gal 1x/week	No irrigation
Year 4 and onward	No irrigation	No irrigation

### 2.3 ANNUAL MONITORING IN 2020

We conducted annual monitoring of survivorship and health and vigor (plant ‘condition’) of all CEFE planted to date on June 10 and June 17, 2020 (Appendix A, photo 7). In addition, I collected data on recruitment (germination) in direct seeded basins throughout spring and recorded any evidence of flowering (February 12, 2020) and fruiting (May 13, 2020) of all plants.

For health and vigor ratings, the following categories were developed using a condition rating system (Table 3).

**TABLE 3. Health and Vigor Ratings for Coyote Ceanothus Plantings**

Rating	Condition
3	Excellent (substantial leaf & branch development, plant robust, dark green glossy leaves)
2.5	Excellent, but some leaf chlorosis (less than 25%)
2	Good (moderate branch & leaf development, leaves dark green)
1.5	Good, but some leaf chlorosis
1	Fair/Poor (few leaves, plant stunted and/or chlorotic)
0	Dead

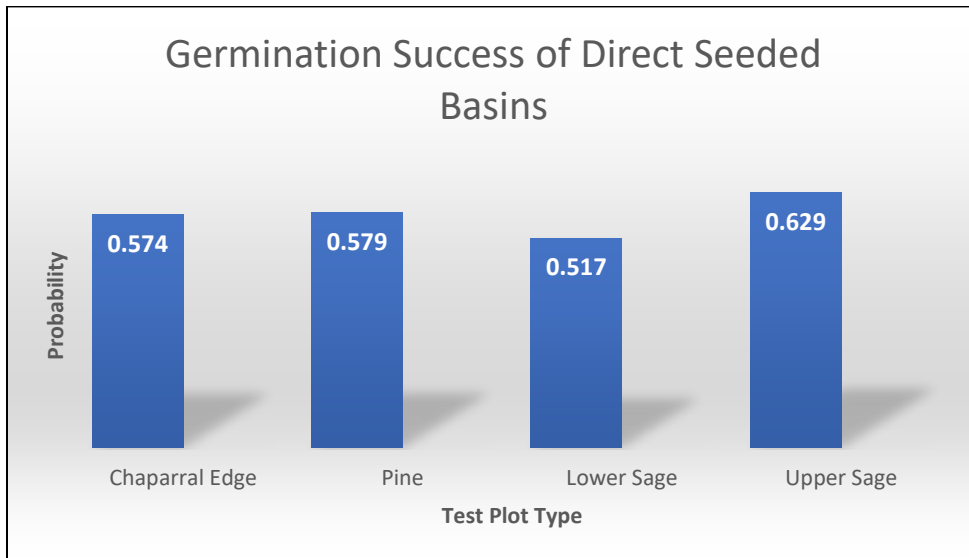
The monitoring data were entered into a master spreadsheet in Excel and then descriptive statistics were generated using the statistical program R, by a statistician, in June and July 2020. There were no statistical tests run, but rather descriptive analyses were used to identify patterns and trends. Groups of variables tested were plot type (Chaparral Edge, Pine, Lower Sage, Upper Sage), method of planting (direct seed or container), and year of planting (2015-2019). Response variables were germination (recruitment) rate, survival of a plant in each basin to year 1, 2, 3, 4, and 5, plant condition (see Table 3 above for condition ratings), plant height, and flowering and fruiting data observed in 2019 and 2020. Survival was recoded in the data analyses as “0 or 1” for either dead or living; therefore, survival probability was the proportion of basins with surviving plants within a grouping variable.

### 3. RESULTS

As of June 2020, a total of 781 basins had been created and planted since 2015. Of those, number of surviving basins with at least one CEFE in them was 608.

#### 3.1 GERMINATION SUCCESS, SURVIVAL, AND PLANT CONDITION (HEALTH AND VIGOR)

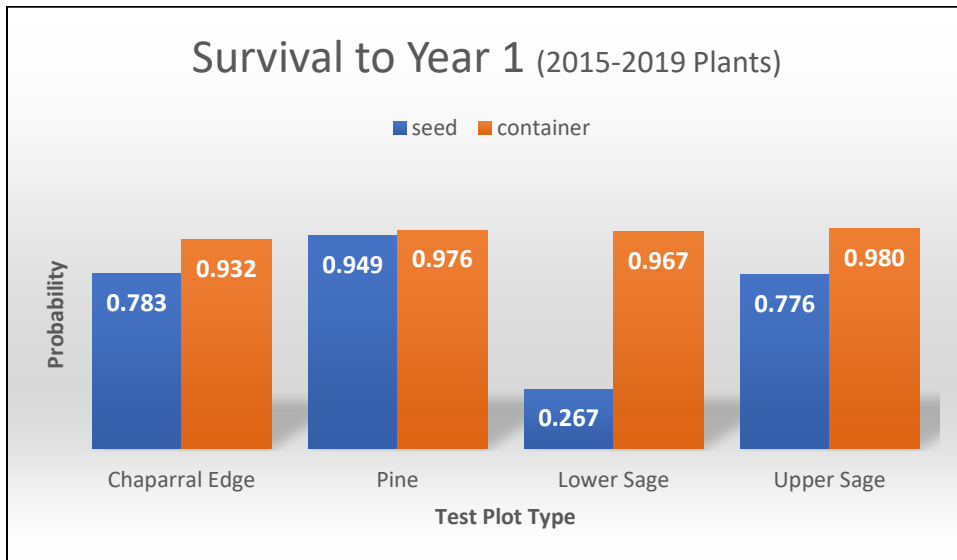
Germination success of direct seeded basins was similar across the different test plots over all the years of direct seeding (Figure 5). The highest germination success, or proportion germinated (expressed on the y-axis in graphs below as Probability), was in the Upper Sage test plot, at 0.629, or 62.9% (Appendix A, Photo 8). As is demonstrated in Figure 5, we have achieved germination success in the field ranging from 52% to 63% on average over 5 years of direct seeding.



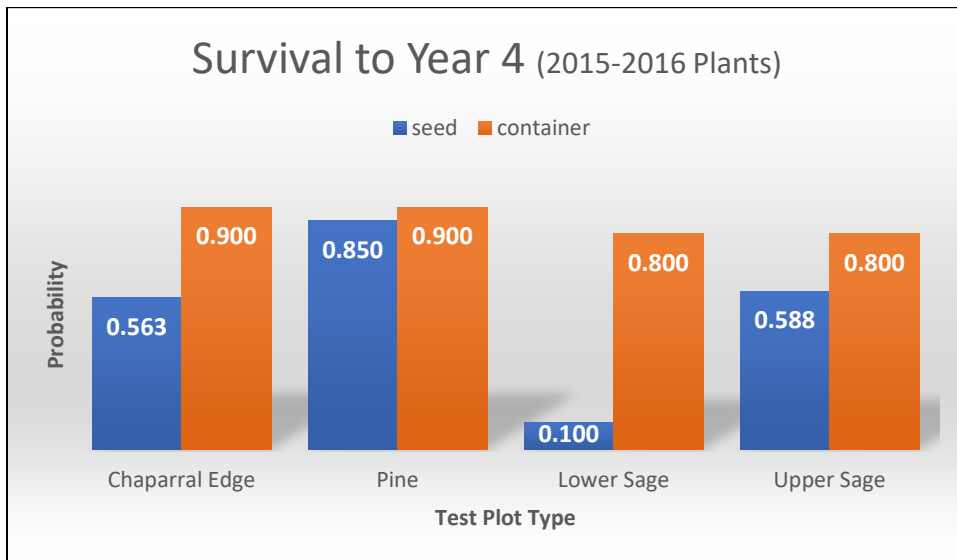
\*There is no germination success presented for container plants since they were grown in a nursery rather than planted as seeds in the introduction site.

