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Identifying practical, small-scale disturbance to restore habitat for an endangered annual forb

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We sought to identify appropriate treatments to restore a small, urban patch of habitat for the endangered *Clarkia franciscana* (Presidio clarkia) in serpentine grassland. Goals included identifying effective and pragmatic treatments for introducing disturbance to the site and determining whether treatments used to establish Presidio clarkia would be appropriate in areas already occupied by this endangered serpentine endemic. This experiment tested fall burning, fall flaming, fall mowing with thatch reduction, fall scraping, fall tarping, spring burning, and spring mowing with and without thatch reduction. Half of all treated plots were seeded with clarkia. Clarkia density and vegetation composition were measured one and two years after treatment. Fall scraping, fall tarping, and fall flaming stood out as the most effective methods for increasing density. Fall scraping and fall flaming enhanced clarkia populations in unseeded plots where clarkia was initially present. In Year 1, these three treatments were also most successful in reducing annual grass cover and decreasing nonnative plant cover. Although other studies have shown spring treatments to be useful for reducing annual grass and thatch, and increasing native forbs, this study found that treating in late fall, after annual grasses had germinated, was critical for this site – and not, as was previously presumed, harmful to the clarkia.

Keywords: *Clarkia franciscana,* disturbance, endangered species, restoration ecology, serpentine grasslands, urban preserve

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Lands set aside for conservation are still threatened by habitat fragmentation (Quinn and Hastings 1987, Bolger et al. 1991), invasive species (Mooney and Hobbs 2000), and climate change (Vitousek et al. 1997), and require active management to conserve biodiversity

(Hobbs and Huenneke 1992, Meffe and Carroll 1997). In many cases, management seeks to restore or mimic historic disturbance regimes, such as grazing or fire. These landscape-scale techniques can be difficult to implement in small, urban settings. Managing for rare species may increase the complexity of introducing disturbance, because of the potential risk of harming individuals (Pendergrass et al. 1999, Marcot and Sieg 2007).

This project sought to identify appropriate treatments to enhance habitat for the endangered *Clarkia franciscana* Harlan Lewis & Raven (Presidio clarkia) at a 6-ha remnant serpentine grassland in the Presidio of San Francisco. Goals included identifying effective and pragmatic treatments for the small, urban site; quantifying the value of seeding treated areas; and determining whether treatments used to establish Presidio clarkia would be appropriate in areas already occupied by this endangered serpentine endemic.

Serpentine soils are generally characterized by low levels of macronutrients such as nitrogen and phosphorus, low calcium to magnesium ratios, and high concentrations of heavy metals such as nickel, chromium, and cobalt. This unusual chemistry of serpentine soils creates a harsh environment for plant growth, and many of the species adapted to serpentine soils are rare (Kruckeberg 1984, 2006).

California grasslands are dominated by invasive plants, primarily annual grasses of Mediterranean origin (Bartolome et al. 2007). In many cases these invasives are less competitive in serpentine soils due to the unique composition of those soils (Huenneke 1989, Huenneke et al. 1990); as a result, California serpentine grasslands act as refuges for many native grasses and forbs (Murphy and Ehrlich 1989).

Invasives are still a threat in serpentine grasslands, particularly where nutrient addition alters the chemically harsh serpentine soil. Both dry nitrogen deposition from air pollution (Weiss 1999) and organic matter from tree plantings are adding nutrients to serpentine soils in the Presidio (NPS 2001).

Presidio clarkia is a slender, erect, herbaceous annual of the evening-primrose family (Onagraceae) that grows up to 40 cm tall with few, very small and narrow leaves. It has unlobed and unclawed petals, which are pink with a red blotch at the base. Generally restricted to serpentine soils, Presidio clarkia blooms from May to July. In a study of reproductive success at the Presidio habitat, each Presidio clarkia plant produced an average 872 ± 84 seeds (Bode 2000). These seeds are presumed, but not confirmed, to be "long-lived" (Roof 1972).

Until the 1980s, Presidio clarkia was believed to be restricted to the Presidio of San Francisco, but several small populations are known to exist in the Oakland Hills in Alameda County (USFWS 1998, EBRPD 2008). Presidio clarkia was listed as an endangered California taxon in 1989 (Sanguamphai 1989) and as federally endangered in 1998 (USFWS 1998). It is known from only five sites, two of which are in the Presidio.

