Western Riverside County
Multiple Species Habitat Conservation Plan
Biological Monitoring Program

2022 Brand's Phacelia Habitat Enhancement Study
(*Phacelia stellaris*)

Brand's phacelia. Photo: Marisa Grillo

March 2024

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NOTE TO READER:

This report is an account of survey activities conducted by the Biological Monitoring Program for the Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP). The MSHCP was permitted in June 2004. Reserve assembly is ongoing and is expected to take 20 or more years to complete. The Conservation Area includes lands acquired under the terms of the MSHCP and other lands that have conservation value in the Plan Area (called public or quasi-public lands in the MSHCP). In this report, the term "Conservation Area" refers to these lands as they were understood by the Monitoring Program at the time the surveys were conducted.

The Monitoring Program monitors the status and distribution of the 146 species covered by the MSHCP within the Conservation Area to provide information to Permittees, land managers, the public, and the Wildlife Agencies [i.e., the California Department of Fish and Wildlife (CDFW, formerly California Department of Fish and Game) and the U.S. Fish and Wildlife Service]. Monitoring Program activities are guided by defined conservation objectives for each Covered Species, other information needs identified in MSHCP Section 5.3 or elsewhere in the document, and the information needs of the Permittees. A list of the lands where data collection activities were conducted in 2021 is included in Section 8.0 of the Western Riverside County Regional Conservation Authority (RCA) Annual Report to the Wildlife Agencies.

The primary authors of this report were Marisa Grillo, Botany Program Lead 2020-2022, and Karyn Drennen, Botany Program Lead 2011-2019. This report should be cited as: Biological Monitoring Program. 2022. Western Riverside County MSHCP Biological Monitoring Program 2022 Brand's Phacelia Habitat Enhancement Study. Prepared for the Western Riverside County Multiple Species Habitat Conservation Plan. Riverside, CA. Available online: https://www.wrc-rca.org/species-surveys/.

While we have made every effort to accurately represent our data and results, it should be recognized that data management and analysis are ongoing activities. Any reader wishing to make further use of the information or data provided in this report should contact the Monitoring Program to ensure that they have access to the best available or most current data.

Please contact the Monitoring Program Administrator with questions about the information provided in this report. Questions about the MSHCP should be directed to the Executive Director of the RCA. Further information on the MSHCP and the RCA can be found at www.wrc-rca.org.

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INTRODUCTION

The effects of disturbance on rare plant populations depends on the nature of the disturbance and the ecological needs of individual plant species in question. Some plants are adapted to limited disturbance and depend on aspects of this disturbance to thrive (Reed et al. 2021; Hobbs & Huenneke 1992), particularly annuals that depend on early succession open or sandy habitats (Harper 2007; Eichberg & Donath 2018). However, disturbance from human activities such as horseback riding and hiking also results in destructive trampling of individual plants (O'Brien & Fraga 2013). Whether a population can recover from disturbance events also depends on intensity and frequency of disturbance (Hobbs & Huenneke 1992). Managing for small populations of rare annual plants, such as Brand's Phacelia, therefore requires a clear understanding of the species' response to the aspects of disturbance to which it is subjected.

Brand's phacelia (*Phacelia stellaris*), a Covered Species under the Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP), is a small annual herb in the borage family with lobed, hairy leaves, and small purple flowers. It occurs along a mostly open, sandy river bench of the Santa Ana River in the Santa Ana Wilderness Area in Riverside, California. It is ranked 1B.1, seriously threatened in California and elsewhere, by the California Native Plant Society (CNPS 2022). The Santa Ana Wilderness site is the sole known remaining population of Brand's phacelia in Riverside County (Figure 1). This population is traversed by trails used for hiking and horseback riding and trampling of the tiny plants and sandy habitat may be deleterious to the survival of the population (O'Brien & Fraga 2013). For this reason, in 2013, the Riverside County Regional Park & Open-Space District reinforced trail fencing to divert recreational traffic around the Brand's phacelia population.

The impacts of the above-mentioned types of disturbance to Brand's phacelia population(s) are generally unclear in existing literature. An in-depth species assessment by the Rancho Santa Ana Botanical Garden (RSABG) cites trampling as a direct threat to the species (O'Brien & Fraga 2013), whereas a United States Fish and Wildlife Service (USFWS) Candidate Species Assessment, in regard to the City of Riverside population, states that "light to moderate disturbance seems to have benefitted this species at other locations; therefore, it is possible that minimization of use of this area by horses and people may have been detrimental to *P. stellaris*" (USFWS 2012). California State Parks conducted a study from 2013 through 2015 at Silver Strand State Beach in San Diego County to evaluate the impacts of different types of disturbance on Brand's phacelia at that site. Results showed no significant difference in abundance of *P. stellaris* between plots that received annual or biennial raking and plots that did not receive any raking disturbance treatment, while fencing to prevent trampling by human recreation was found to be a benefit to the species and to native species richness (Stafford & Smith 2016).