**FIGURE 5. Germination Success of Direct Seeded Basins, from 2015-2019**

Survival success was consistently higher for container plants than direct seeded plants across plant age and test plot (Figures 6 and 7; note that not all graphical results are shown but only a sample to indicate trend). Direct seeded plants had the lowest survival rate in the Lower Sage test plot, at 26.7% survival one year after planting (Figure 6) and 10% survival four years after planting (Figure 7). As a result, we completely abandoned direct seeding in this plot and have only installed container plants since 2016. Highest survival rates occurred in the Pine test plot, with little difference between planting methods (85% survival rate for direct seeded plants and a 90% survival rate for container plants, by Year 4). Variables shown indicate the probability of at least one plant surviving to its 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup>, and 5<sup>th</sup> year, respectively. Proportions are computed across all years of plantings (2015-2019) using observations recorded in 2020.

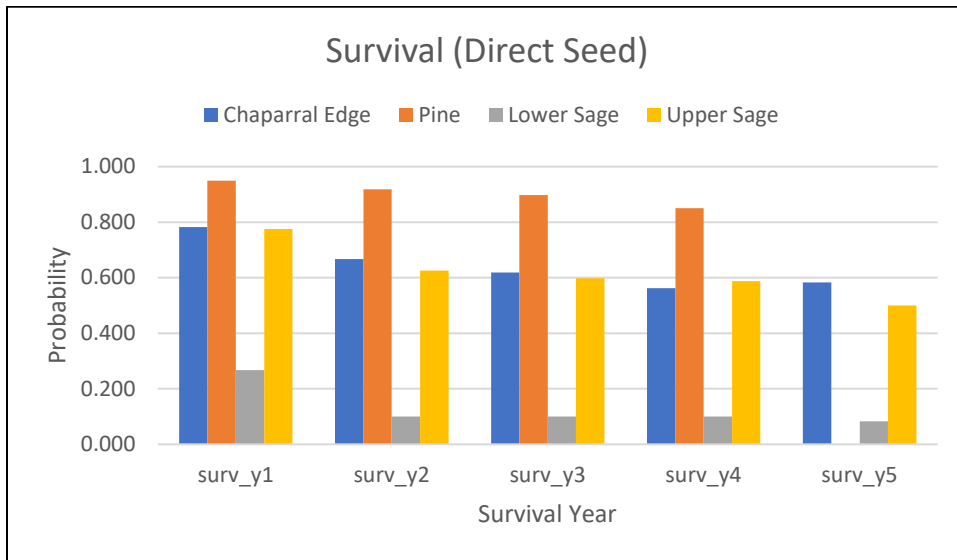


**FIGURE 6. Survival Probability of Direct Seeded and Container Plants One Year After Planting**



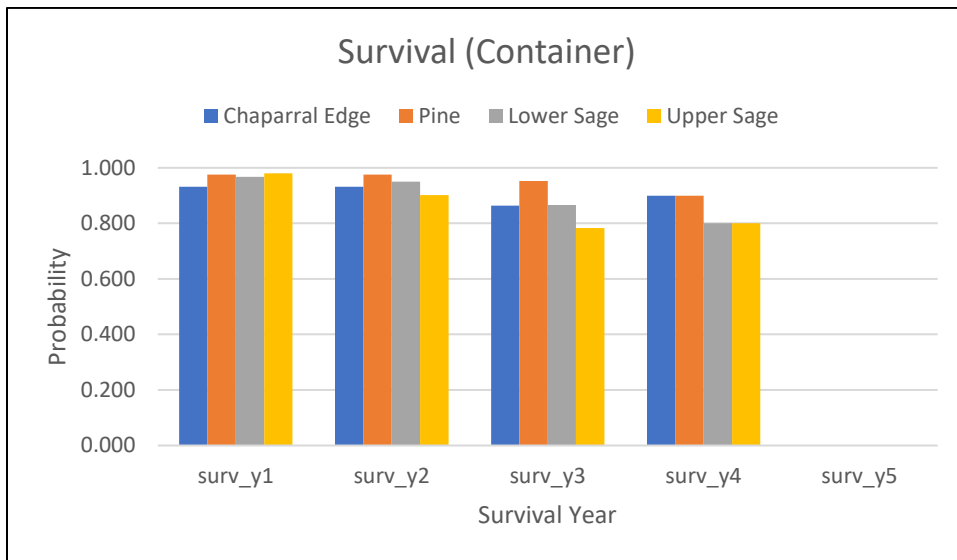
**FIGURE 7. Survival Probability of Direct Seeded and Container Plants Four Years After Planting**

Survival success was highly variable for the direct seeded planting method (Figure 8). The poorest overall survival rate was found in the Lower Sage test plot, while the highest survival rate was in the Pine test plot.



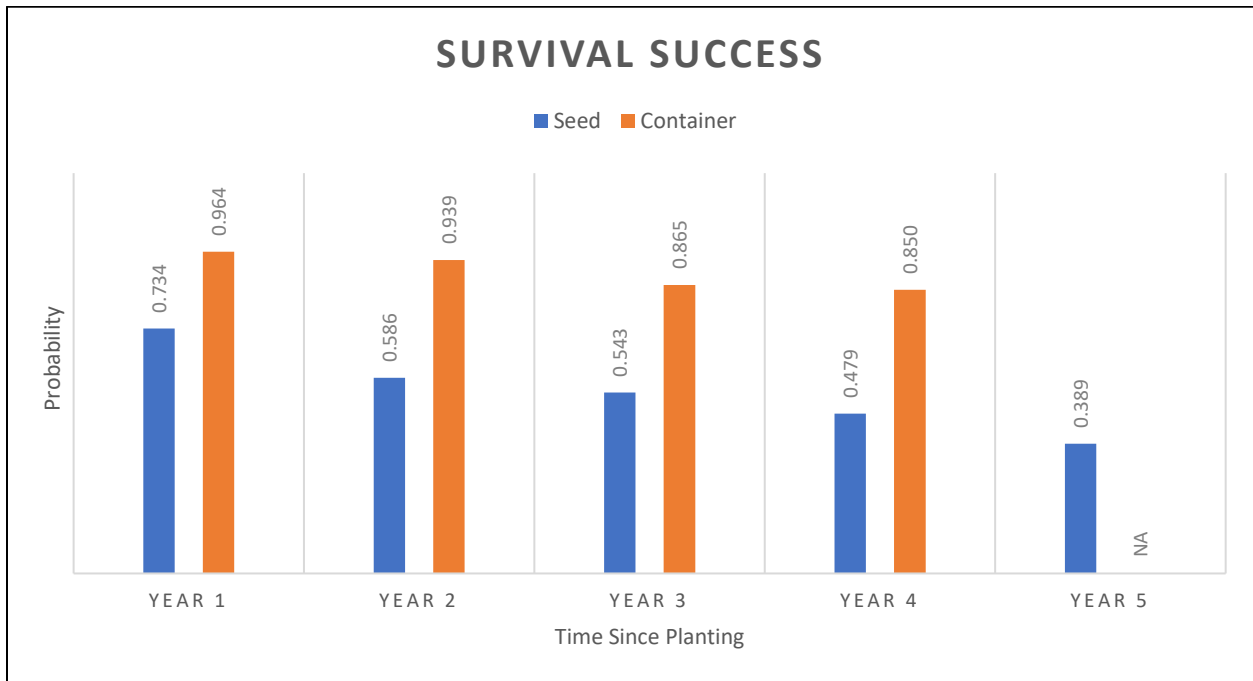
**FIGURE 8. Survival Success Over Time for Direct Seeded Plants in Different Test Plots**

Survival amongst container plants was similar across test plots and changed little as plants aged (Figure 9). There is a slight decline as would be expected in survival success over time.