In large habitat areas, various management techniques such as grazing (Heady 1988, Huenneke et al. 1990, Weiss 1999, Safford and Harrison 2001, Weiss et al. 2010), burning (Harrison et al. 2003, Weiss et al. 2010), and mowing (Maron and Jefferies 2001,Weiss 2002, EBRPD 2008) have effectively reduced invasives and increased biodiversity on serpentine soils. However, these techniques are challenging in small habitat fragments, particularly those in urban settings such as that of the Presidio. Burning poses the risk of an escaped fire, and air quality concerns are high in this urban matrix. Grazing is difficult at this small site, which includes high numbers of recreational users, including dog walkers. However, managers agreed to introduce these treatments if they proved more effective than alternative simpler treatments at improving habitat for the clarkia. Stakeholders agreed to test a variety of treatments concurrently to compare efficacy and pragmatism on the site.

Because the clarkia is listed as endangered, all treatments must minimize take. It was assumed (though not previously tested) that management during the growing season would harm established clarkia. It was believed that treatments in habitat occupied by clarkia should take place only in the period between set seed and germination. This study tested treatments throughout the season, both in potential clarkia habitat and in areas where clarkia was already present. The suitability of each treatment was measured by comparing species composition in each plot pre- and post-treatment.

Methods

Study area.—This study was conducted in the Presidio of San Francisco, at a 6-hectare remnant serpentine grassland named Inspiration Point (37° 47' 32.80" N, 122° 27' 26.75" W, WGS 1984). Inspiration Point is the type locality for Presidio clarkia, which was first collected in 1956 (Lewis and Raven 1958). Average October–May precipitation from 1960 to 2013 at the Presidio is 56.5 cm. Precipitation during the study period was lower than average (Table 1) (PRISM 2014). The average annual minimum temperature is 9.9º C; the average maximum is 17.6º C (WestMap 2009). Summers are relatively cool and foggy.

Growing season	Mean precipitation Oct–May (cm)
2006-2007	37.7
2007-2008	46.5
2008-2009	47.9
Mean 1960–2013	56.5

Table 1.—Precipitation during the study period (2006–2009) compared with long-term mean precipitation (1960–2013) at the Presidio of San Francisco, California.

The 600-hectare Presidio, part of the Golden Gate National Recreation Area, lies at the northern tip of the San Francisco Peninsula in a densely populated urban setting. It receives heavy recreational use from walkers, joggers, cyclists, and dog owners. A former military post, the Presidio is a cultural landmark with a number of historic buildings. In 1994, the region was transferred to the National Park Service, which now manages the coastal areas; the Presidio Trust now manages the interior 80% of lands. Remaining wild lands at this site are small and fragmented, and provide habitat to more than 350 native plant species, five of which are federally listed as threatened or endangered, including the Presidio clarkia.

During the late 19th and early 20th centuries, tree planting efforts throughout the Presidio converted the original coastal prairie into stands of Monterey pine (*Pinus radiata*), Monterey cypress (*Hesperocyparis macrocarpa*), coast redwood (*Sequoia sempervirens*), and blue gum eucalyptus (*Eucalyptus globulus*). The resulting litter and duff created thick organic layers that enriched the nutrient-poor serpentine soil, and nonnative annual species invaded remaining grassland patches (NPS 2001). Annual grasses and thatch have been shown to have negative effects on forbs (Huenneke et al. 1990, Coleman and Levine 2007).

Although Presidio clarkia population estimates are unavailable prior to 1970, it is reasonable to assume based on observations that populations of this and other serpentine-restricted species dropped in the newly shaded, nutrient-rich, invaded environment (USFWS 1998, NPS 2001). The invasive grasses on site — including *Avena barbata* Link (wild oats), *Festuca perennis* Lam. (Italian ryegrass), and *Bromus hordeaceus* L. (soft chess) — also threaten other native species, both common and rare (USFWS 1998, Strathmann 2001). Controlling invasive grass to enhance clarkia habitat should also benefit these other native plants.

Experimental Design.—The experiment uses a Before-After Control-Impact (BACI) randomized block design, with three blocks placed in Presidio clarkia habitat. The blocks were placed in three areas that captured a range of clarkia habitat variability on site: a southeast-facing slope west of the main Presidio clarkia population, a gentle east-facing slope with high bunchgrass cover, and a northeast-facing slope. Each block has nine treatments in 1x1 m plots spaced 0.5 m apart, with nine replicates of each treatment, for a total of 243 treatment plots. Within each large block, 3×3 sub-blocks were defined to account for fine-scale variability and to disperse the treatments throughout the large block, with treatments randomly assigned within the sub-blocks.