The MSHCP identifies three Conservation Objectives for Brand's phacelia. The first Objective requires the conservation of ≥6100 acres (ac) or ≥2469 hectares

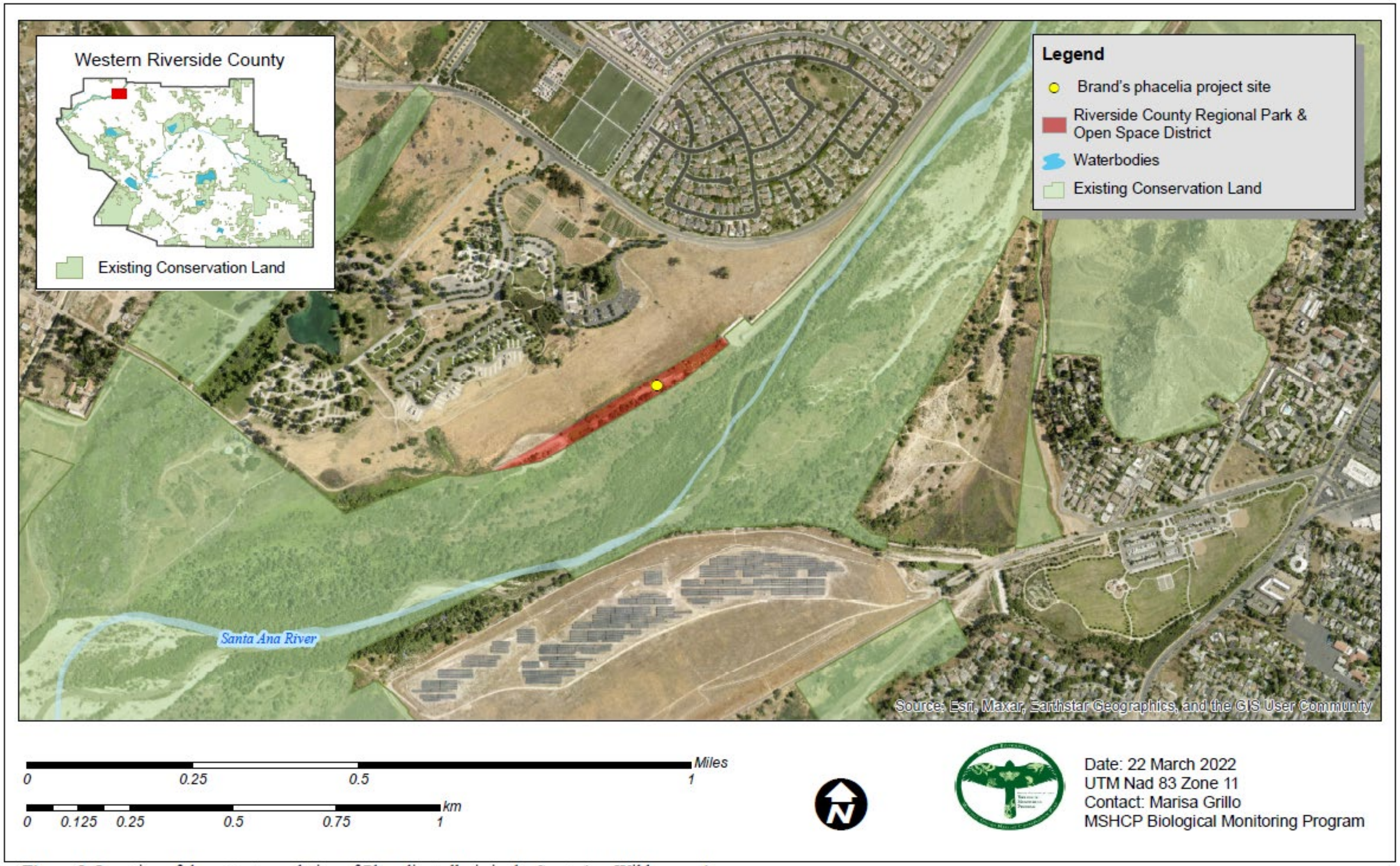

Figure 1. Location of the extant population of Phacelia stellaris in the Santa Ana Wilderness Area.

(ha) of suitable habitat (meadows/marshes and playa/vernal pools between 5 and 500 meters [m] within the Riverside Lowlands Bioregion). The second Objective requires the conservation of at least the two known localities along the Santa Ana River at Fairmont Park and in the Santa Ana Wilderness Area. Finally, the third Objective requires that surveys for Brand's phacelia be conducted as part of the project review process for public and private projects within the Narrow Endemic Plant Species survey area where suitable habitat is present (Dudek & Associates 2003). The MSHCP Biological Monitoring Program (BMP or Monitoring Program) is responsible for monitoring the location(s) specified in Objective 2 for a 75% minimum level of occupation of known locations within an 8-year monitoring period as required by MSHCP Table 5-8. However, only the Santa Ana Wilderness population, along the Santa Ana River, was extant at the time of the MSHCP implementation (2004). Therefore, this report is based on data from the one extant population.