**FIGURE 9. Survival Success Over Time for Container Plants in Different Test Plots**

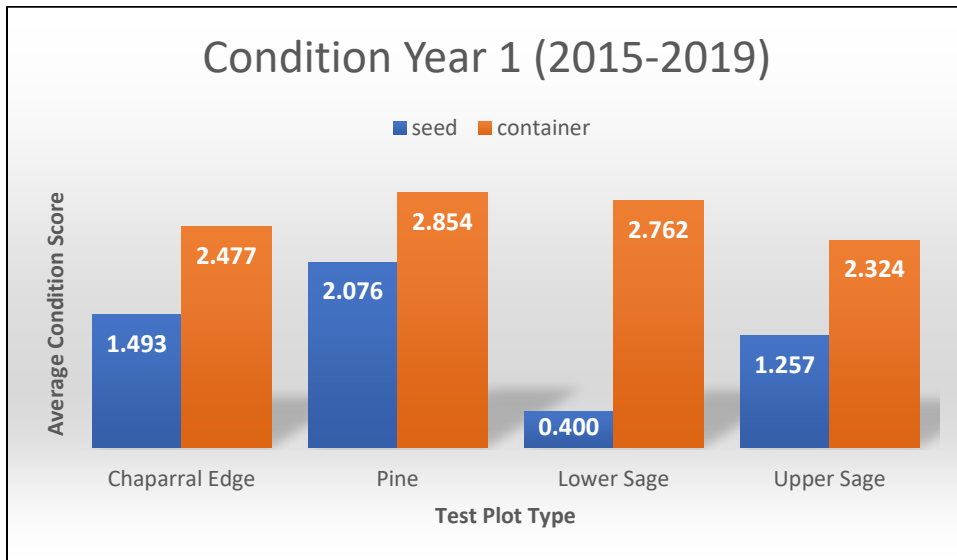
Comparing the probabilities of survival success over time for the different planting methods, there is a slight decline over time (Figure 10). However, the decline appears to be fairly slight after the first year of survival for container plants, with 85% of plants surviving to Year 4. For direct seeded plants, only 47.9% survived to Year 4 and 38.9% survived to Year 5. It is expected these numbers will improve as the planting method for direct seeding has been refined over time and with experience working with the seeds, installation and irrigation methods (see Discussion).



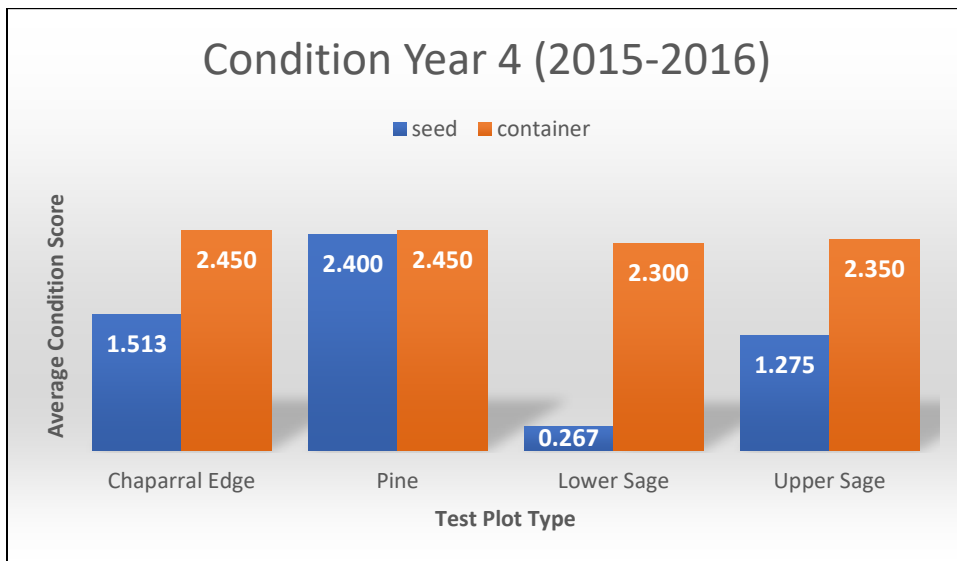
\*Note that Year 5 has no data for container plants since the first year they were installed was 2016.

**FIGURE 10. Survival Probability/Success Over Time by Planting Method**

Average health and vigor scores (plant 'condition') were consistently higher for container plants than for direct seeded plants, across plant age and test plot (Figures 11 and 12; note that not all graphical results are shown but only a sample to indicate trend). A condition rating of 3 is 'excellent'; 2 is 'good', and 1 is 'fair/poor' (Appendix A, Photos 9a-9d). Direct seeded plants had the highest average health and vigor score in the Pine plot, with the lowest average score in the Lower Sage plot. Container plants had consistent condition ratings throughout years and test plot type.

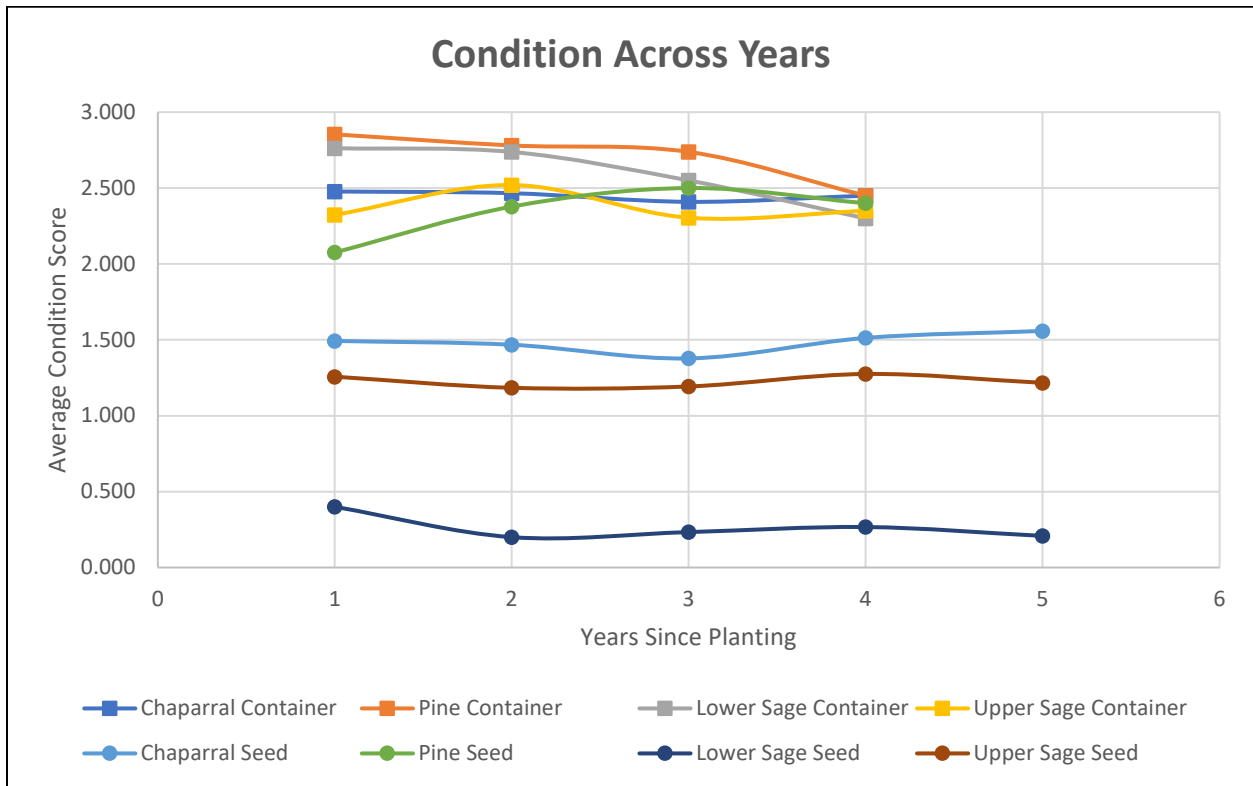


**FIGURE 11. Average Condition of Plants in Their First Year After Planting, in Different Test Plots**



**FIGURE 12. Average Condition of Plants in Their Fourth Year After Planting, in Different Test Plots**

In annual monitoring results through June 2020, the average condition of a plant appears consistent across time as plants mature (Figure 13). Once a plant establishes in a basin, it appears that the general condition remains the same; however, there were clear differences between plants direct seeded versus planted from a container. In general, container plants appear to do better or have a higher condition rating, except in the Pine plot where there appears to be little difference. Note that monitoring results presented here only follow plants for the first 5 years after planting, as that is the age of the oldest plants installed in the introduction site to date.