We randomly assigned nine treatments a plot within each sub-block: control (no treatment), fall burning, fall flaming, fall mowing with thatch reduction, fall scraping, fall tarping, spring burning, spring mowing with thatch reduction, or spring mowing without thatch reduction. Treatments were selected because they have improved serpentine habitats at other sites, or because they seemed logical tools for reducing the annual grasses and associated thatch that are likely the primary threats to the clarkia in the open grasslands. Baseline percent cover of all species was recorded before treatments in April 2007, and plot treatments took place spring and fall 2007.

Following treatment, the left half of each plot was broadcast with 100 Presidio clarkia seeds (collected throughout the site in summer 2007) in late November 2007 before major rains. Density of Presidio clarkia was measured in spring 2008 by counting individuals on each half of the 1-m^2 plots. To reduce edge effects, species composition data were collected from a 0.25-m^2 quadrat at the center of each 1-m^2 plot. Plots were re-examined in late April or early May 2008 to determine treatment effects on clarkia density and community composition. Plots were read a final time in early May 2009 to determine which effects persisted two years after treatment.

Statistical analyses.—All analyses were conducted in JMP 10.0 (SAS Institute). Clarkia counts were log(x+1) transformed and analyzed with ANOVA, with treatment and block effects. Plots were divided into those that had clarkia in 2007 and those with none, and the seeded and unseeded halves of the plot were analyzed separately. Individual treatments were compared pairwise by Tukey HSD post-hoc-tests.

Vegetation composition data were analyzed as a BACI design, within a randomized block ANOVA, with Tukey HSD post-hoc testing. For each species and abiotic metric, data were log(x+1)-transformed. For Year 1 results, log-transformed 2007 cover was subtracted from transformed 2008 cover to determine the change in cover at each treatment plot. For Year 2 results, transformed 2007 cover was subtracted from transformed 2009 cover. We set $\alpha = 0.05$ as the threshold for significance for all statistical tests.

Treatment methods and timing.—Each plot was treated once in the baseline year (2007). Plots were not treated in Year 1 (2008) or Year 2 (2009).

Spring burning was conducted in July, as soon as thatch was dry enough to carry a fire, but before annual grass seeds had shattered. The fire carried well, consuming all thatch, but it is unknown whether it was hot enough to destroy seeds. Burns were conducted in burn boxes, constructed of four ~1×1.5-m metal sheets bolted together, to contain the fire treatment in the desired plot and enhance safety.

Spring mowing (with and without thatch reduction) was conducted in early May when the *Festuca* was at a soft to medium dough stage (seeds had formed, but were still soft). Plots were mowed with a stringcutter. In plots with thatch reduction treatment, biomass was raked from the plot.

Fall burning was conducted in October, during dry conditions after seeds had fallen. Burn boxes again were used. The burn thoroughly consumed thatch and standing dead biomass.

Fall flaming took place in November on a cold, dewy day just before the season's first significant rain; burn boxes were not required. Nonnative annual grasses were about 5-cm tall. A propane torch was passed over live plants and held in place long enough to burn litter, a more intense treatment than the typical method of passing the torch quickly over the plant until it wilts.

Fall mowing with thatch reduction was conducted in late November, using the method described for spring mowing with thatch reduction. The purpose of fall mowing is largely to break up the thatch. Nonnative annual grasses were about 5-cm tall, and no major rains had fallen.

Fall scraping took place in November; annual grasses were about 5 cm tall. A McLeod was used to remove 8-10 cm of topsoil. Fall tarping also occurred in November. Plots were securely tarped using Lumite® weed barriers. Annual grasses had germinated and grown to about 5-cm tall. Tarps were left on for about six weeks, with the aim of killing annuals but not perennials.

With the exception of the tarped plots, each plot (including the control) was seeded with Presidio clarkia in late November 2007, following completion of all 2007 treatments. Tarped plots were seeded upon tarp removal, in January 2008. A total of 100 seeds were broadcast on half of each plot. Seeds were mixed with clean sand for better dispersion, and then broadcast on the left half of each square meter plot, facing uphill.