In 2008 and 2013, BMP biologists observed 18 and 68 Brand's phacelia individuals respectively at the Santa Ana Wilderness site. No individuals were observed during surveys conducted in 2014 through 2016. Concerned that the population was declining rather than improving after the exclusionary fencing was installed, we began developing a protocol to investigate whether disturbance that did not include individual plant trampling (i.e., soil disturbance) might benefit the Brand's phacelia population at this site. Anecdotally, we had observed in 2013 that Brand's phacelia tended to grow along the edges of equestrian disturbance. Furthermore, the RSABG report (O'Brien & Fraga 2013) states that Brand's phacelia does not inhabit soils that tend to "cement" or "seal" on the surface, nor does it grow on cryptogamic crust. The report also states that aggressive mustard species with large rosettes create excessive shade and competition (O'Brien & Fraga 2013). Having observed both of these features at the site, we were interested in testing whether weeding and/or raking, as a form of disturbance to break up surface crusts and dislodge germinating weedy competitors, might improve the habitat for the Santa Ana Wilderness population of Brand's phacelia.

In 2016 the BMP biologists started a randomized block experiment to determine the best approach to managing the population of Brand's phacelia within the MSHCP Plan Area, whether it be a controlled disturbance regime, weeding exotic competitors, or both. Our primary hypothesis was that disturbance to loosen the soil, applied before the growing season, increases the number of Brand's phacelia plants that germinate. Our secondary hypothesis was that weeding of invasive competitors early in the growing season increases the number of Brand's phacelia plants that germinate. Our third hypothesis was that the combined treatments of weeding and disturbance increases the number of Brand's phacelia plants that germinate. We were interested in which of these treatments provides the greatest benefit to the population. We tested these hypotheses by conducting a controlled experiment using plots with random treatment assignments, including control plots, and comparing the germination counts between plots receiving different treatments. If these treatments promote increased germination, we expected that the number of Brand's phacelia germinants would be significantly higher in plots receiving treatments than in control plots.

METHODS

Protocol Development

In 2016, the Monitoring Program began developing an experimental protocol to study the impacts of disturbance and weeding treatments on the Santa Ana Wilderness population of Brand's phacelia. Treatment application methods were designed in consultation with the Brand's phacelia Candidate Conservation Agreement (CCA) working group members under the direction of Nancy Ferguson, USFWS Carlsbad. The first draft of field methods was reviewed on site by Dr. Chris McDonald with the University of California Cooperative Extension (UCCE), who offered suggestions and improvements that were included in our final protocol. Following is the timeline showing all the actions performed until the final protocol was established in 2020:

- *November 2016* – We established the study plots.
- *December 2016* – We began applying the first treatments for the 2017 growing season, beginning with the Disturbance treatments in December.
- *March 2017* – The first Weeding treatment was applied.
- *December 2017* – Another Disturbance treatment was applied. We changed the protocol for Disturbance by raking disturbance plots more deeply to stir up the seed bank in addition to breaking up surface crust at the suggestion of Nancy Ferguson.
- *February/March 2018* – We modified the Weeding treatment application protocol slightly, changing the hand-pulling of weeds to clipping with scissors at the surface.
- *January-April 2019* – We collected data on all Brand's phacelia in plots by tracking individual germinants with unique numbers since germination numbers were low.
- *January-April 2020* – Modification of the protocol was necessitated by the much greater numbers of germinating individuals in 2020. Because tracking individual germinants throughout the season was no longer feasible, we decided to survey total counts of individuals, beginning with the 2020 survey season, and used the largest counts observed at any one time in our data analyses.

Survey Methods

The survey protocol used from 2019-2022 is described more completely in the *Western Riverside County MSHCP Biological Monitoring Program Protocol for Brand's Phacelia Habitat Enhancement*, available from the Biological Monitoring Program.

Training

All surveyors for this study were trained by the Botany Program Lead to identify Brand's phacelia in all stages, including newly emerged cotyledons, and to identify reproductive structures of mature individuals. Surveyors were also trained to identify species targeted for removal in the Weeding treatments. We trained surveyors on the line-point intercept cover protocol before completing the vegetation surveys. All surveyors demonstrated familiarity with survey methods and data collection prior to working independently.

Survey Design

The study site is centered over the Santa Ana Wilderness population observed by the Monitoring Program in previous years. The site was divided into 48 1-meter x 2.5-meters sample plots distributed in pairs and spaced one meter apart. Wooden stakes (1.4 centimeters [cm] x 3.5 cm x 44 cm) were used to mark the corners of each plot.