**FIGURE 13. Average Plant Condition Over Time in Different Test Plots and Planting Method**

The average plant height was consistently taller for container plants relative to direct seeded plants (data not shown). For any given year of planting, the germination advantage and head start of container plants appears to remain into subsequent years, so far.

### 3.2 PLANT FLOWERING AND FRUIT PRODUCTION

Flowering of planted CEFE in the introduction site was first documented in 2019, with very limited fruit production that year. More plants flowered in 2020, and viable seed production was noted that year (Appendix A, Photos 10 and 11). Plants flowered in all four of the test plots. In general, flowering first occurs as early as two to three years after planting, with a higher chance of flowering, and flowering occurring sooner, for container plants. Ten percent of direct seeded plants had flowered by age four or five, while 29.2% of container plants had flowered by age 2 or 3 (data not shown).

In 2019, only 3.9% of two-year-old container plants that flowered also produced fruit. In 2020, 22% of container plants three to four years old produced fruit. Since fruiting was not observed for direct seeded plants until 2020, and only for the oldest plants (four to five years old), direct seeded plants appear to lag behind container plants by a year, in time to first fruit production. Qualitative observations indicate that the percentage of a plant in flower appears to have some bearing on whether a plant then produces fruit. If there are few inflorescences on a plant, it is less likely to produce fruit than if the majority of the plant blooms. Similarly, if many plants in a test plot bloom, more pollinators are seen visiting the flowers and fruit is more likely to be produced.

## **4. DISCUSSION AND LESSONS LEARNED**

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### **4.1 DATA ANALYSIS**

We analyzed the data using descriptive statistics rather than statistical tests for several reasons. First, the data collected over time do not represent a replicated experiment with a balanced design, so it would be hard to meet the assumptions of typical statistical analyses. Second, the patterns of the data are obvious and informative, regardless of any hypothesis test. Third, the purpose of the population creation effort is just that- to successfully create a new and self-sustaining population of CEFE. The studies conducted to date (microsatellite genetic work, soil relationships, water potentials, site suitability, and field assessments of known populations as well as potentially suitable introduction sites) have been used to create a foundation and framework to guide the successful creation of a new population, increase understanding of this taxon and hopefully contribute to eventual recovery of the species. Following the insights gained from these studies, the purpose of the pilot study was to try different planting methods in different pre-existing plant community associations and was a very hands-on experimental effort. In other words, the purpose was to successfully grow and establish plants, rather than to develop a statistically rigorous research project.

### **4.2 DIFFERENCES IN DIRECT SEEDED PLANTS VERSUS CONTAINER-ESTABLISHED PLANTS**

While the results presented in this report show that container plants have consistently outperformed plants established via the direct seeding method in survival, average health and vigor, time to first flowering, and fruit production, it is still early in the population establishment phase and the project to make long-term predictions of overall plant success. Direct seeding as a method of plant establishment is still very important from several perspectives. First, it reduces the potential for an inadvertent introduction of pathogens to a very pristine location in the upper watershed. The additional seed sterilization treatments proposed for subsequent planting (see below) will further ensure that seed introduced to the site is clean and does not harbor pathogens on the seed coat. The additional benefit is that seeds are planted into basins created out of native soil, without the incorporation of a nursery potting mix that comes with container plants. Second, there is increased genetic diversity and resilience that results from a direct seeding method- four seeds are planted into each basin, and the seeds which germinate and survive as seedlings have a better chance of being adapted to flourish in that particular microsite. With container plants there is inevitably some selection to the nursery environment where seeds first germinate, and then are potted up prior to being outplanted at the site. Direct seeding ensures that the plants that do establish likely have a better chance ultimately to flourish and contribute to a self-sustaining population. In this project, both methods of planting are important to overall success. Finally, we predict that over time and as the plants mature, the method of plant establishment will be less important and that direct seeded plants will 'catch up' to container stock.

### **4.3 OBSERVATIONS OF FLOWERING AND FRUITING**

Container plants have shown evidence of flowering and fruiting before plants established by direct seeding. These lags are not unexpected, since the container plants are both chronologically and developmentally older than direct seeded plants from the same year. Container plants have a head start in the nursery environment with more optimal conditions for seedling establishment, and when the plants are planted, the container plants have an

approximate six-month developmental advantage after germination and growth in in the nursery rather than direct seeded at the site. We have also occasionally planted larger stock (i.e., 10 five-gallon plants in 2017) that was surplus from a previous planting year (these plants are very carefully tested for *Phytophthora* before they leave the nursery). Those plants have flowered and set seed sooner than most of the rest of the planted population.

The production of fruit after flowering appears to be influenced by the number of inflorescences and the number of plants in flower in a given plot. This is likely due to pollinator attraction-few-flowered plants are not enough of a 'draw' to the plant or the area, while plants covered in blossoms typically have large numbers and even swarms of bee flies, also called flower flies (family Syrphidae) and occasionally bumble bees (likely *Bombus vosnesenskii*) and honey bees, visiting the flowers (Appendix A, Photo 10).

#### **4.4 INCREASED OVERALL SUCCESS OF COYOTE CEANOTHUS PLANTS IN THE PINE TEST PLOT**

Results for 2020 indicated that the highest survival rates for seedlings occurred in the Pine test plot, with little difference between direct seeded and container plants. Direct seeded plants had the highest average health and vigor score in the Pine plot and showed little difference from container plants in condition over time. This mirrors results seen since the start of the project. CEFE plants in the Pine plot have always seemed to do better than in the other test plots. It's possible that the Pine plot, with its east facing slope and overstory shading provided by foothill pines (*Pinus sabiniana*), provides some shelter and a less harsh microclimate for establishing CEFE. In addition, the Pine plot is the most protected from the prevailing NW winds, which can get quite strong along the ridge and may result in increased drought stress due to evapotranspiration in young plants in other plots, particularly Chaparral Edge and Upper Sage.

Preliminary soil sampling in different test plot areas of the introduction site in 2012 did show some slight difference in the soils. Soils are predominantly serpentine, as would be expected, with low amounts of nitrogen, phosphorus, potassium, copper, zinc, and sulfate (Soil & Plant Laboratory, Inc., 2012b). Calcium to magnesium ratios are less than 0.95 in all plots except the Chaparral Edge plot, with Ca:Mg ratios of 0.56 for the Pine plot, 0.75 for the Upper Sage plot, 0.54-0.80 for the Lower Sage plot, and 1.07 for the Chaparral Edge plot (Soil & Plant Laboratory, Inc., 2012a and 2012b). Serpentine soils typically have a calcium to magnesium ratio of less than 1, so from this indicator the Chaparral Edge plot is right on the edge of what would be classified as serpentine. Soils in different test plots across the introduction site are slightly acidic at pH values ranging from 6.6 to 6.7. Soil textures range from clay loam to sandy clay loam. The Pine and Upper Sage test plots have a significant amount of larger particle size (greater than 2mm), indicating the soils are "gravelly" with approximately 27% gravel dry weight. The Pine plot has not only a lower calcium to magnesium ratio than the majority of other test plots (Soil & Plant Laboratory, Inc., 2012b), but also higher levels of nickel and chromium (Test America 2012). In this feature it is most similar to the Anderson Ridge and Anderson Shoreline portions of the extant Anderson Dam CEFE occurrence.

