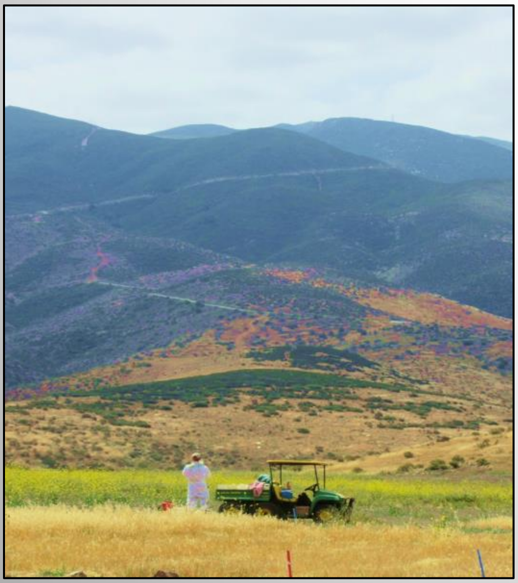
Otay Tarplant Habitat Experimental Project



Prepared for

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Prepared by

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Executive Summary

The Conservation Biology Institute (CBI), The Nature Conservancy (TNC), LandIQ, and the California Department of Fish and Wildlife (DFW) conducted a 3-year experiment on Rancho Jamul Ecological Reserve (RJER) to assess different control methods for enhancing Otay tarplant (*Deinandra conjugens*) in recently burned habitat.

The Otay tarplant Habitat Experimental Project (project) goals included: (1) determine whether an Otay tarplant soil seed bank exists onsite, (2) assess the response of Otay tarplant to prescribed fire and nonnative plant control methods and (3) enhance Otay tarplant habitat by controlling nonnative seed production and inputs to the soil seed bank.

Treatment methods included (1) control (burn + no treatment), (2) herbicide (burn + Fusilade II® + glyphosate), (3) line trim (burn + string trimmer/edger), and (4) mow (burn + rotary mow via tractor attachment).

Over the 3-year project period (2013–2015) we collected quantitative data for Otay tarplant density, nonnative and native species richness and cover, bare ground and litter, and treatment effort.

Post-fire herbicide treatments achieved the project goals most effectively. Line trimming and mowing did not differ significantly from control plots with respect to Otay tarplant germination, and were not effective methods for stimulating the soil seed bank. Trimming and mowing positively affected Otay tarplant density and reduced nonnative grass cover, but these benefits were marginal relative to herbicide. The higher cost of line trimming versus herbicide makes it an impractical treatment choice

It can take multiple years of treatment to achieve meaningful results. We did not observe Otay tarplant in 2013, the first year post-treatment. Otay tarplant was extremely sparse the second year (2014), but by the third year (2015) had proliferated throughout all herbicide treated areas.

This project demonstrated that there was an existing Otay tarplant seed bank onsite. Removing nonnative grass thatch and controlling nonnative grasses allowed the seed bank to express in just three years, resulting in thousands of flowering individuals that produce seed and contribute to the soil seed bank. We expect above-ground population numbers to increase in favorable years as DFW continues to treat and maintain the site, but perpetual maintenance is necessary due to adjacent nonnative seed propagule sources (untreated, nonnative grassland habitat).

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Introduction

The Conservation Biology Institute (CBI), The Nature Conservancy (TNC), LandIQ, and the California Department of Fish and Wildlife (DFW) conducted a 3-year experiment on Rancho Jamul Ecological Reserve (RJER) to assess different control methods for enhancing Otay tarplant (*Deinandra conjugens*) in recently burned habitat. The DFW implemented control treatments, while CBI, TNC, and the San Diego Monitoring and Management Program (SDMMP) conducted qualitative and quantitative monitoring. The SDMMP and CBI conducted data analysis and interpreted results.

Background

A large population (>100,000 individuals) of the federally threatened and state endangered Otay tarplant was mapped on RJER in 2003. The entire population burned in the 2003 Cedar Fire after mapping was completed. In 2004, just over 2,000 individuals represented the above-ground portion of this population (D. Lawhead, pers. comm.). After the fire, nonnative grasses invaded the area and Otay tarplant was not located in subsequent years.

In October 2012, the California Department of Forestry and Fire Protection (CAL FIRE) conducted a 16-acre controlled burn on RJER. The burn perimeter included an estimated 3-4 acres of habitat previously occupied by Otay tarplant. A post-burn site assessment indicated the controlled burn killed most subshrubs and annuals; however, native geophytes (e.g. blue dicks [*Dichelostemma capitatum*], mariposa lily [*Calochortus splendens*], variegated dudleya [*Dudleya variegata*] and others) and bunchgrasses (*Stipa* sp.) resprouted after the fire.

We believed that Otay tarplant was still present in the seed bank; however, the species could not germinate or flower due to nonnative grass thatch and nonnative grass competition. The controlled burn removed the thatch, presenting a unique opportunity to test nonnative plant control techniques and impacts on the Otay tarplant seed bank. We tested the effectiveness of herbicide and two mechanical treatments (line trimming and mowing) against experimental control plots using a randomized block design. Our primary hypothesis was that control of nonnative grasses and forbs would stimulate germination and encourage growth of Otay tarplant by reducing competition with nonnative plants and providing suitable recruitment sites.

Project Goals and Objectives

In Phase I of the South County Grasslands project, we developed an Otay Tarplant Management Vision to guide management of this species in the region (CBI 2012). Project goals, objectives, and tasks identified below build off that vision.

Goals

1. Determine whether an Otay tarplant soil seed bank exists onsite.
2. Assess the response of Otay tarplant to prescribed fire and nonnative plant control methods.
3. Enhance Otay tarplant habitat by controlling nonnative seed production and inputs to the soil seed bank

Objective 1. Determine Otay tarplant response to prescribed fire and nonnative plant control over 3 years in five experimental plots established within 3-4 acres of burned, historically occupied Otay tarplant habitat.

Task 1: Count Otay tarplant individuals in experimental plots using monitoring quadrats during the Otay tarplant flowering period (April - June) after the first year of nonnative plant control, then annually for 2 additional years (total of 3 years).

Objective 2. Determine relative effectiveness of prescribed fire in combination with control, herbicide, and mechanical treatments in reducing nonnative plant cover and improving native plant diversity over 3 years in five experimental plots established within 3–4 acres of burned, historically occupied Otay tarplant habitat.

Task 1: Implement a prescribed burn in October 2012.

Task 2: Implement nonnative plant treatments in five experimental plots beginning in February 2013. Continue all treatments annually through 2015.

Task 3: Collect pre- and post-quantitative (cover and diversity) and qualitative (photo-viewpoints) data in the five experimental plots.

Methods

Experimental Design

We used a randomized block design that divided the study area into five uniformly sized, homogenous units (blocks, Figure 1). We placed blocks subjectively within the burned portion of the historic Otay tarplant population parallel to the slope in a north-south arrangement (Figure 1). Blocks were 20 meters (m) x 40 m with a 5 m buffer around the edge to accommodate a gator-mounted herbicide sprayer and a RC30 skid steer (for mowing).

We divided each block into four plots, and randomly assigned one of four treatments to each plot. Each block received all treatments (Figure 2). Plots were 8 m x 20 m, leaving a 2 m buffer between each (Figure 2). This design produced better estimates of treatment effects by holding spatial factors (e.g., slope, moisture, soils) constant and allowing only treatment to vary within a block.

The treatments included (1) control (burn + no treatment), (2) herbicide (burn + Fusilade II® + glyphosate), (3) line trim (burn + string trimmer/edger), and (4) mow (burn + rotary mow via tractor attachment).

Experimental Treatments

CAL FIRE burned all blocks in October 2012, before we applied treatments. Table 1 presents the treatment schedule. Refer to Figure 3 for photos of the various plot treatments.