The location, size, and plot placement were chosen to cover the population site, to provide a large enough sample for data analysis, and to facilitate ease of treatment application from the spaces between plots. Brand's phacelia observed outside plots were monitored according to the Rare Plant monitoring protocol (BMP protocols can be found at https://www.wrc-rca.org/survey_protocols/) and were not included in these study results.

We assigned treatments with a randomized block distribution to obtain randomization while minimizing the clumping of treatments within the study site (Figure 2). We used 12 horizontal blocks with four randomly placed plots in each. The four treatments depicted in Figure 2 were Disturbance Only ("D"), Weeding Only ("W"), Weeding + Disturbance ("W+D"), and Control (no treatment applied, "C").

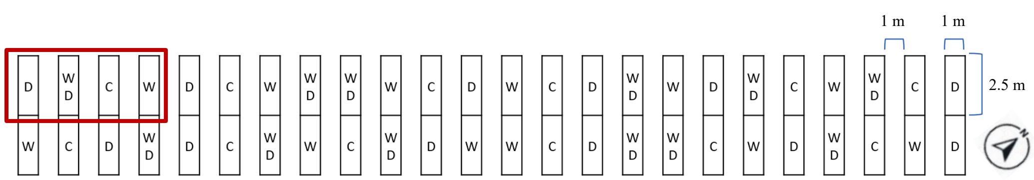

Figure 1. Treatment assignment of the 48 study plots with the first block outlined in red.

Plot Treatments

Disturbance Treatment (D)

The Disturbance treatment was applied to the plots once per year in early December before Brand's phacelia and other annual plants began to germinate at the site. Because we had anectdotally observed that Brand's phacelia grew most abundantly at the transition between equestrian trails and adjacent undisturbed habitat, with a metal bow rake, we raked lengthwise down the center of the plot to create disturbance "trails", keeping the "transition" area within the plots unraked (Figure 3). We raked to a depth of about 10 centimeters once in each lengthwise direction, to loosen the top soil and stir up the seed bank, and then smoothed the loosened soil back over the "trail". We raked as closely as possible to shrubs in the path that were not being removed and we raked over forbs.

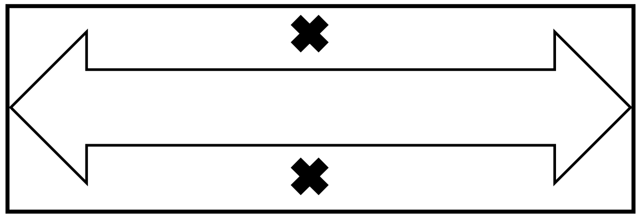

Figure 2. Application of Disturbance Treatment. We applied raking in the lengthwise directions leaving the "transition area" undisturbed (marked by X) inside the plots.

Weeding Treatment (W)

We began applying the Weeding treatment to plots, in a random generated order, when the weeds began to germinate at the site in early January and before Brand's phacelia started germinating. We continued weeding the W and W+D plots until each plot was weeded thoroughly one time early in the season, usually by the end of February. Weeding was applied by hand or using small scissors, with care taken to prevent disturbing the substrate and adjacent species that were not targeted for removal. During weeding, we aimed to avoid disturbing the substrate beyond a depth of three millimeters (mm). A depth of three mm was chosen because the physical soil crust layer is typically the densest within the first three mm of the layer and because permeability to water typically increases dramatically after about five mm (Belnap & Lange 2001).

A list of target species to be removed was provided to surveyors and consisted of plant species believed to not belong in an open, semi-loose sandy river-bench habitat. Thus, native species that were thought to be converting the habitat and stabilizing the substrate were removed as well as invasive exotics (Table 1). These determinations were made by using species descriptions in Jepson eFlora Online (Jepson Flora Project 2023) and by comparing local species to similar species identified in CCA reports (USFWS 2013).

Table 1. Species present at the study site in 2017 and whether they were targeted in the Weeding treatment. **Bold text** indicates non-native species.

Species targeted for removal	Species not targeted for removal
***Bromus* spp.**	*Ambrosia acanthicarpa*
Eriodictyon trichocalyx	*Camissoniopsis* spp.
Erodium cicutarium	*Crassula connata*
Heterotheca grandiflora	*Croton californicus*
Hirschfeldia incana	*Logfia* spp.
Salsola tragus	*Pectocarya* spp.
Schismus barbatus	*Phacelia distans*
***Sisymbrium* spp.**	

Weeding + Disturbance Treatment (W+D)

The Weeding + Disturbance treatment combined both of the described treatments. As with Disturbance Only plots, W+D plots were raked lengthwise before Brand's phacelia began germinating. The W+D plots were also weeded for the same target species (Table 1).

Control Treatment (C)

The Control plots received no treatments over the course of the study.