When considered in their entirety, the control plots do not represent natural recruitment (defined as plants establishing without active management); only the unseeded, right half of the control plots do. Effects of seeding were analyzed only in Year 1. By Year 2 it was assumed plants that reached reproductive maturity on each half of the 1-m^2 plots would naturally drop seed into the adjacent half, obscuring the original seeding effects. To examine persistence, we counted the number of clarkia in the entire plot in Year 2.

Results

Presidio clarkia density.— In unseeded areas, fall scraping significantly increased clarkia (Figures 1 and 2; $F_{8,232}$=4.34, P<0.0001). The seeded half of the plots showed a slightly different pattern. Fall scraping, fall flaming, and fall tarping significantly increased clarkia density (Figures 3 and 4; $F_{8,232}$=34.2, P<0.0001.

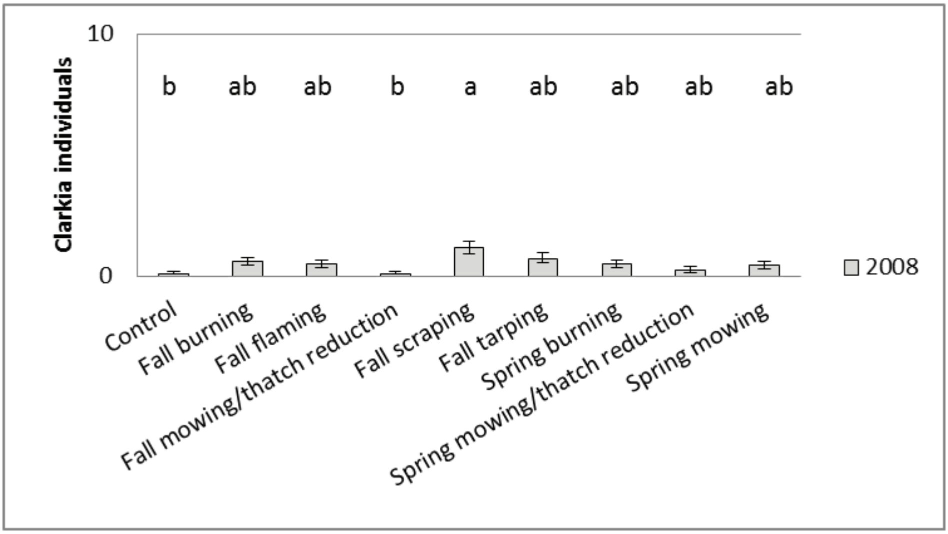

Figure 1.—Presidio clarkia density in unseeded plots, initially absent, ± 1 SE. Levels not connected by the same letter are significantly different.

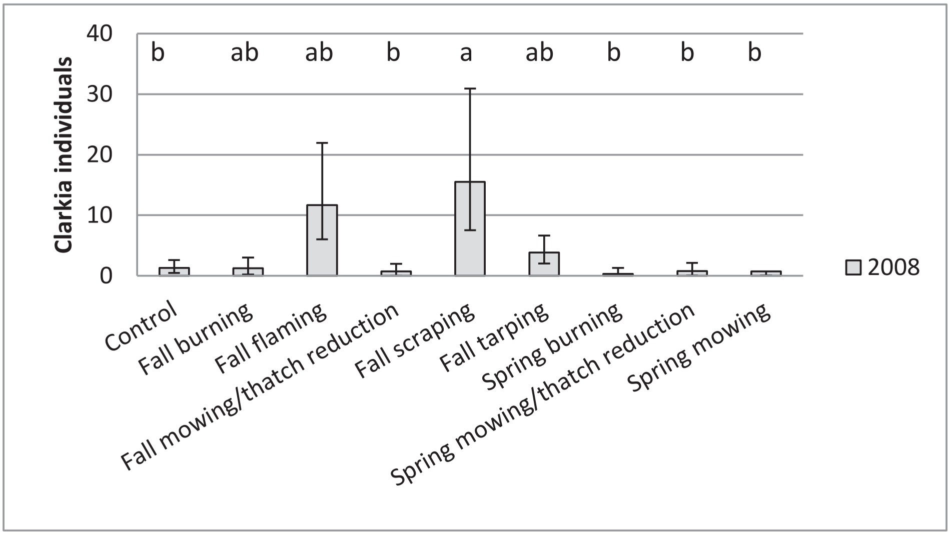

Figure 2.—Presidio clarkia density in unseeded plots, initially present, ± 1 SE. Levels not connected by the same letter are significantly different.