Soils analysis of the three extant occurrences of CEFE (Anderson Dam, Llagas, and Kirby) found comparable soils to the introduction site on Coyote Ridge, though slightly lower calcium to magnesium ratios (Soil & Plant Laboratory, Inc., 2012a). Soils ranged from clay loam to sandy clay loam (with Llagas also qualifying as "gravelly" at 16.4-20.1% dry weight and Anderson at "gravelly" to "very gravelly" at 25.8-36.7% dry weight), and pH values varied from moderately acidic to moderately alkaline (typical for serpentine soils). Calcium to magnesium ratios ranged

from 0.42-0.56 (Anderson Ridge), 0.05-0.58 (Anderson shoreline), 0.12-0.45 (Kirby), and 0.16-0.48 (Llagas; Soil & Plant Laboratory, Inc., 2012b).

While Vasey (2014) found that the Coyote Ridge introduction site appears to fall within the limits of water availability needs of CEFE, the site does occur approximately 70 m (230 ft) higher in elevation than the other three extant populations, which may have some relevance in regard to harshness of the site or influence of the summer marine layer which can provide some additional moisture to the establishing population. This higher elevation of the introduction site is at the upper range of the typical summer marine layer found in the Bay Area.

For these reasons, planting was expanded within the larger introduction site in 2019 and 2020 adjacent to the Pine plot in and amongst the small portion of foothill pine woodland in the eastern portion of the site.

#### 4.5 FINE-TUNING THE IRRIGATION REGIME

Fine-tuning of the irrigation regime for new plantings has been ongoing throughout the project. For the pilot project, watering was more frequent but with less water in each irrigation event. However, after significant damage to the irrigation infrastructure in the Lower Sage test plot from rodents chewing drip line, we removed the irrigation completely in September 2019 in this test plot and have been hand watering the plantings since then. The irrigation events have been less frequent but with more water per event, in order to facilitate deeper root growth from a deeper, more widely spaced watering event. The plants responded very well to this approach with healthy, robust foliage. As a result, the irrigation regime is being revised for 2021 for all plantings to occur less frequently but with more water per event (Table 4). Hopefully this will help mitigate some of the late summer drought stress that the plantings experience annually (evidenced by yellowing of foliage and some leaf drop). Lower Sage continues to be the only area that is hand watered.

**TABLE 4. Proposed Irrigation Schedule for 2021**

Year Since Planted	Planting via Direct Seeding	Planting via Containers
Year 1 (First Year)	1.0 gal 2x/week	2.0 gal 1x/week
Year 2	2.0 gal 1x/week	2.0 gal every 2-3 weeks
Year 3	2.0 gal every 2-3 weeks	No irrigation
Year 4 and onward	No irrigation	No irrigation

While evidence of summer drought stress is most pronounced in older plants which have since been removed from irrigation, encouraging deeper roots from less frequent but longer irrigation events in the first few formative years of a seedling may assist in mitigating drought stress once plants are dependent only on seasonal rainfall. Vasey (2014) also found that the vapor pressure deficit (VPD), an indicator of evaporative demand (and a function of temperature and relative humidity) of CEFE plants in the three extant occurrences was greatest in the months of June and July, while leaf wetness (a proxy for foggy or misty conditions) was greatest in August and September. He concluded that the last two months of the summer dry season may be the most critical in reducing the minimum water potential experienced by CEFE shrubs in the extant populations and could explain why the summer marine layer is of critical importance to water availability.

In late 2019 the irrigation infrastructure was switched from drip tubing to PVC pipe and a thicker IPS flex tubing in order to deter rodent chewing on the lines (K. Leopold, personal communication, November 11, 2020). The harsh and extreme nature of the site, with wide fluctuations in temperature over the seasons, has led to breaks and separations in the irrigation lines (causing the tanks to fully drain at times), and has led us to develop and implement a more robust and heavy duty irrigation infrastructure. Changes include the placement of heavy filters on the main lines running from the two 5,000 gallon water tanks to reduce sediment entering and clogging the irrigation lines, use of heavy UVR (ultraviolet resistant) PVC pipe on the mainlines (rather than standard schedule 40 pipe) that connect the tanks to the line valves, and heavier fittings to reduce the tendency for the pipes to separate at couplings which then causes water loss from the tanks.

#### 4.6 ONGOING ISSUES WITH HERBIVORY

Issues with herbivory of seedlings and young plants continue. The most difficult months are in late summer (July-September and into October) when surrounding vegetation is very dry and there is little other greenery for herbivores to consume or gnaw on (Appendix A, Photo 12). Regular application of Liquid Fence (an organic spray repellent comprised primarily of putrescent whole egg solids and garlic) sprayed on the young plants does help. There have also been issues with irrigation lines and tubing being chewed. This was especially acute in the Lower Sage plot, where sagebrush (*Artemisia californica*) provides ample cover for rodents/rabbits/voles and there was the lowest survivorship of direct seeded basins in any of the plots (only 10% surviving by Year 4; Figure 7). As a result, we completely abandoned direct seeding in this plot and have only installed container plants since 2016. In addition, we abandoned irrigation by drip in this plot and only hand water the plantings.

#### 4.7 PATHOGENS

In early to mid-July 2020, a sudden and mysterious die off of the 2019 planted container stock was documented in one portion of the site near the Pine plot. In all, a total of 10 plants located near each other either died or had significant dead branches and/or leaf chlorosis and scorching (Appendix A, Photo 13). The plant roots and associated basin soil of affected plants was analyzed by Phytosphere Research in mid-July. In order to determine the cause of plant die off and mortality, plant root balls were completely excavated and taken for samples, along with adjacent soil and loose roots (Swiecki & Bernhardt 2020a; Swiecki & Bernhardt 2020b). Low stem cankers were seen on all dead plants and on two plants with partial die off. Samples were baited to detect *Phytophthora* with green pears and then rebaited using rhododendron leaves.

No *Phytophthora* was detected with either pear or rhododendron baiting tests. However, continued investigation did reveal the presence of *Fusarium proliferatum*, a relatively common fungal pathogen. *F. proliferatum* has a broad host range, causing root, crown, and other rots, and cankers in both dicots and monocots worldwide (Swiecki & Bernhardt 2020b). No additional die off has been observed since the summer event.

As is usual practice prior to the annual planting event, container plants installed at the introduction site in December 2020 were sampled prior to site arrival to ensure they were *Phytophthora*-free. All tests for *Phytophthora* came back negative from both the nursery and Phytosphere Research; however, there was a detection of another *Fusarium*, *F. oxysporum* on roots of some sampled nursery-grown plants (T. Swiecki, personal communication, December 11, 2020). *F. oxysporum* is a very widespread species that has both pathogenic and nonpathogenic strains. In a wound inoculation test on terminal shoots, *F. oxysporum* caused

larger lesions (9.4x area of non-inoculated controls) than *F. proliferatum* (2.9x area of controls) after 45 days, but neither species was highly virulent. It was hypothesized that both taxa might act as secondary opportunistic pathogens in stems. Based on its low virulence, *F. proliferatum* did not appear likely to have been the primary cause of the stem cankers observed in the plants sampled in summer 2020. *F. oxysporum* may serve as a weak root pathogen of CEFE, at least under nursery conditions (T. Swiecki, personal communication, December 11, 2020 and January 19, 2021). We do not have sufficient data to know whether these *Fusarium* species can affect the health of CEFE in the field.