Brand's Phacelia Counts

From 2019 through 2022, we surveyed plots every few weeks throughout the Brand's phacelia growing season, typically January through April, counting the total number of Brand's phacelia individuals in each plot during each survey round. The highest count for each plot was used in germination analysis. Based on phenology of co-occurring species, we started scouting for seedlings in early January while applying the Weeding treatment. Count surveys started when Brand's phacelia seedlings were identifiable in the plots, which is usually by mid-January when the distinctive hairy cotyledons begin to emerge. Count surveys ended when most individuals had bloomed and fruited and were beginning to senesce, approximately mid-April. The goal was to capture the highest amount of germination in each treatment. The peak of germination typically occurs early in the season, due to more optimal weather conditions and while plants are still very small, before most individuals have begun to bloom and before intraspecific self-thinning.

Data Analysis

We used Microsoft Excel 2016 to compile data and calculate total plant counts by treatment. We used R statistical program version 3.63 and ran non-parametric Kruskal-Wallis rank sum test for multiple independent samples to check whether there were any significant differences between treatments. Then we used R package "PMCMRplus" and ran the post-hoc Dunn method to identify which of the treatments was significantly different.

We also performed parametric testing. We first transformed the data with a log +1 transformation. We then used R statistical program to run a One-Way Analysis of Variance (ANOVA), Welch F-test (not assuming equal variances) on all treatments. Then we performed a One-Way ANOVA with Tukey's pairwise comparisons of means to identify which treatments were significantly different.

We performed the non-parametric and parametric tests on both the entire set of 48 plots and also on the northernmost 32 plots, removing four complete blocks. Removing complete blocks at one end of the site, we preserved random treatment assignments and eliminated null data while better centering our results over the existing Brand's phacelia population.

RESULTS

Brand's Phacelia Counts

From 2019 to 2022, we counted a maximum total of 5278 Brand's phacelia plants germinated within the study plots (Table 2). The highest number of individuals observed during any single survey round for each year, by treatment type, are reported in Figure 4, though the actual number of individuals germinated may be higher due to multiple cohorts. The treatment plots consistently producing the most germinating Brand's phacelia were the Disturbance (D) and the Weeding + Disturbance (WD) treatment plots.

Table 2. Count of plots containing Brand's phacelia and total individuals each year during the course of the study.

Year	C	D	W	W+D	Total Plots	Total Brand's phacelia*
2019	3	3	3	6	15	51
2020	6	6	5	7	24	2488
2021	4	5	4	7	20	445
2022	6	7	7	8	28	2294

* The actual number of individuals germinated may be higher due to multiple cohorts.

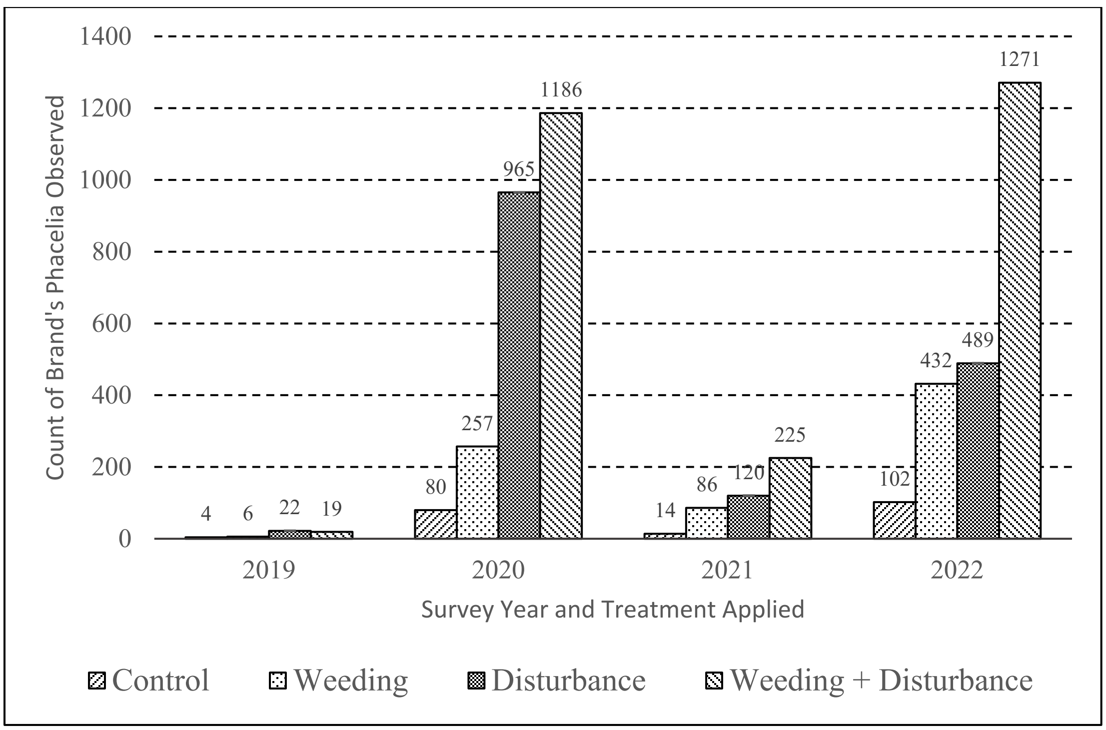

Figure 3. Highest count of Brand's phacelia observed at any one time, by treatment, by year. The actual number of individuals germinated may be higher due to multiple cohorts.