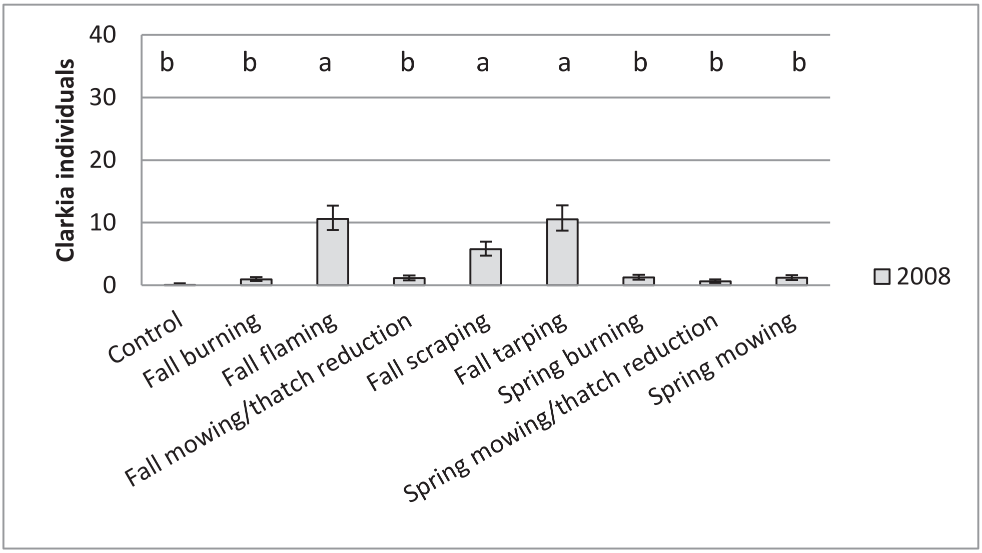

Figure 3.—Presidio clarkia density in seeded plots, initially absent, ± 1 SE. Levels not connected by the same letter are significantly different.

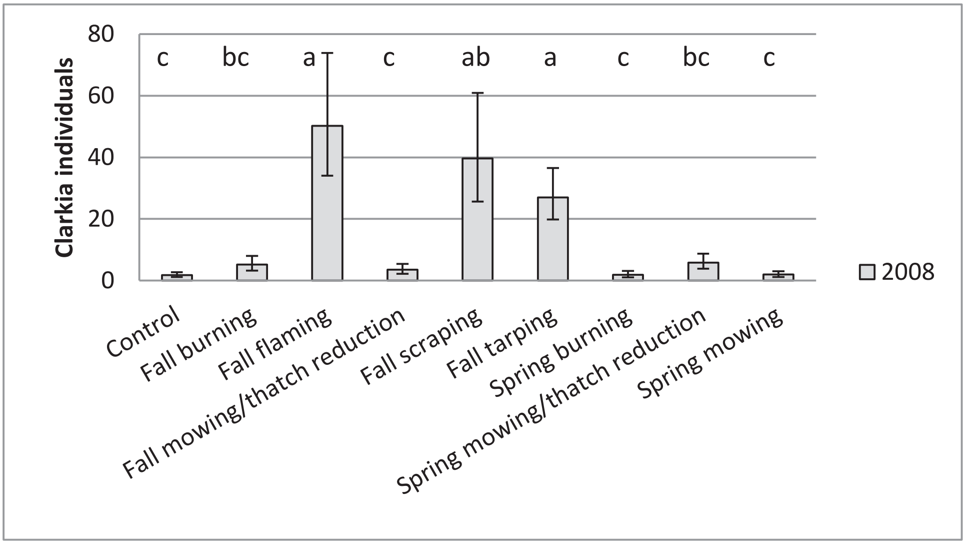

Figure 4.—Presidio clarkia density in seeded plots, initially present, ± 1 SE. Levels not connected by the same letter are significantly different.

Overall clarkia density showed similar patterns. Combining the seeded and unseeded halves of plots, fall flaming, fall scraping, and fall tarping showed the largest increases in clarkia numbers in Year 1 ($F_{8,\ 232}$=29.83, P<0.0001). By Year 2, only fall flaming and fall tarping remained significant (Figure 5; $F_{8,230}$=5.43, P<0.0001). Density throughout the site was greatly increased as clarkia persisted throughout areas where it was initially absent (Table 2).