Given the uncertainties that existed as to the cause of the summer 2020 mortality, the following procedures were implemented prior to planting. Each container plant was given a close, visual inspection. Shoot growth, stems and roots were all carefully inspected. Plants with mild root decay at the bottom of the root ball had infected roots carefully removed by hand, sanitizing between plants, and then planted. Approximately 10% of the plants had some small brown spots with very limited root decay (K. Leopold, personal communication, December 17, 2020). One larger plant (TB4 container size) had more significant root decay and was not planted. All removed, decayed roots and associated soil samples were sent overnight to Phytosphere Research for additional testing. *F. oxysporum* was detected in these samples, but no *Phytophthora* was detected via pear baiting. At the time of this report, investigation is continuing as to the cause of localized plant mortality at the site in July 2020.

There have been some past issues as well on CEFE container plants at the nursery prior to outplanting. In late 2017 some seedlings exhibited leaf necrosis and wilted shoot tips. Further examination revealed infection of some seedlings by *Botrytis*, which is a common fungal pathogen and can be a problem under cool and moist conditions (T. Swiecki, personal communication, December 18 and December 27, 2017).

In order to increase the level of phytosanitation throughout the planting process, the following protocols will be observed for future seed collection and processing, treatment of seeds prior to sowing, and inspection of plants prior to delivery to the site:

- During seed collection, the condition of the inflorescences will be closely inspected to make sure they are healthy. Developing seed inflorescences will be 'bagged' with nylon stocking (pantyhose) as close as possible to seed dehiscent time to avoid prolonged seed time enclosed in seed collection bag.
- After collection, seed will be processed immediately to avoid prolonged contact of seeds with dried plant tissue.
- The seed surface will be disinfected at multiple stages in the seed treatment process with both a bleach solution and a hydrogen peroxide solution prior to sowing in the nursery or at the planting site (see details below).
- Minimum temperatures attained during heat pasteurization/treating of nursery potting media will be closely monitored and recorded, especially noting presence of any possible cold spots in the pile corners and at edges. To obtain good levels of efficacy against *Fusarium* spp., media should be treated at 150 degrees F (65 degrees C) for a minimum of 60 minutes (Swiecki & Bernhardt 2020b).
- The level of inspection and testing of nursery plants will be increased (Appendix A, Photo 14). Plants will be checked at the nursery before shipping, as well as prior to

planting, for any evidence of stem cankers. Particular attention will be given to older stock that may have been held over from a previous year. All dead leaves will be removed from containers and any leaves that have areas of necrosis will be removed. Gloves and tools will be sanitized after removing any leaf tissue and before handling another container plant. Infected plants will be culled.

- Planting of container plants will occur in mid-November if feasible, just prior to the beginning of seasonal rainfall. This prevents handling of plants and soil when conditions are wet, and potential contact with and spread of *Botrytis*, a common fungal pathogen. Care will be taken to avoid breaking of stems or leaves, as *Botrytis* tends to infect through wounds or dead tissue.

Rancho Santa Ana's seed treatment process (Meyer 2013) was to place seeds in boiling water, soak for 12 hours, then surface sterilize with a 10% bleach solution; this resulted in laboratory germination percentages ranging from 67% to 100% for CEFÉ- not out of the range of our field germination average success rates of 52%-63% over 5 years of direct seeding (Figure 5). After discussion with Phytosphere Research and The Watershed Nursery, we have developed a new seed sterilization protocol, which is outlined below:

1. Pre-storage surface sterilization- 0.52% bleach (sodium hypochlorite) solution, 4x seed. Agitate for 60 seconds, pour off solution. Rinse with distilled water. Allow to dry in a clean, covered area and then put into cold, dry storage in a refrigerator at ~ 42 degrees F.
2. Seed treatment prior to use:
  - a. Surface sterilize- 0.52% bleach (sodium hypochlorite) solution 4x seed. Agitate for 60 seconds, pour off solution.
  - b. Hot water soak at 190 degrees F, at least 4x seed volume, cover with lid – change water every few hours, changed water is sterilized/distilled but not reheated.
  - c. Final surface disinfection and germination stimulation- 3% hydrogen peroxide, solution 4x seed volume. Agitate for 60 seconds, pour off solution. Rise with sterile or distilled water 1x.
3. If seeds are going to be direct sown, they are put into covered containers after the final surface disinfection and taken to the field for sowing the following day. Because direct sowing happens in the winter (December) and ambient temperatures are low over night the containers are not refrigerated overnight. If sowing is delayed due to unforeseen reasons the seeds are kept in a refrigerator until sown. If the delay is more than a day or two a piece of sterile germination paper slightly moistened with distilled water will be placed in container to keep seeds from drying out.
4. If seeds are going into container production, they are put into a heat-treated germination mix moistened with distilled water after final surface disinfection and put into a refrigerator at ~ 42 degree F for 1 month after which time they are sown in heat-treated germination mix and placed in greenhouse.

Seed testing for fungal contaminants/endophytes may also be explored, via a culturing from seeds and identification of isolates by DNA sequencing. The work would be conducted by

Phytosphere Research and the Plant Pest Diagnostics Lab at California Department of Food and Agriculture (CDFA). This would be explored if the proposed seed surface sterilization technique and other phytosanitary measures do not remedy the pathogen issues seen periodically in container seedlings.

#### **4.8 OTHER CHANGES TO PLANTING METHODS**

Because CEFE plants tend to grow laterally more than vertically, they quickly outgrow (within 6 months) even the larger, custom-made wire enclosure cages we have been using to deter herbivory. Therefore, starting in 2020, all new plantings will only have cages on the direct seeded basins. Herbivory protection will be accomplished by a greater attention to regular and systematic application of Liquid Fence applied to plant leaves and stems to deter herbivores such as rabbits, gophers, and voles. We have been using Liquid Fence for the past several years and have found the regular application does reduce herbivory on seedlings and young plants.

## 5. CONCLUSIONS AND ONGOING EFFORTS

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### 5.1 LONG TERM PLANTING AND MAINTENANCE SCHEDULE

The long-term planting schedule is to plant 200 container plants and 60 direct seeded basins annually in December 2021 and 2022. This will add 260 new plants to the introduction site per year for the next two years. At 1,042 current basins (as of Dec 2020), this would add an additional 520 basins, for a total of 1,562 basins. Assuming some level of mortality—and some natural recruitment—this is probably the appropriate size of the planted population of CEFE at the introduction site. If needed, an additional year of planting may be proposed. After this, it is estimated that there will be an additional two to three years of irrigation. Ongoing site maintenance will likely be needed to control weeds and monitor the effects of herbivory.

Regular monitoring will continue in order to evaluate if the seeds which are naturally produced in the population lead to recruitment and natural regeneration, as well as to ensure that the created population remains healthy. At some point, prescribed burns may be considered to stimulate natural recruitment and maintain the population.