Non-parametric Testing

Kruskal-Wallis tests did not show a significant difference in germination counts among treatments for any single year; however, when all years were combined, there was a significant difference in Brand's phacelia counts among treatments (Table 3). Dunn's post-hoc pairwise comparison of all plots and all years combined revealed a significant difference between Control and the Weeding + Disturbance treatment (Table 4).

Table 3. Kruskal-Wallis test results for germination counts by year, all plots ($\alpha = 0.05$, $n = 48$). Bold text and asterisks (*) indicate a significant *p* value.

Year	x^2	*df*	*p*
2019	2.874	3	0.4115
2020	4.8897	3	0.1801
2021	3.8217	3	0.2814
2022	3.0641	3	0.3818
All years	**8.8456**	**3**	**0.03142***

Table 4. Dunn's post-hoc method results pairwise comparison of treatment results, all plots, all years. Bold text and asterisks (*) indicate a significant *p* value ($\alpha = 0.05$, $n = 48$).

Treatments	z value	***P*** **r (>|z|)**
D - C == 0	0.816	0.621929
W - C == 0	0.363	0.716840
W+D - C == 0	**2.728**	**0.038269***
W - D == 0	0.453	0.716840
W+D - D == 0	1.912	0.111781
W+D - W == 0	2.365	0.054091

Plots 1-13 had no germination throughout the entire study period. When we removed data from the four southernmost blocks (i.e., plots 1 through 16), Kruskal-Wallis tests did not show a significant difference in germination counts among treatments for any single year; however, when all years were combined, treatment results were significant ($p = 0.0095$; Table 5). Dunn's post-hoc pairwise comparison of all years combined revealed a significant difference between Control and Weeding + Disturbance ($p = 0.01718$) and also between Weeding and Weeding + Disturbance ($p = 0.01678$; Table 6).

Table 5. Kruskal-Wallis test results for germination counts by year, plots 17-48 ($\alpha = 0.05$, $n = 32$). Bold text and asterisks (*) indicate a significant *p* value.

Year	x^2	*df*	*p*
2019	3.8109	3	0.2826
2020	2.9661	3	0.3969
2021	4.4349	3	0.2182
2022	3.9577	3	0.2661
All years	**11.458**	**3**	**0.00949***

Table 6. Dunn's post-hoc method results pairwise comparison of treatment results, plots 17-48, all years. Bold text and asterisks (*) indicate a significant *p* value (α = 0.05, *n* = 32).

Treatments	z value	***P* r (>|z|)**
D - C == 0	1.347	0.213669
W - C == 0	0.226	0.821046
W+D - C == 0	**2.763**	**0.017175***
W - D == 0	1.573	0.213669
W+D - D == 0	1.416	0.213669
W+D - W == 0	**2.365**	**0.016776***

Parametric Testing

Welch's F-test (not assuming equal variances) showed a significant difference in Brand's phacelia counts among all treatments for all plots, all years combined ($F = 4.1434$, $df = 3$, $p = 0.0082$).

Tukey's pairwise comparisons of means showed a significant difference between Control and Weeding + Disturbance and also between Weeding and Weeding + Disturbance ($t = 3.536$, $p = 0.0029$ and $t = 2.795$, $p = 0.0295$, respectively; Figure 5.)