We took no action in the control plots post-burn. We applied the grass-specific herbicide Fusilade II® in herbicide plots using a John Deere 6X4 gator supporting an 80-gallon (g) "Stadium 80" by Brayton spray tank. We applied Fusilade II® slightly above the recommended label rate of 16 ounces (oz) per acre and when the grasses were between four and eight inches (in) high. We mixed the surfactant No Foam A with the water and Fusilade II® mixture (i.e., 16 oz Fusilade II® + 32 g of water + 11 oz of No Foam A) and we also mixed a blue marking dye into the herbicide mixture to identify the sprayed plots.

DFW applied the herbicide mixture with a three nozzled short boom that did not extend beyond the gator. The spray width was approximately 4.5 m and there was some spray overlap in the treated plots. DFW used a backpack sprayer mixed with water and a glyphosate-based herbicide (i.e., 2 oz per g of water) to spot treat the nonnative, broad-leaved plants twice per year.

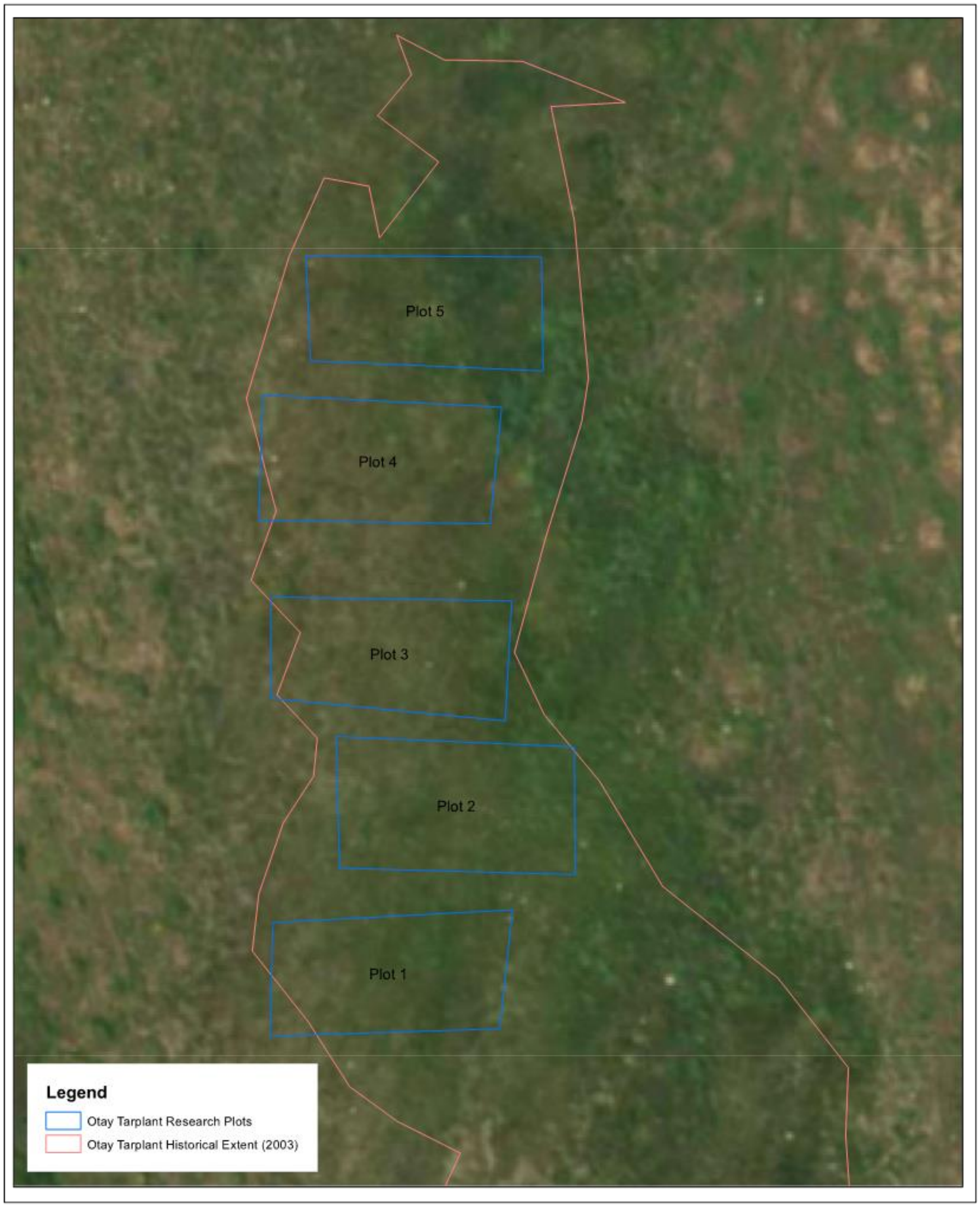

Figure 1. Experimental Research Block Position Relative to Otay Tarplant Historical Distribution.

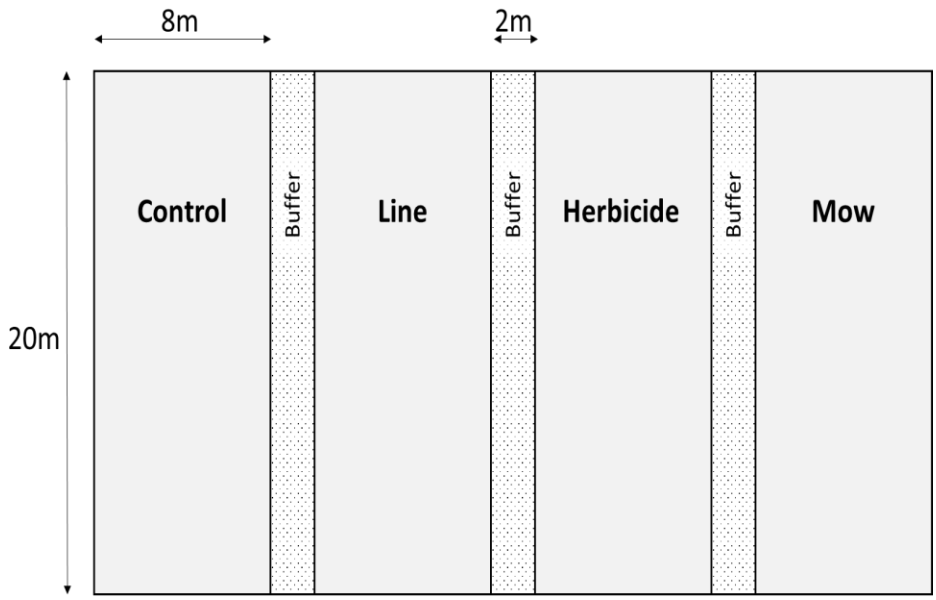

Figure 2. Experimental Plot Arrangement within a Block.

Table 1. Treatment Schedule.

Task	Treatment Month	Treatment Year(s)
Prescribed Fire	October	2012
Fusilade II® Application	February	2013, 2014, 2015
Glyphosate Application	March and April (2x/year)	2013, 2014, 2015
Mowing and Line Trimming	March	2013, 2014, 2015

DFW staff mowed or line trimmed nonnative grasses before seed set at the flowering and early fruit stage. DFW used an RC30 skid steer with an attached rotary mower in the mow plots and line trimmers (with plastic string) in the line trim plots. DFW left cut biomass in place within the plots (Figure 3).

Monitoring

We conducted both qualitative and quantitative monitoring annually from 2013–2015. We collected post-treatment data in April of each year. Qualitative methods included photos and general observations. Quantitative methods are described below and include point intercept transects for cover and quadrats for species richness and Otay tarplant density. In 2015, we counted Otay tarplant within each block and plot.