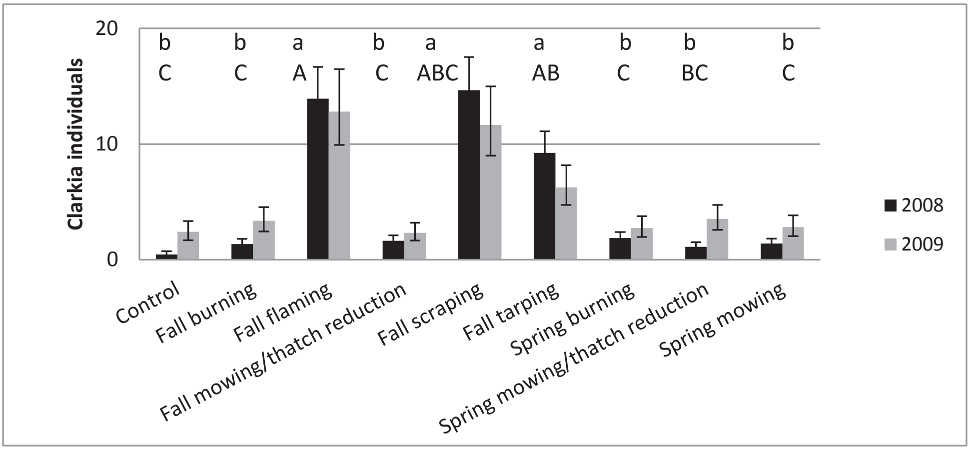

Figure 5.—Presidio clarkia density per treatment, seeded and unseeded plot halves combined, ± 1 SE. Levels not connected by the same letter are significantly different.

Table 2.—Number of study plots containing clarkia by Year 2, compared to initial presence or absence at Inspiration Point, Presidio of San Francisco, California, 2007–2009.

Block	Clarkia status	2007	2009
1	absent	38	33
1	present	43	48
2	absent	78	13
2	present	3	68
3	absent	81	30
3	present	0	51

Cover by guild.—Guilds are defined as functional groups based on life form, further divided between native and non-native species. We present data on key guilds of this system: nonnative annual grass, native annual/biennial forbs, and native perennial grasses. Total native cover, total nonnative cover, bare ground, and thatch are also examined. There was a significant difference in non-native annual grass cover among treatments ($F_{8,230}$=26.5, P<0.001). In Year 1, the control increased 42.33% in absolute cover, with the wild oats reaching more than 1.7 m high in many plots. The most effective treatments in reducing annual grass cover were fall tarping, fall scraping, and fall flaming. The spring mow with thatch reduction also had significantly less annual grass than the control (Tukey HSD P<0.05). By Year 2, treatment effects persisted (Figure 6; $F_{8,232}$=3.54, P<0.001), but only plots treated with fall scraping were significantly different from the control (Tukey HSD P<0.05).

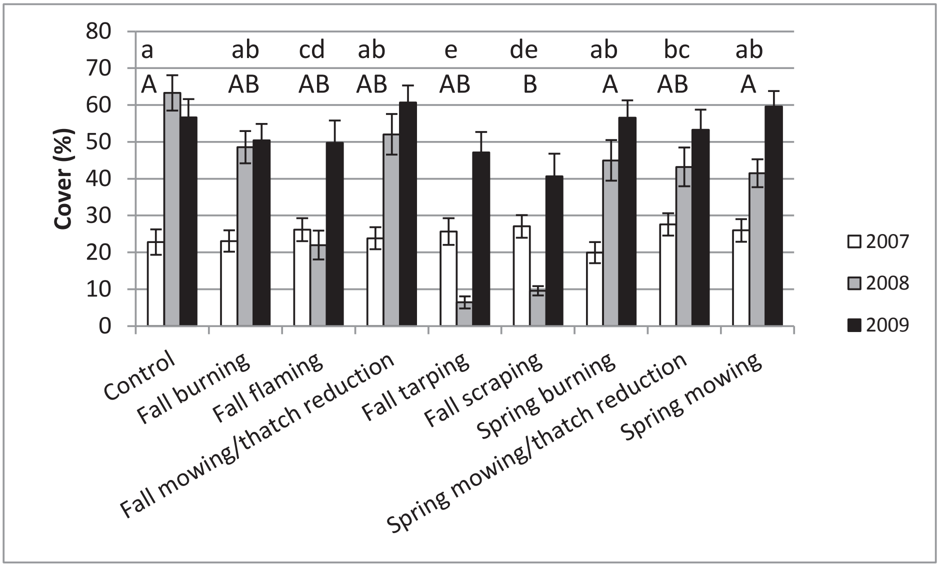

Figure 6.—Non-native annual grass, P<0.0001 (2008); P=0.0008 (2009). Error bars show ± 1 SE. Levels not connected by the same letter are significantly different. Lower case letters denote changes from baseline to Year 1 (2008); capital letters denote changes from baseline to Year 2 (2009).