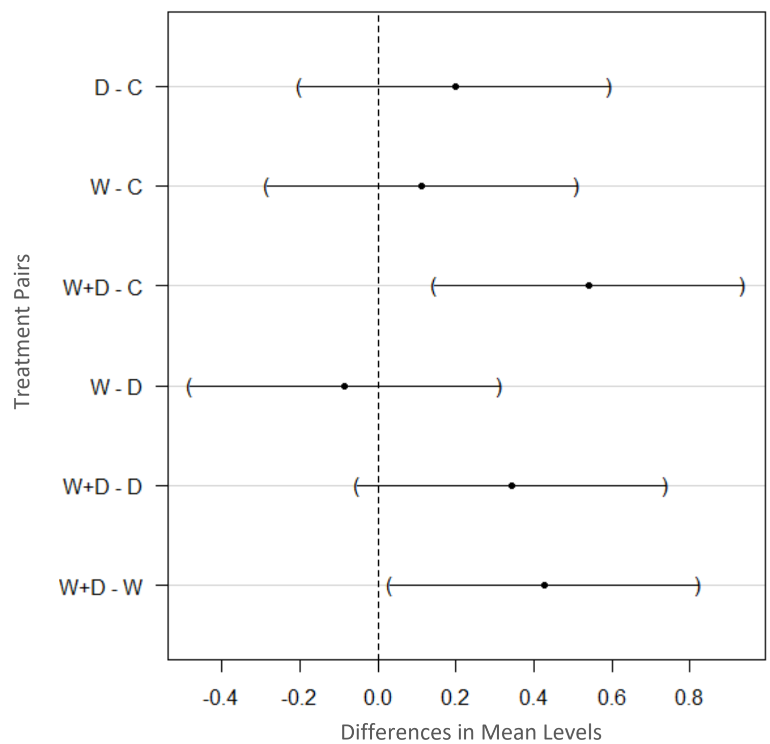

Figure 4. Tukey's pairwise comparisons of means, 95% family-wise confidence level, all plots, all years. A confidence interval that does not contain zero is significant.

Welch's F-test (not assuming equal variances) showed a significant difference among all treatments for plots 17-48, all years combined ($F = 4.6589$, $df = 3$, $p = 0.0051$).

Tukey's pairwise comparisons of means showed a significant difference between Control and Weeding + Disturbance and also between Weeding and Weeding + Disturbance ($t = 3.447$, $p = 0.0043$ and $t = 3.253$, $p = 0.0078$, respectively; Figure 6.)

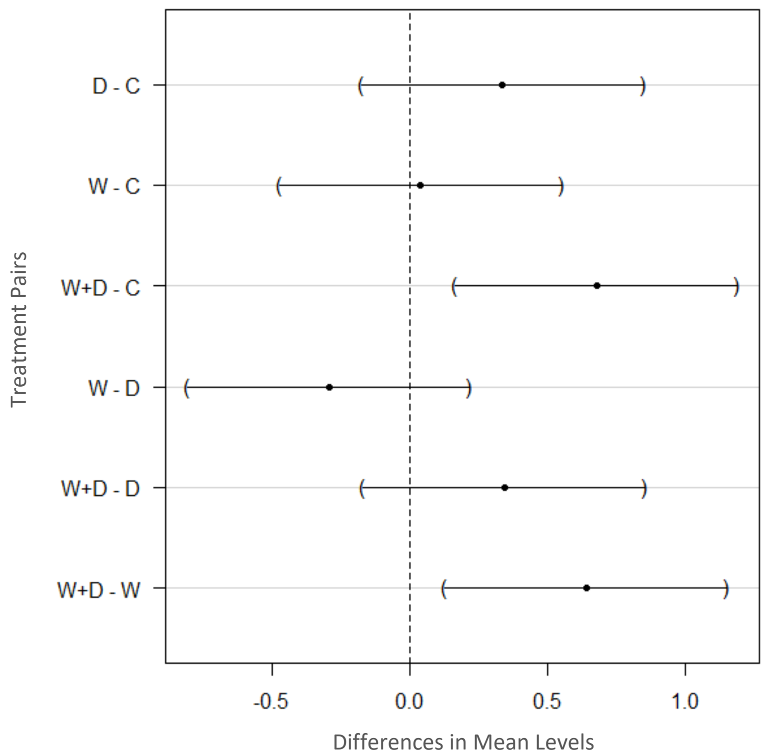

Figure 5. Tukey's pairwise comparisons of means, 95% family-wise confidence level, plots 17-48, all years. A confidence interval that does not contain zero is significant.

DISCUSSION

Rare annuals, such as Brand's phacelia, often benefit from or even require a particular soil disturbance regime for germination that no longer exists at a particular location. While trampling disturbance can be detrimental to annuals, we explore a less damaging type of soil disturbance. In this study, we employed a random block experimental design and created disturbance "trails" in plots assigned a Disturbance treatment, to evaluate whether this type of disturbance, with or without Weeding, encourages the germination of Brand's phacelia, especially when the potential for destruction by trampling is restricted.

Our results suggest that weeding and disturbance, when applied together, provide the most benefit to Brand's phacelia germination. None of the results were significant when tested for individual years; however, when we combined data from all four years of the study, both non-parametric and parametric testing showed a significant difference between Weeding + Disturbance and Control plots suggesting that both Weeding and Disturbance must take place to see a significant increase in Brand's phacelia germination. Neither Disturbance nor Weeding resulted in statistically significant differences from Control plots when applied without the other. However, consistently higher numbers of Brand's phacelia in Disturbance plots and Weeding plots suggest that both of these treatments are possibly beneficial on their own. Further studies with a larger sample size may be needed to detect within year differences or a significant benefit from Weeding or Disturbance applied alone.

We believe there may be a difference in the soil, seedbank, or other unknown variable on the southwest end of the study site because plots 0 through 13 had no Brand's phacelia throughout the entire study period. Therefore, we removed the first four blocks (plots 1 through 16, to retain only complete randomized blocks) from the dataset and ran the tests again. An additional significant result, Weeding + Disturbance compared to Weeding alone suggests that Disturbance may have a somewhat greater impact than Weeding.