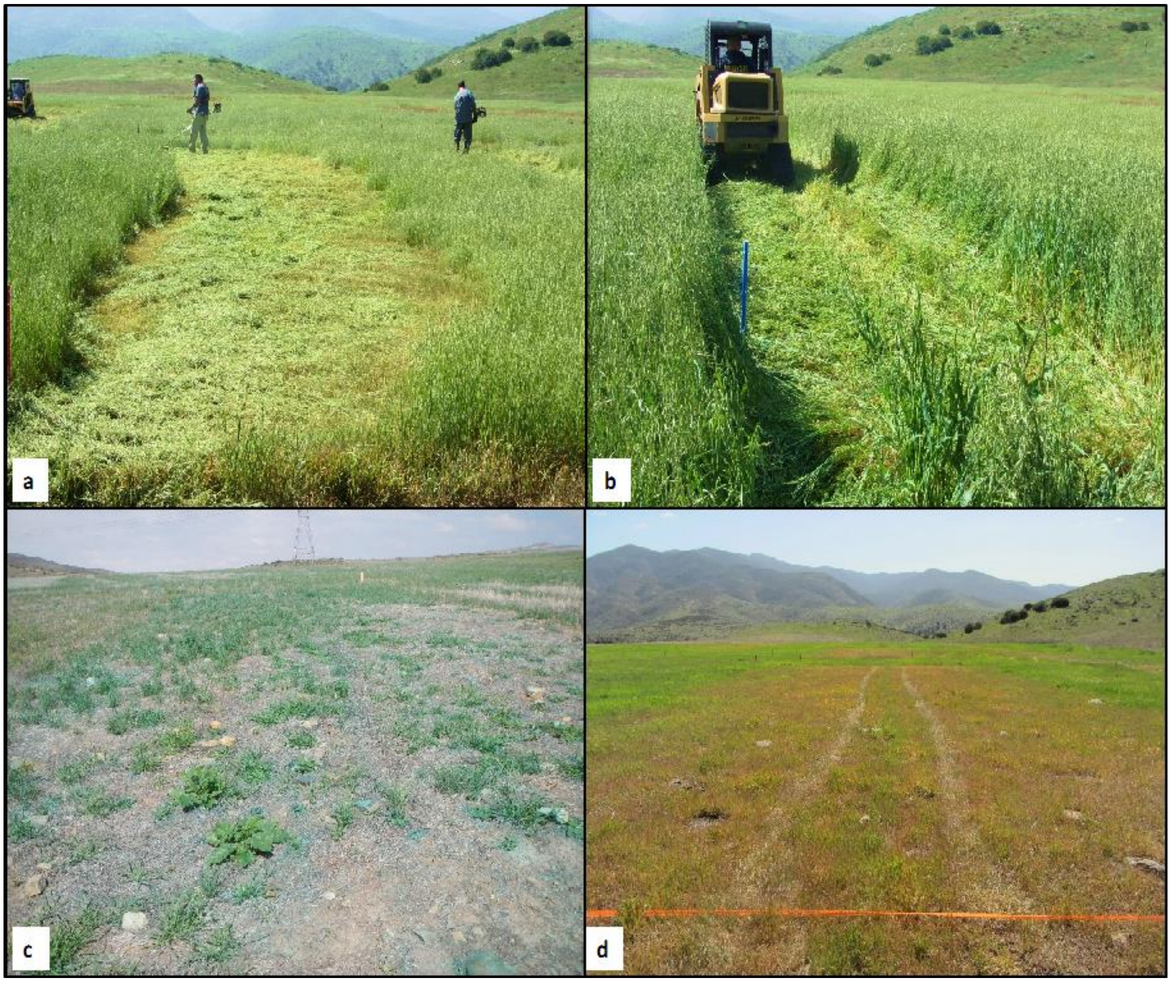

Figure 3. Plot Treatments. (a) line trim plot, (b) mow plot, (c) herbicide spot treatments, and (d) post-Fusilade II® treatment. Photo credits: Jessie Vinje.

We randomly placed two transects along the short axis of each plot between the 1 m and 7 m marks. Transects were 20 m long and stretched between 0 m and 20 m parallel to the long axis of the plot (Figure 4).

Point intercept data were collected at 0.5 m intervals along each transect beginning at 0.5 m and terminating at 19.5 m (39 points per transect). At each 0.5 m mark, we recorded the plant species that were "hit" by the point intercept pin in addition to either litter, bare ground, or rock. We later converted these data into cover values.

Quadrats were 0.5 x 1 m in size. The quadrat location alternated from side to side with the initial location chosen randomly (i.e., 0 right, 0 left, 1 right, or 1 left) (Figure 4) and additional quadrats placed at 2 m intervals along the tape for a total of 10 quadrats per transect (20 quadrats per plot).

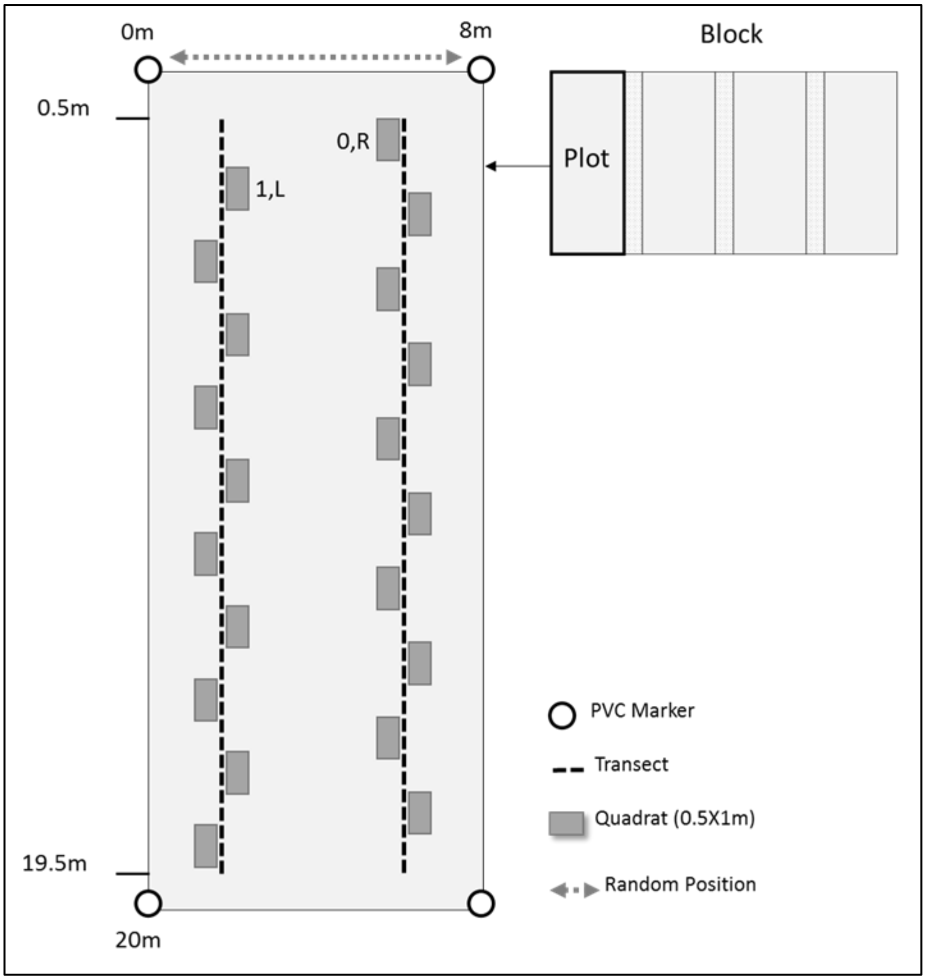

Figure 4. Quantitative Monitoring Design.