### 5.2 AN EVALUATION OF SUITABLE HABITAT AND ADDITIONAL POPULATION CREATION EFFORTS

To evaluate suitable habitat for CEFE within the Habitat Plan area in Santa Clara County, we overlaid several data layers in ArcMap 10.4.1. Specifically, we used the following data layers of known habitat preference, soils, and elevational range to create a map of modeled suitable habitat:

1. Serpentine soils (Santa Clara County Planning Dept) and/or serpentine geology (United States Geological Survey; USGS)
2. Vegetation type/natural community (Habitat Plan land covers)
  - a. Serpentine bunchgrass grassland
  - b. Mixed serpentine chaparral
  - c. Serpentine seep
  - d. Northern mixed chaparral/chamise chaparral (on serpentine)
  - e. Northern coastal scrub/Diablan sage scrub (on serpentine)
  - f. Foothill pine/oak woodland (on serpentine)
3. Known elevational range for CEFE (394 ft-1,509 ft)- from the California Natural Diversity Database (CNDDB)
4. Valley Habitat Plan area

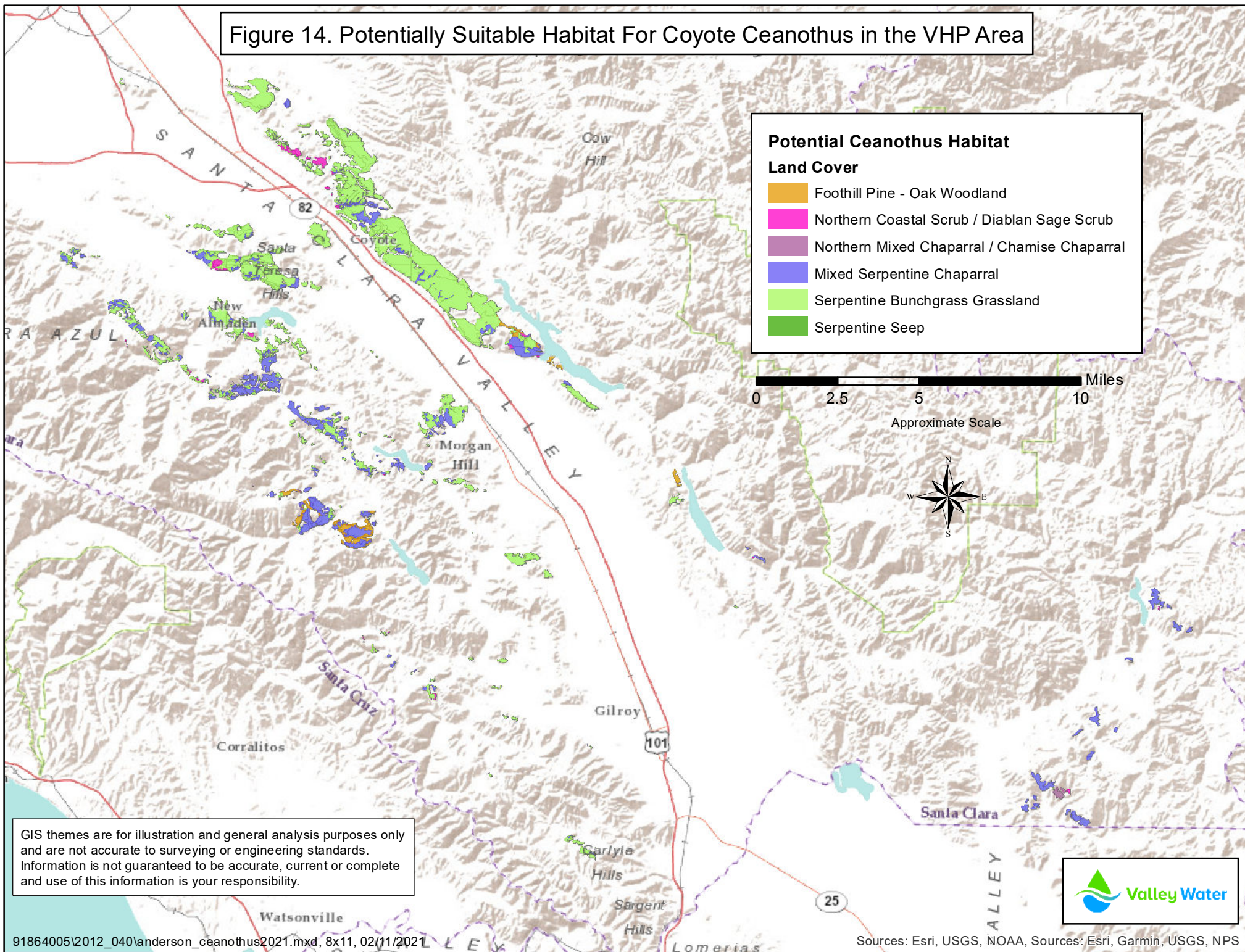
This resulted in a map showing locations in the county where all the features associated with known occurrences of CEFE co-occur (Figure 14). Broken down by natural community, this results in a total of 12,197 acres of potentially suitable habitat in the Plan area (Table 5). This is slightly lower than the reported acreage of 14,187 acres in the Habitat Plan (ICF 2012) and in the USFWS 5 Year Status Review (USFWS 2011); likely because that evaluation did not take into consideration elevational range. Vasey (2014) estimated the elevational range for the three extant populations of CEFE during his microclimate suitability study at approximately

145 m (475 ft) at the low end (Kirby population) to 340 m (1,115 ft) at the high end (upper portion of the Anderson Dam population). Vasey estimated the Llagas population to be at approximately 150-200 m elevation but this should be field verified, as there was not access to the Baird portion of the occurrence (Tilton Ranch) during the time of his study.

**TABLE 5. Acres of Potentially Suitable Habitat for Coyote Ceanothus in the Habitat Plan Area**

<b>Vegetation Type/Natural Community</b>	<b>Acres</b>
Foothill Pine/Oak Woodland	441
Mixed Serpentine Chaparral	2,950
Northern Coastal Scrub/Diablan Sage Scrub	246
Northern Mixed Chaparral/Chamise Chaparral	64
Serpentine Bunchgrass Grassland	8,482
Serpentine Seep	14
<b>TOTAL</b>	<b>12,197</b>

Figure 14. Potentially Suitable Habitat For Coyote Ceanothus in the VHP Area



**Potential Ceanothus Habitat**

**Land Cover**

- Foothill Pine - Oak Woodland
- Northern Coastal Scrub / Diablan Sage Scrub
- Northern Mixed Chaparral / Chamise Chaparral
- Mixed Serpentine Chaparral
- Serpentine Bunchgrass Grassland
- Serpentine Seep

0 2.5 5 10 Miles  
Approximate Scale



GIS themes are for illustration and general analysis purposes only and are not accurate to surveying or engineering standards. Information is not guaranteed to be accurate, current or complete and use of this information is your responsibility.



Additional efforts for population creation should focus on the west side of the valley near the Llagas occurrence, if possible. That population has been shown to be the most genetically diverse (Honeycutt 2012), has shown some evidence of recruitment even without fire (Hillman, personal observations), and may have more resilience in the face of climate change, as the western side of the valley near the Santa Cruz Mountains and Pajaro Gap is more mesic. The current distribution of CEFE does fall within the zone of influence by the summer marine layer (Vasey 2014), and it's likely summer fog also plays a key role in determining suitable habitat for CEFE and facilitates the establishment of young plants.

In addition, plastid DNA work conducted by Potter (2012) showed major plastid haplotype variation correlated with geographic locations and distances among the three extant populations of CEFE. In other words, the Anderson Dam and Kirby populations make up an east race, and the Llagas population makes up a west race on west side of the valley. The number of mutations seen for the haplotype data suggest that the Llagas population has been isolated for a long period of time, and coupled with the high levels of genetic diversity seen in this population relative to the other two populations, it seems likely that Llagas was the origin population of CEFE.

If another population creation effort is attempted, planting should occur annually over a series of years using seed collected regularly from the Llagas population. This method mimics natural recruitment and allows the establishment of multiple age classes in the created population, which increases population structural complexity and diversity as well as safeguarding against future stochastic events. As has been noted, this experimental approach is especially important for extremely rare taxa such as CEFE, which have a limited number of extant populations and typically have never before been the focus of a population creation effort.

Creating another population on the west side of the valley using seed collected from the Llagas population would ensure that there is a full complement of both geographic location and genetic diversity to guard against future stochastic events which could threaten persistence of the species.