There was a significant difference in bare cover among plot treatments. In Year 1, fall scraping yielded the greatest bare ground. Fall flaming, fall tarping, spring burning, and spring mowing also resulted in significant increases in bare cover (Figure 7; $F_{8,232}$=10.3, P<0.0001). By Year 2, treatments were significant ($F_{8,232}$=3.08, P=0.0025), only fall scraping was significantly different from the control (Tukey HSD P<0.05).

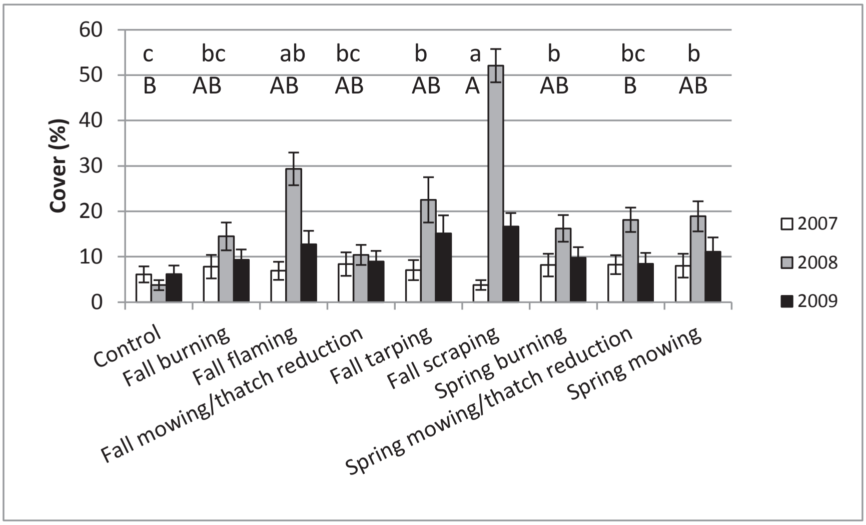

FIGURE 7.—Bare cover, *P*<0.0001 (2008); *P*=0.0025 (2009). Error bars show ± 1 SE. Levels not connected by the same letter are significantly different. Lower case letters denote changes from baseline to Year 1 (2008); capital letters denote changes from baseline to Year 2 (2009).

In Year 1, fall tarping showed significantly more thatch than the other treatments (Figure 8; $F_{8,232}$=12.1, *P*<0.0001). However, measurements of cover did not account for variation in biomass; while tarped plots appeared to have high levels of thatch and less live cover, the tarps also appeared to have broken down the thatch biomass. Measuring only absolute cover rather than biomass may have misrepresented these results. In Year 2, the overall treatment effect was significant ($F_{8,232}$=2.5, *P*=0.0125; Tukey HSD 0.05<*P*<0.10).