We used the same quadrat starting locations selected randomly in Year 1 (2013) in the following years. We recorded all species rooted inside the quadrat and counted numbers of Otay tarplant.

Data Analysis

Data analysis is the process by which experimental results are turned into information that provides actionable and scientifically supported guidance for management. In other words, statistical testing and the interpretation of results indicate whether a management action is a good use of time and money. The transformation of data into information follows a simple process, illustrated in Figure 5, with examples from this project

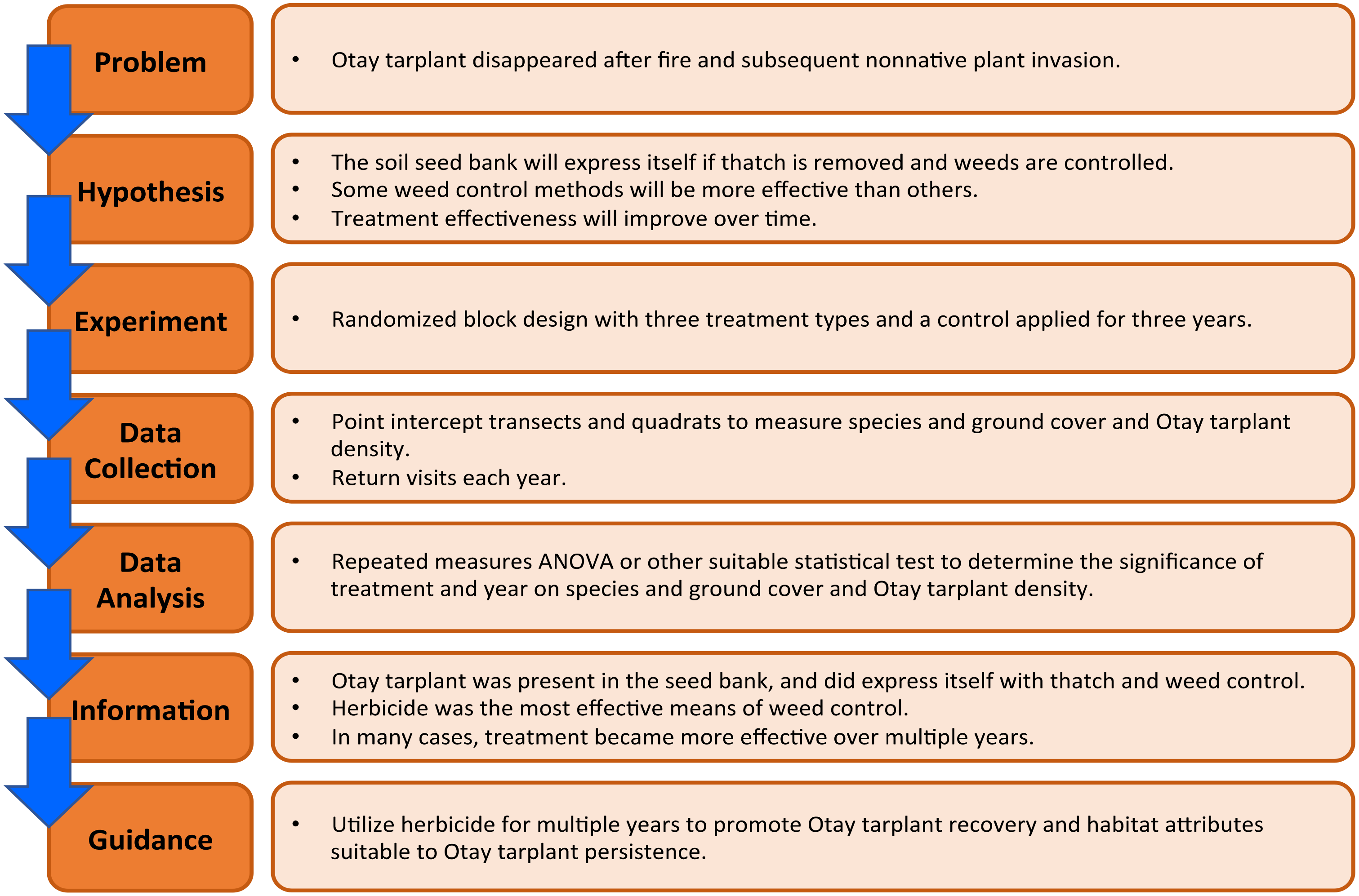

Figure 5. Generalized Data Analysis Process.

While this process is conceptually intuitive, the real-world application of statistical testing can be a nuanced exercise because ecological data are often noisy (highly variable) and skewed (with many observations on one end of the spectrum and few on the other). While a statistical approach may be pre-determined as part of the experimental design (here a randomized block design utilizing a repeated measures analysis of variance [RANOVA]), the actual data may require special handling or different approaches if they break the assumptions of the predetermined test.

We used two types of statistical testing, based on the experimental design and the properties of the data for this project (Table 2). Where possible we used RANOVA, as planned initially. However, when the data were highly skewed, we used a related alternative, the non-parametric Kruskal-Wallace test.

Table 2. Project Statistical Tests.

RANOVA	Kruskal-Wallis Test
• Nonnative Richness • Native Richness • Nonnative Grass/ Wild Oat Cover • Bare Ground • Litter	• 2015 Otay Tarplant Density • Nonnative Forb Cover • Native Forb Cover • Native Grass Cover

RANOVA

RANOVA tests detect differences between related means. In the case of this project, plots were retreated and monitored the same way each year, making year the relating group. RANOVA presents an advantage over testing each year's results separately (e.g., performing multiple comparisons across tests) because the false positive (Type I error) rate is fixed at the significance level (α, usually set at 5%), instead of inflating with each additional test performed.

Another advantage of RANOVA is the ability to explore the interaction between different factors. This is especially important when working with annual plants whose germination rate, phenology, and response to treatment can vary dramatically under different annual weather conditions. Plants are often spatially patchy as well, so a means of accounting for location (e.g., block) is desirable. Our model therefore assessed the main effects of year, treatment, and block, and the interactive effects of year and treatment, and year and block. We used an all pairs comparison post-hoc test to determine the relationship of each treatment relative to the others, although this test does not take year into account. The primary drawback of RANOVA is the requirement for normally distributed data within each factor (in this case, year). Skewed data can moderately to severely affect test results, often inflating the false-positive rate. Unfortunately, many biological data sets are right-skewed (with many zeros or small values and few large values). Native and nonnative forb and native grass cover results were highly right-skewed for this project. Skew can often be addressed by transforming data (here log(X+1)), but the technique was unsatisfactory for those three variables. As a result, we used a non-parametric Kruskal-Wallis test as the primary means of determining the significance of treatment for those variables and used the RANOVA result (on transformed data) informally to explore the effect of year and interaction terms.

Kruskal-Wallis Test

The Kruskal-Wallis test is the non-parametric analog of a one-way analysis of variance (ANOVA) which tests for a difference in medians (rather than means) of the treatment groups being analyzed. It does so by ranking data values across all groups, and comparing the distribution of those ranks between groups. For these reasons, the Kruskal-Wallis test is less sensitive to skewed data distributions.

Non-parametric approaches do not allow for repeated measures analyses, so we had to test each year separately. The inability to include year in the model presents a drawback, because year strongly influences annual plants and performing multiple tests increase the false-positive rate. In addition, non-parametric approaches do not include multiple levels or interactions, so we could only assess treatment (as a main effect) with no respect to block. We compared these results against RANOVA results (on log(x+1) transformed data) informally as an indication of the role played by changing conditions each year.

We performed Wilcoxon signed rank tests as post-hoc tests on skewed data to determine the relationship of each treatment to the others. We performed these tests for each year individually, increasing the false-positive rate. We compared the results against the RANOVA all pairs comparison post-hoc test informally.