### **5.3 NEXT STEPS AND FUTURE RESEARCH TOPICS**

There are several additional research topics which could be explored to more fully understand why CEFE has established populations in some suitable habitat areas but is generally absent in other areas of seemingly suitable habitat, as well as how to better manage existing and introduced populations and to facilitate and contribute to recovery of the species as a whole. These research topics include the following:

- Further exploration of soil microsymbiont relationships such as *Frankia* in managed and created populations of CEFE.
- Further exploration of plant pathogen introductions and potential impacts on managed and created populations of CEFE. This should include not just *Phytophthora*, but also *Fusarium* and *Botrytis*, which are known to impact seedlings.
- Additional habitat suitability needs and potential locations for another population creation effort.
- Focus on the Kirby population to further understand reasons for decline; protection of Kirby occurrence through a conservation easement or similar land management action.

- An additional seed banking effort in all three populations.
- Serious consideration into the feasibility of prescribed fire as a management tool and development of a prescribed burn plan to stimulate recruitment and reduce dead wood build up in extant occurrences (such as Llagas) or in areas of high grass thatch that preclude natural recruitment.
- Set up wildlife cameras in extant occurrences of CEFE to examine browse pressure and herbivory, with possible caging of naturally recruited seedlings to prevent herbivory.

The CEFE plants in the population creation site will be tested for presence of *Frankia* in summer 2021. While *Frankia* cannot be grown in a lab, and no one knows how it spreads or is introduced into new geographic areas, all existing natural populations of CEFE showed presence of *Frankia* on roots of sampled plants (Battenberg and Berry 2014). In contrast, the introduction site before CEFE was planted did not show any evidence of *Frankia*. However, we have observed in the past couple of years some planted CEFE in the introduction site with particularly vigorous growth as well as dark green and glossy leaves, which can be an indicator of a soil-based nitrogen fixation associated with a microsymbiont such as *Frankia*. This is in starkest contrast in late summer when the plants typically exhibit signs of drought stress such as yellowing chlorotic leaves and leaf drop. Sampling of both vigorous plants and stressed plants for presence of soil-based nitrogen in leaf tissue could yield an insight into whether *Frankia* has found its way into the population creation site, which is considered important for long-term persistence of the created population.

We also plan to further explore the plant pathogen issue in both naturally collected seeds as well as during nursery production, in the hopes of identifying better strategies for growing, planting and maintaining healthy plants.

Besides participating in an updated seed banking effort of all three extant occurrences, the other research topics are currently beyond the scope of the present effort and level of commitment by Valley Water. However, Valley Water may partner with the Habitat Agency to further develop and explore the other research topics listed above.

#### **5.4 PLANT SENSITIVITY TO CHANGES IN PRECIPITATION AND HYDROLOGY – WHAT DOES THE FUTURE HOLD?**

In late summer 2015 we observed some die off of closely spaced CEFE on the hillside above Anderson Spillway, in the area that burned in 2003. The hillside was the site of massive CEFE recruitment in the year following a large vegetation fire in 2003 (Janell Hillman, personal observation). Sampling of the hillside in 2015 by Phytosphere Research revealed no presence of *Phytophthora* plant pathogens (Swiecki & Bernhardt 2015a, 2015b) so we hypothesized the mortality was due to drought conditions, though there was probably also some density dependent thinning. The drought hypothesis was substantiated by the lack of flowering and fruit production of CEFE that year (Janell Hillman, unpublished data) due to lack of significant rainfall.

In contrast, in wet years and years with late spring rainfall, we have observed CEFE to flower a second time in the natural populations (much later into spring and early summer than the first, typical flowering which occurs from late January to March). Sometimes these buds are formed in response to late rains but remain latent or dormant on the branches. In the Kirby population, the only natural recruitment we have observed is on the banks, somewhat shaded, just above

the perennial stream that bisects the occurrence. In the population creation site, the greatest survival and health and vigor of both planted seedlings and direct recruits has consistently been seen in the Pine test plot, where there is overstory shading from interspersed foothill pines. In contrast, where plants have been planted in full sun, on thinner soils and/or in more exposed areas (e.g., the Chaparral Edge test plot and the Upper Sage test plot), we see summer drought stress where the older leaves of plants turn yellow and drop off, but then green up again in winter with the return of seasonal precipitation.

The importance of the summer marine layer to enhance water availability for coastal chaparral shrubs was documented in the past by Vasey et al., (2012) and for this study (Vasey 2013; 2014), and as has been mentioned, the Coyote Ridge introduction site is at slightly higher elevation (380 m or 1,247 ft) than where the other extant populations of CEFE occur. Although the introduction site is within the influence of the summer marine layer, and appears to be suitable to establish a new population of CEFE (Vasey 2014), it is still a very harsh site with extremes of wind, hot summer temperatures, and bitterly cold winters.

These observations lead us to hypothesize that drought and altered precipitation patterns can and will significantly affect natural populations of CEFE. It is possible that water availability associated with a combination of the summer marine layer and winter rainfall is a factor that constrains the distribution of CEFE (Vasey 2014). Combined with the very limited number of populations despite a fairly large amount of suitable habitat available in the Plan area (Figure 14), and suggestion from the genetic study results that CEFE may in fact be a paleoendemic species, it is possible that this taxon may not persist naturally in the face of impending climate change and a warming San Francisco/Monterey Bay Area of the future. From this perspective, the current population creation effort can also be seen as an assisted migration of the species northward to help mitigate potential stochastic events.

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## 8. APPENDIX A—SITE PHOTOGRAPHS

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**PHOTO 1.** Coyote ceanothus on the east shoreline of Anderson Dam. Photo date: February 11, 2011.



**PHOTO 2.** Solarized basin in the Upper Sage plot after removal of planted Coyote Ceanothus in 2014. Photo date: February 4, 2015.



**PHOTO 3.** Solar oven baking contaminated soil in the Pine plot. Photo date: July 10, 2018.



**PHOTO 4.** Coyote ceanothus container plants arrive at the introduction site on Coyote Ridge, ready for planting. Photo date: November 25, 2019.



**PHOTO 5.** Planting Coyote ceanothus container plants in the introduction site on Coyote Ridge, Chaparral Edge plot to the left and Anderson Reservoir in the distance. Photo date: November 25, 2019.



**PHOTO 6.** Direct seeding Coyote ceanothus in the Pine plot of the introduction site. Photo date: December 17, 2019.



**PHOTO 7.** Annual monitoring of Coyote ceanothus in the Chaparral Edge plot, Anderson Reservoir in the distance. Photo date: June 10, 2020.



**PHOTO 8.** Germination of Coyote ceanothus in the Upper Sage test plot, with all four seeds planted having germinated. Photo date: February 27, 2020.



**PHOTOS 9A AND 9B.** Condition 3 'excellent' rating during the annual monitoring effort. Plants robust, dark green leaves. Note: different plant sizes are due to different age of plants. Photo date: June 10, 2020.



**PHOTO 9c.** Condition 2 or 2.5 'good' rating during annual monitoring effort. Some leaf chlorosis but plant multi-branched. Photo date: June 10, 2020.



**Photo 9d.** Condition 1 'fair-poor' rating during the annual monitoring effort. Significant leaf chlorosis and plant stunted. Photo date: June 17, 2020.



**PHOTO 10.** Flower fly (family Syrphiidae) visiting Coyote ceanothus flowers in the Pine plot.  
Photo date: February 12,2020.



**PHOTO 11.** Coyote ceanothus in fruit in the Chaparral Edge plot. Photo date: June 10, 2020.



**PHOTO 12.** Evidence of herbivory on planted Coyote ceanothus in the Chaparral Edge plot.  
Photo date: September 02, 2020.



**PHOTO 13.** Partial plant die-off from Fusarium pathogen in the 2019 planted container stock.  
Photo date: July 08, 2020.



**PHOTO 14.** Coyote ceanothus container plant with healthy root system, right before planting into the Pine plot. Roots are white and extend to the bottom of the container. Photo date: December 2017.