A similar study on Brand's phacelia disturbance conducted by California State Parks at Silver Strand State Beach from January 2012 through March 2015 showed very different results than this Santa Ana Wilderness study (Stafford & Smith 2016). The Silver Strand study found only that exclusionary fencing had a statistically significant positive impact on the population counts of Brand's phacelia. There was no indication that disturbance by raking was beneficial. Though the study was designed with a similar random block design and included weeding, raking (comparable to our Disturbance plots), and fenced control plots, it did not include the combined Weeding + Disturbance treatment that we found to be significant. In the Silver Strand study weeded plots showed the greatest number of *P. stellaris* for all four years, though the effect of weeding alone was not statistically significant from the control or other treatments. The Control plots had the second highest numbers of *P. stellaris*, greater than the Annual Raking plots (Stafford & Smith 2016). At the Santa Ana Wilderness site the Weeding treatment consistently produced higher numbers of germinating *P. stellaris* than the Control plots, but fewer than Disturbance (Annual Raking). These results were not statistically significant, however, and only suggest patterns.

Observations were different between the Silver Strand State Beach and Santa Ana Wilderness sites potentially due to large differences in both population size and site ecology. The Santa Ana Wilderness site had counts ranging from 51 to 2488 while the Silver Strand site had 100s of thousands of individuals. The large difference in population sizes could be due to the level of degradation at the Santa Ana Wilderness site at the beginning of the experiment, whereas the Silver Strand site had been managed under the CCA for several years prior to that experiment and may have already been seeing the benefits of multiple years of weeding and be closer to carrying capacity. The differences between the coastal dune setting and inland river bench likely introduces many differences between the two ecosystems as well, such as soil composition. The Santa Ana Wilderness site is dominated by Redstemmed filaree and Mediterranean grass, which grow in sand but also grow in hard packed soils, whereas weeding at Silver Strand focused on sea rocket and ice plant, a common weed of sandy back dune habitats (Stafford & Smith 2016). Lastly, the only significant result in our study was observed when we combined Weeding and Disturbance (Raking) which did not occur at the Silver Strand site.

Our study and results were limited by the small size of the site, relatively low counts of Brand's phacelia in this population, and small sample size (12 plots per treatment). It is notable that after four years of treatments (2017 through 2020) we began observing the largest counts of Brand's phacelia recorded at this site since the implementation of the MSHCP. In fact, in 2020, we noticed that the population appeared to be spreading at the site, possibly due to inadvertent disturbance while conducting the study. However, there may be any number of other factors affecting Brand's phacelia at this site. The number of plots containing Brand's phacelia grew over the course of the experiment from 15 to 28 and we began anecdotally observing more patches of Brand's phacelia outside of plots, notably along a foot trail that the surveyors were using. Other studies suggest that the apparent spread of the population within and adjacent to the plots may be a result of environmental conditions not tested for (e.g. precipitation) or even more complex mechanisms, such as allowing for multiple years of increased moisture to break seed dormancy (Belnap & Lange 2001; Freas & Kemp 1983), stirring the seeds until they are at the appropriate depth for germination (Eichberg & Donath 2018; Freas & Kemp 1983).

Due to the rarity of this species, further studies are warranted. Studies of additional factors, such as ideal frequency of Disturbance and Weeding treatment, and other physical and environmental applications should be examined. However, this study may help inform management decisions at this site.

MANAGEMENT RECOMMENDATIONS

As a result of our study, we recommend annual weeding and raking of the Santa Ana Wilderness site of Brand's phacelia. Raking disturbance to break-up the soil crust should occur in late fall or early winter, depending on rainfall timing, but before Brand's phacelia germinants emerge. Weeding should occur in winter after the first rains when annual weeds begin sprouting.

We recommend that annual raking continues even if annual hand weeding is not feasible. Raking is far less resource-intensive than hand weeding. For example, we spent an average of 150 hours applying the Weeding treatments per season and only 16 hours applying Disturbance treatments per season. Though results were not significant for Disturbance alone, the consistently higher counts of *P. stellaris* germinants in Disturbance plots suggest that raking may still be beneficial.

During our final day of surveys, we observed the invasive species stinknet (*Oncosiphon piluliferum*) growing in two of our study plots. This invasive plant has the potential to over-run this rare plant population if not controlled. At a minimum, the highly invasive stinknet should be addressed appropriately. Although it was only discovered on-site at the end of our study and did not influence our results, it could quickly become a serious threat to this population of Brand's phacelia. Anecdotal evidence reported by the Brand's phacelia CCA Working Group suggests Fusilade® may be harmful to Brand's phacelia and is not recommended for Mediterranean grass control at this site.

ACKNOWLEDGMENTS

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