Results and Discussion

In this section, we present treatment results (including graphs) for the 3-year project period (2013–2015) for Otay tarplant density, nonnative and native species richness and cover, bare ground and litter, and treatment effort. For all graphs, the error bars represent the standard error of the mean (SEM).

Otay Tarplant Density

We did not detect Otay tarplant in the study site or adjacent herbicide treated buffer after the first round of treatments in 2013. In 2014, after a decade of absence, we detected two Otay tarplants in the treatment plot quadrats (herbicide and mowing) and an additional eight plants within the herbicide treated buffer. In 2015, following 3 years of treatment, we detected 210 plants in the treatment plot quadrats. That same year we detected thousands of plants inside herbicide treatment plots and within the herbicide treated buffer (Figures 6 and 7). This suggests that the impact of treatment on Otay tarplant was cumulative over time.

Treatment affected Otay tarplant density significantly in 2015 ($P<0.001$, Figure 6). All treatments produced a significant (or approaching a significant) improvement over control plots ($P_{herbicide}=0.042$, $P_{trim}=0.068$, $P_{mow}=0.039$). Herbicide was particularly effective compared to mowing (P=0.042, Figure 6). Line trimming had an intermediate effect that was not significantly worse than herbicide (P=0.5) or significantly better than mowing (P=0.465).

Nonnative Plant Richness and Cover

Nonnative Plant Richness

Treatment had a significant effect on nonnative forb richness (P=0.028) due to the release of nonnative forbs from competitive exclusion by nonnative grasses. In general, nonnative forbs are a far richer functional type than nonnative grasses, which tend to occur in monocultures or assemblages with few species (Cox and Allen 2008, Molinari and D'Antonio 2014).

Herbicide (P=0.05) and line trimming (P=0.008) increased nonnative forb richness significantly (Figure 8). Line trimming had an intermediate effect, and was not significantly different from herbicide (P=0.075) or mowing (P=0.102). Mowing was not significant over control treatments (P=0.118). Mowing and line trimming produced lower levels of nonnative forb cover because dead biomass was left on the ground after treatment implementation, creating a thick layer of nonnative grass thatch that likely reduced nonnative forb germination (Figure 8).

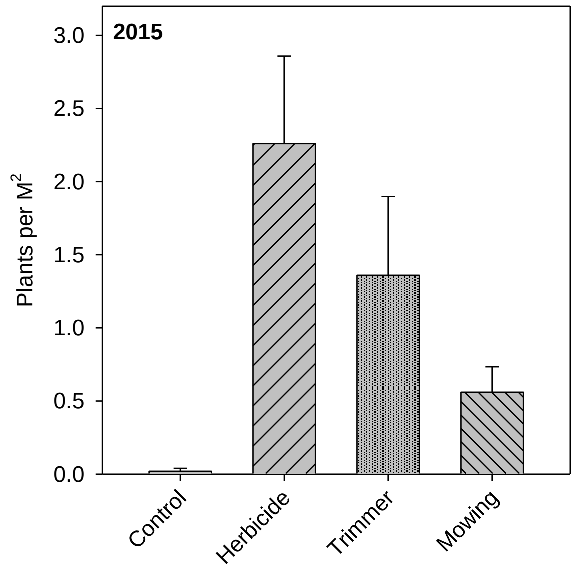

Figure 6. 2015 Otay Tarplant Density.

Figure 7. 2016 Otay Tarplant Restoration Site. (a) Otay tarplant in herbicide-treated buffers (control plot in background), (b) Otay tarplant flower, and (c) fascicled tarplant (*Deinandra fasciculata*) in herbicide-treated buffer. Photo credit: Spring Strahm (a), Jessie Vinje (b-c).

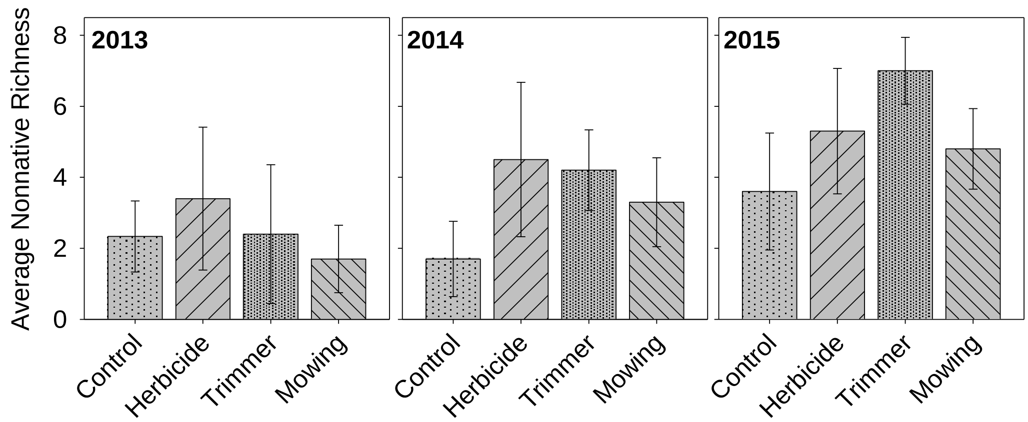

Figure 8. Treatment Effect on Nonnative Plant Richness

Year played a direct role in nonnative plant richness (P<0.001), as did the interaction of year with block (P=0.044) and treatment (P=0.008). The influence of year upon nonnative richness was likely due to the fact that the germination and growth of annual species was entirely reliant upon yearly weather patterns. The interaction of year and block indicated that parts of the study area responded differently in some years. This could be due to a number of factors, including topography and soils that could alter the distribution of moisture throughout the site. The interaction of treatment with year indicated that some treatments worked differently in some years. Treatments had a negligible impact in 2013, improved somewhat in 2014, but then had a much greater effect in 2015 (Figure 8). The lag time in nonnative forb richness may indicate that treatment has a cumulative effect over time.

Nonnative Plant Cover

Treatment also had a significant effect on nonnative grass cover (primarily wild oat, P=0.001, Figure 9). All treatment types performed significantly better than controls (P<0.001 for all three treatments). In addition, herbicide was significantly better than line trimming and mowing in reducing nonnative grass cover (P=0.006 for both comparisons). Although we saw the best results with herbicide, all treatments were effective (Figure 10).

The interaction of treatment with year was also significant (P=0.013), indicating that some treatments worked differently in some years. Treatment produced no significant

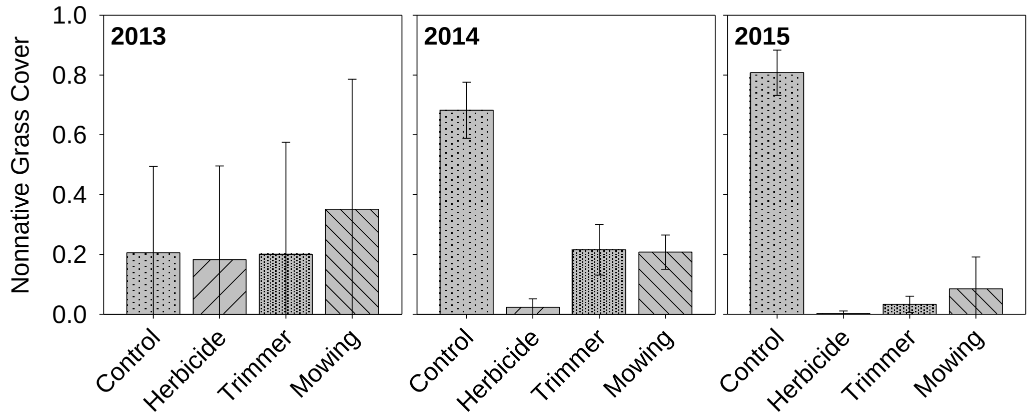

Figure 9. Treatment Effect on Nonnative Grass Cover.

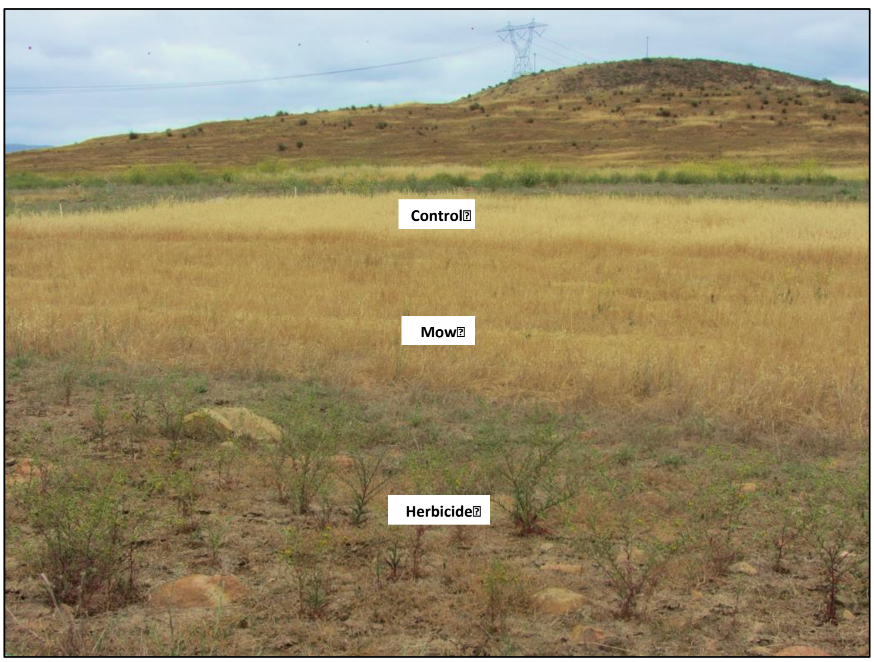

Figure 10. 2015 Nonnative Grass Cover Treatment Response.

effect on nonnative grass the first year (2013) because nonnative grasses had been removed by fire and site conditions (including all plots) were homogeneous. Treatment produced a significant effect by the second (2014) and third year (2015) (Figures 9 and 10). By 2015, we observed (a) Otay tarplant in all herbicide treatment plots and (b) no nonnative grass in herbicide treatment plots (Figure 10). This suggested that a single year of treatment was inadequate for significant nonnative grass cover reduction post-burn and that treatment likely had a cumulative effect over time as the nonnative grass cover increased post-burn.

Despite the reduction of nonnative grass cover, nonnative forbs never achieved high cover during the experiment (Figure 11) for two reasons: (1) we treated nonnative forbs in herbicide plots and (2) persistent nonnative grass thatch, produced by line trimming and mowing, reduced or precluded nonnative forb germination. Nonnative forb cover was so sparse and patchy that we did not see a statistically significant treatment effect until 2015 (P=0.003); however, considering that there was no nonnative forb cover in 2013, very little in 2014, and substantially more in 2015, it was likely that treatment had an overall cumulative effect each subsequent year.

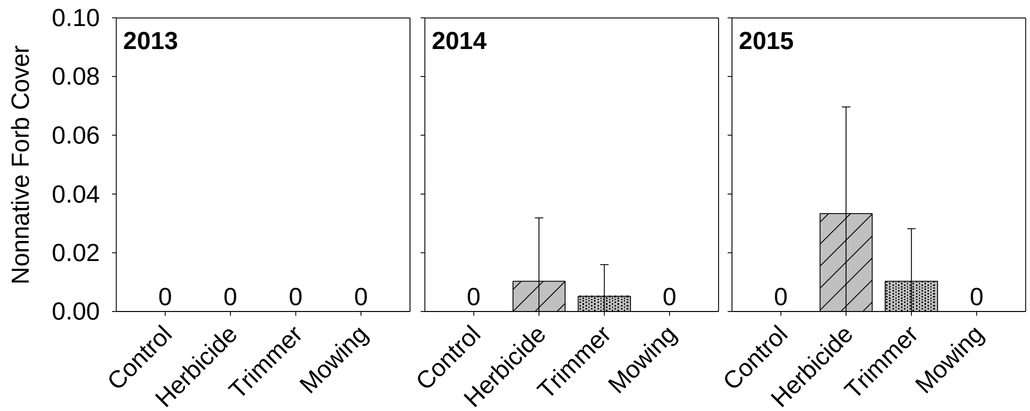

Figure 11. Treatment Effect on Nonnative Forb Cover.

Although increasing nonnative forb cover is not ideal, it indicates a release of nonnative forbs from competitive exclusion by nonnative grasses meaning that treatments were achieving their primary goal.

Comparisons between treatments were difficult to interpret due to the low cover values and high variance of nonnative forb data. Post-hoc testing indicated that herbicide plots had significantly more nonnative forb cover than control (P=0.041) and mow plots (P=0.041) in 2015. Line trimming was intermediate but not significantly different from control or mowing (P=0.102 for both). Nonnative forb cover never surpassed 10% cover over three years for any of the treatment or control plots.

Native Plant Richness and Cover

Native Plant Richness

Treatment significantly impacted native richness (P=0.036); however, post-hoc testing indicated that only the herbicide treatment produced a significant effect. Given enough time, trimming and mowing could potentially improve native richness based on the steady increase in native richness over time in both the trimming and mowing plots (Figure 12).

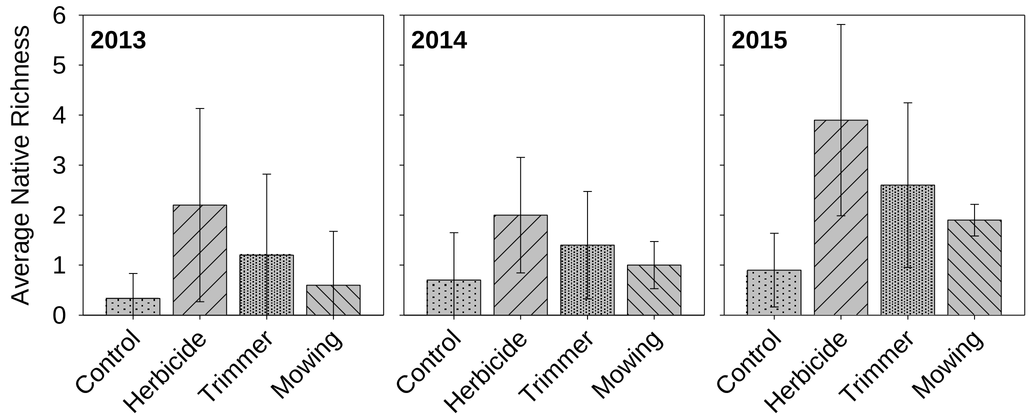

Figure 12. Treatment Effect on Native Plant Richness.

Native richness was also driven by year (P<0.001). Although all three years took place during a drought, 2014 was particularly dry, receiving about half of average annual rainfall (NOAA 2017). Treatment had little impact on native richness in 2014 likely due to low nonnative and native forb germination associated with very dry conditions (Figure 12). Conversely, herbicide treatments substantially enhanced native richness in 2015, when higher rainfall stimulated both nonnative and native forb germination.

There was also a significant interaction between year and block for native richness (P=0.014). This could be due a number of factors, including topography and soils that may alter the distribution of moisture throughout the site.

Native Plant Cover

Treatment did not significantly affect needlegrass (*Stipa* spp.) cover because of patchy distribution, perennial life cycle, and seedling mortality (Figure 13). Needlegrass occurred as scattered individuals in some of the plots. While annual plants are dependent on yearly weather conditions, mature bunchgrasses maintain their cover from year to year. Herbicide treatment did not affect mature needlegrass, but did kill needlegrass seedlings.

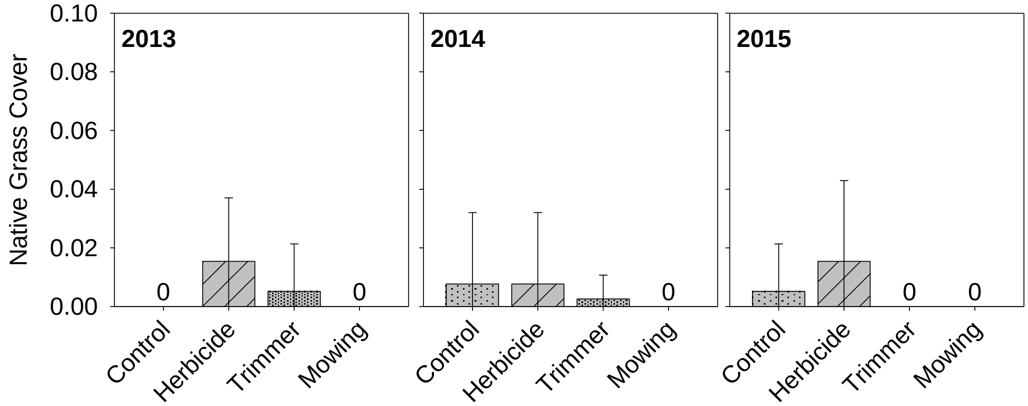

Figure 13. Treatment Effect on Native Grass Cover.

Native forb cover increased significantly in 2014 (P=0.001) and again in 2015 (P<0.001, Figure 14). The effect of herbicide was particularly striking in 2015 when small flowered morning glory (*Convolvulus simulans*) comprised greater than 17% average cover in herbicide plots. In 2015, herbicide and line trimming significantly increased native forb cover (P=0.043 for both), with herbicide performing significantly better than line trimming (P=0.043, Figure 14).

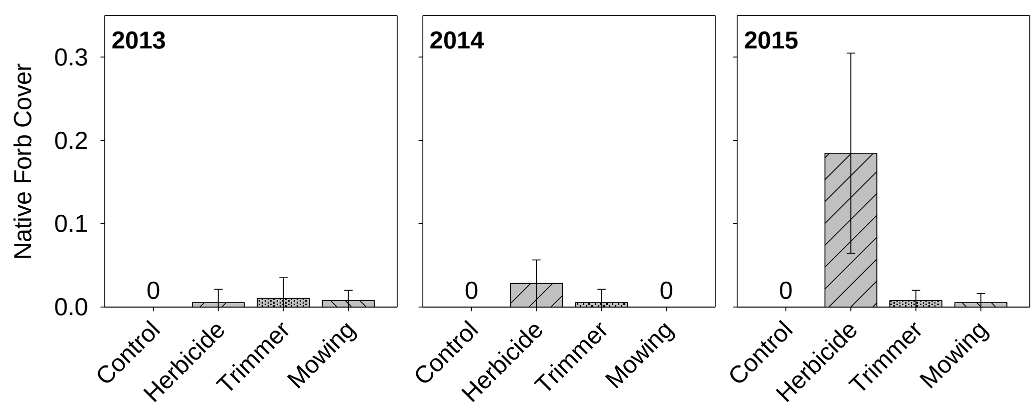

Figure 14. Treatment Effect on Native Forb Cover.

Ground Cover

Percent bare ground differed by treatment (P=0.001) but this effect was only consistent in 2014 and 2015. We excluded 2013 from data analysis because treatments did not significantly affect bare ground, likely due to homogenous post-fire ground cover conditions across all blocks produced by a lag in nonnative grass germination.

Herbicide was the only treatment that significantly promoted bare ground (P=0.019) and this effect was first observed in 2014, approximately one and a half years post-burn. Line trimming and mowing were not significantly different from the control treatment ($P=0.396_{linetrim}$, $P=0.215_{mow}$) (Figure 15).

Statistical testing also indicated that year played a significant role in the expansion of bare ground, stemming primarily from an increase in bare ground in line trimming plots (P=0.026, Figure 15). In this case, operator skill level may drive the significant year effect for mowing and line trimming. Mowing and line trimming produce varying levels of bare ground based on operator implementation/skill level, equipment restraints (i.e., mower height – too high or too low), and site terrain (rocky versus flat). Due to this variability, bare ground levels may fluctuate annually in an unpredictable manner.

Treatment (P<0.001) played a significant role in the amount of litter in plots (Figure 16). Herbicide was the only treatment that decreased litter cover significantly (P=0.013). Line trimming and mowing were not significantly different from the control treatment ($P=0.448_{linetrim}$, $P=0.119_{mow}$).

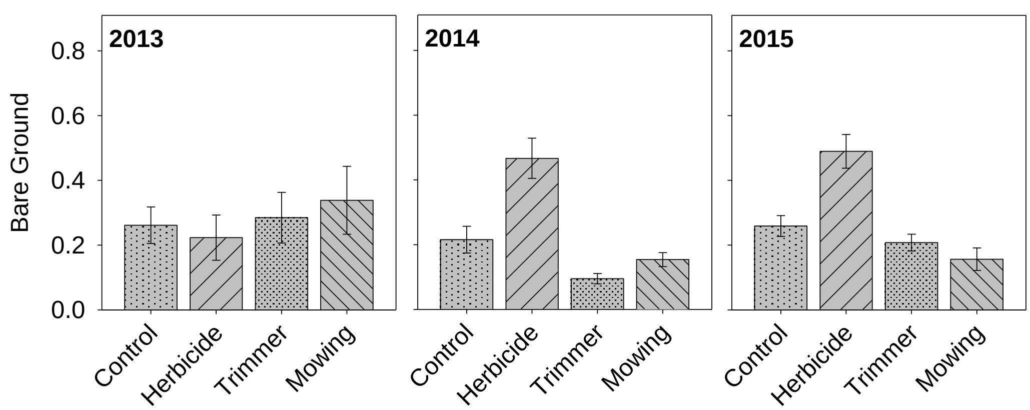

Figure 15. Treatment Effect on Bare Ground.

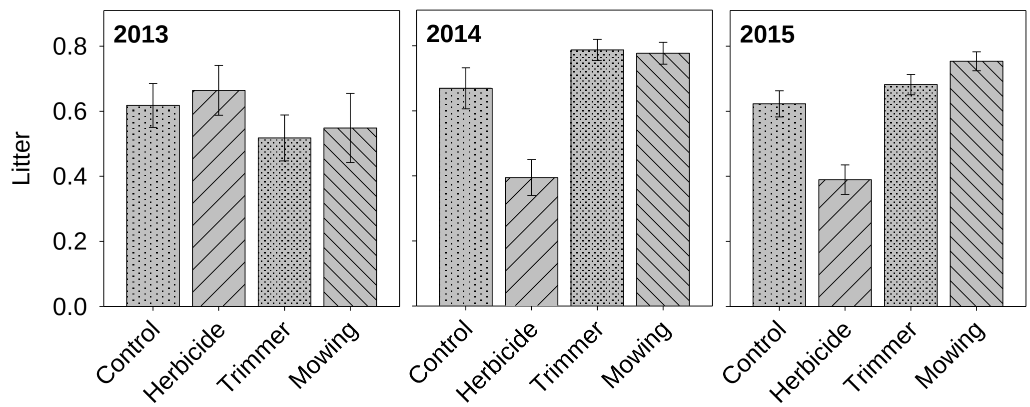

Figure 16. Treatment Effect on Litter.

Year also had a significant effect on litter (P=0.046), even after 2013 was excluded from the data analysis. As with bare ground, this effect is likely due to implementation method. Mowing and line trimming produce varying levels of litter based on operator implementation/skill level, equipment restraints (i.e., mower height – too high or too low), and site terrain (rocky versus flat). Due to this variability, litter levels may fluctuate annually in an unpredictable manner.

Treatment Effort

Table 3 lists treatment method with hours and cost per acre. Cost estimates are for labor only and do not include other expenses such as herbicide, surfactant, or equipment.

Table 3. Treatment Effort and Cost per Acre.

Method	Hours per acre	Cost per acre
Herbicide (Polaris + Back Pack Applications)	7.16	$86-$308
Herbicide (Back Pack Only Applications)	12	$144-$516
Mow	2.9	$35 - $125
Line Trim	7.5 (2 people)	$180 - $645

Labor rates vary dramatically between non-profit organizations, federal and state agencies, and environmental consultants; therefore, a cost range is presented based on labor rates obtained from a variety of sources.

Mowing is the quickest and least expensive method to reduce nonnative grass (e.g., wild oat) cover post-fire. However, it does not promote high Otay tarplant germination and establishment because it does not remove litter or increase bare ground. Herbicide treatments using an all-terrain vehicle (ATV) mounted boom sprayer are the second quickest and least expensive method and promote Otay tarplant recruitment from an existing seed bank by removing litter and providing bare ground for establishment.

Conclusions

The overall project goal was to promote Otay tarplant germination from the soil seed bank using various restoration techniques post-fire in an area where the species had not been seen for about a decade. Otay tarplant best management practices based on the post-fire restoration techniques included in this project are included as Appendix A.

Herbicide achieved the project goal most effectively (Table 4). Line trimming and mowing did not differ significantly from control plots with respect to Otay tarplant germination, and were not effective methods for stimulating the soil seed bank. Trimming and mowing positively affected Otay tarplant density and reduced nonnative grass cover, but these benefits were marginal relative to herbicide. The higher cost of line trimming versus herbicide makes it an impractical treatment choice

We conclude that using herbicide (Fusilade II® + spot treatments with broad spectrum systemic herbicide [e.g., glyphosate]) is the most efficient method for significantly reducing nonnative grass cover post-fire. This method also yields additional benefits, including increasing Otay tarplant density, native forb richness and cover, and bare ground, and reducing litter.

Herbicide treatments using an ATV-mounted boom sprayer are the second quickest and least expensive method and yield habitat conditions suitable to high levels of Otay tarplant recruitment.

It can take multiple years of treatment to achieve meaningful results. We did not observe Otay tarplant the first year post-treatment. Otay tarplant was extremely sparse the second year, but by the third year had proliferated throughout all herbicide treated areas. Multiple years of treatment increased the chance that a favorable weather year would occur, allowing the target species to take full advantage of the treatment.

This project demonstrated that there was an existing Otay tarplant seed bank onsite. Controlling nonnative grasses allowed the seed bank to express in just three years, resulting in thousands of flowering individuals that produce seed and contribute to the soil seed bank. We expect above-ground population numbers to increase in favorable years as DFW continues to treat and maintain the site, but perpetual maintenance is necessary due to adjacent nonnative seed propagule sources (untreated, nonnative grassland habitat).

Table 4. Treatment Effectiveness Summary.

Variable	Order of Effectiveness	Explanation
Otay tarplant density	H>LT≥M>C	Herbicide is better at increasing Otay tarplant density than line trimming. Line trimming may or may not be better than mowing. Mowing is better than doing nothing.
Nonnative richness	H>LT>M=C	Herbicide increases nonnative richness more than line trimming and line trimming elevates nonnative richness more than mowing. Mowing is equivalent to doing nothing.
Nonnative grass	H>LT=M>C	Herbicide is more effective at decreasing nonnative grass cover than line trimming or mowing; however, bot mechanical treatments are better than no treatment.
Nonnative forb cover	H>LT=M=C	Herbicide increases nonnative forb cover while the other treatments have no effect.
Native richness	H>LT≥M=C	Herbicide is the only treatment that elevated native richness substantially. Line trimming may be fractionally better than mowing or no treatment. Mowing does not increase native richness.
Native grass cover	H=LT=M=C	Over a three-year period treatments did not increase or decrease native grass cover.
Native forb cover	H>LT=M=C	Herbicide is the only treatment that significantly raised native forb cover.
Bare ground	H>LT=M=C	Herbicide is the only treatment that significantly raised bare ground.
Litter	H>LT=M=C	Herbicide is the only treatment that significantly lowered litter.

[1] The “>” sign indicates that a treatment was significantly better than its neighbor. “≥” indicates that the treatment may or may not be better than its neighbor. H = herbicide, LT=line trim, M=mow, C=control.

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Appendix A

Best Management Practices

Otay tarplant Post-burn Habitat Restoration

Best Management Practices

Otay Tarplant Post-burn Habitat Restoration

This document outlines Best Management Practices for herbicide and mechanical treatments in Otay tarplant habitat for 1-3 years following a burn event. Refer to the Otay Tarplant Experimental Project report for a full discussion of the benefits and costs associated with the various treatment methods.

Herbicide

Fusilade II®

Spray Fusilade II® in late winter (January – early March) when most nonnative, annual grasses are between 4 – 6 inches (in) tall. Some grasses (*Avena* spp.) may be taller than 4 – 6 in. Spray prior to the target species bolting and flowering. Several site visits conducted by experienced restoration ecologists/biologists and/or applicators are necessary to ensure correct application timing.

Apply Fusilade II® at least once per year. Budget a second application in case of additional rain after the first Fusilade II® application.

Mature bunchgrasses will not die from Fusilade II® application. Nonnative, annual grasses will die from Fusilade II® application with the exception rat-tail fescue (*Festuca myuros*), which is unaffected by this herbicide. Fusilade II® kills native, annual grasses and native, perennial grass seedlings.

Spray using a backpack sprayer, truck-mounted sprayer with hose and reel, or all terrain vehicle mounted skid sprayer. Chosen method is based on terrain, site access, existing vegetation community, and budget.

Spray herbicide under shrubs and the shrub drip line. Spray applicators often miss these areas or under spray nonnative grass seedlings, allowing for germination, flowering and seed set.

Glyphosate

Treat nonnative forbs and target species unaffected by Fusilade II® (i.e., *Festuca myuros*) in late winter and early spring (March – April). Several site visits conducted by experienced restoration ecologists/biologists and/or applicators are necessary to ensure correct application timing. Spot treat basal rosettes and bolting and flowering target species.

Apply glyphosate-based herbicide at least two times per year. Budget a third application to accommodate above average rainfall years.

Spot treat using a backpack sprayer. Expect some native species collateral damage where native and nonnative species co-occur densely.

Mow

Mow nonnative, annual grasses with a tractor-mounted rotary mower in February – March, prior to fruit formation (when species is flowering or just as fruit is forming). If fruit has matured and seed is setting, then it is too late to mow. Leave all cut biomass in place.

Several site visits conducted by experienced restoration ecologists/biologists are necessary to ensure correctly timed mowing.

Line Trim

Mow nonnative, annual grasses with a line (string) trimmer in February – March, prior to fruit formation (when species is flowering or just as fruit is forming). If fruit has matured and seed is setting, then it is too late to mow. Leave all cut biomass in place.

Several site visits conducted by experienced restoration ecologists/biologists are necessary to ensure correctly timed line trimming.

Conclusion

Perpetual treatment will be necessary once Otay tarplant site restoration begins. After three consecutive years of treatment, land managers can reassess site conditions and determine an appropriate length of time between treatments.