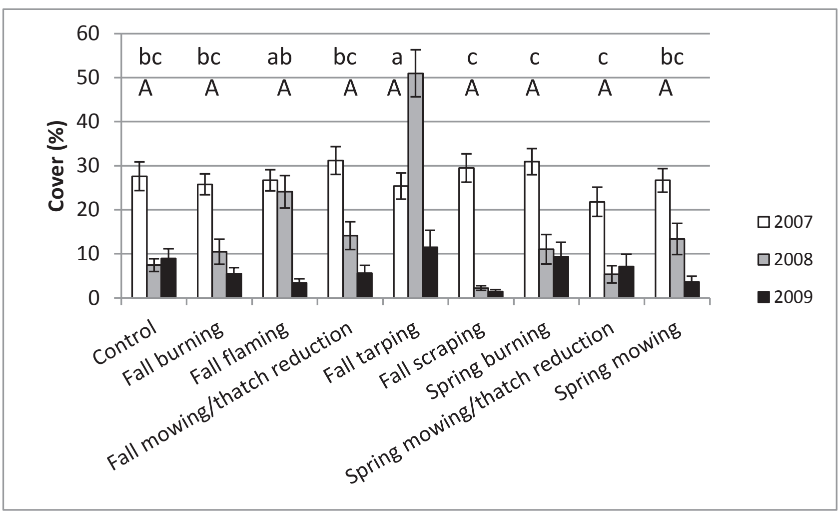

FIGURE 8.—Thatch cover, *P*<0.0001 (2008); *P*=0.0125 (2009). Error bars show ± 1 SE. Levels not connected by the same letter are significantly different. Lower case letters denote changes from baseline to Year 1 (2008); capital letters denote changes from baseline to Year 2 (2009).

Total native cover declined across all treatments and the control, likely due to below-average precipitation in 2007–2009 (Table 1). There was no difference in total native cover among treatments in 2008 (Figure 9; $F_{8,232}$=0.75, P=0.65) or in 2009 year ($F_{8,232}$=0.79, P=0.61).

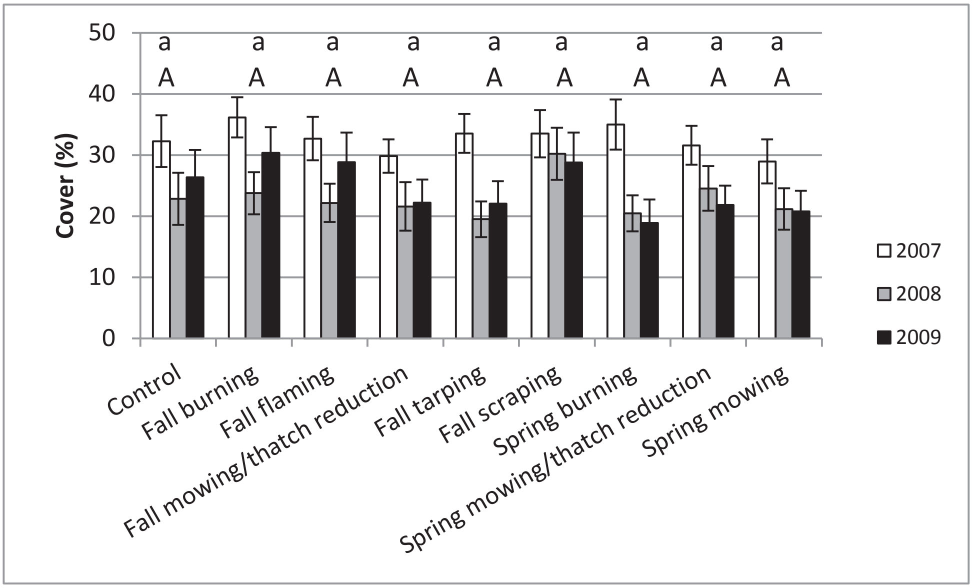

Figure 9.—Total native cover, P=0.65 (2008); P=0.6116 (2009). Error bars show ± 1 SE. Levels not connected by the same letter are significantly different. Lower case letters denote changes from baseline to Year 1 (2008); capital letters denote changes from baseline to Year 2 (2009).

Changes in annual grass cover drove changes in total nonnative cover (Figure 10). In Year 1, nonnative cover was significantly lower with the fall flaming, fall tarping, and fall scraping ($F_{8,232}$=24.6, P<0.0001). By Year 2, treatment effects were significant ($F_{8,232}$=3.05, P=0.0027) but no treatment plots differed significantly from the control (Tukey HSD P>0.05). In Year 1, plots treated with spring mowing with thatch reduction, fall flaming, fall tarping, and fall scraping showed significantly more native annual/biennial forbs than the control ($F_{8,232}$=6.63, P<0.0001). However, by Year 2, treatment effects were no longer significant ($F_{8,232}$=1.86, P=0.68). Additionally, even the control plots showed decreases from the baseline. The dry years of 2008 and 2009 appear to have greatly decreased native forb cover (Figure 11).

In Year 1 treatment effects led to significantly different native perennial grass cover (Figure 12; $F_{8,232}$=3.33, P=0.0012), but no treatment was significantly different from the control (Tukey HSD P>0.05). In Year 2, treatment effects persisted ($F_{8,232}$=3.21, P=0.0018), but no treatment was significantly different from the control (Tukey HSD P>0.05). Species richness was also investigated for each guild, with no effects lasting into Year 2 (data not shown).

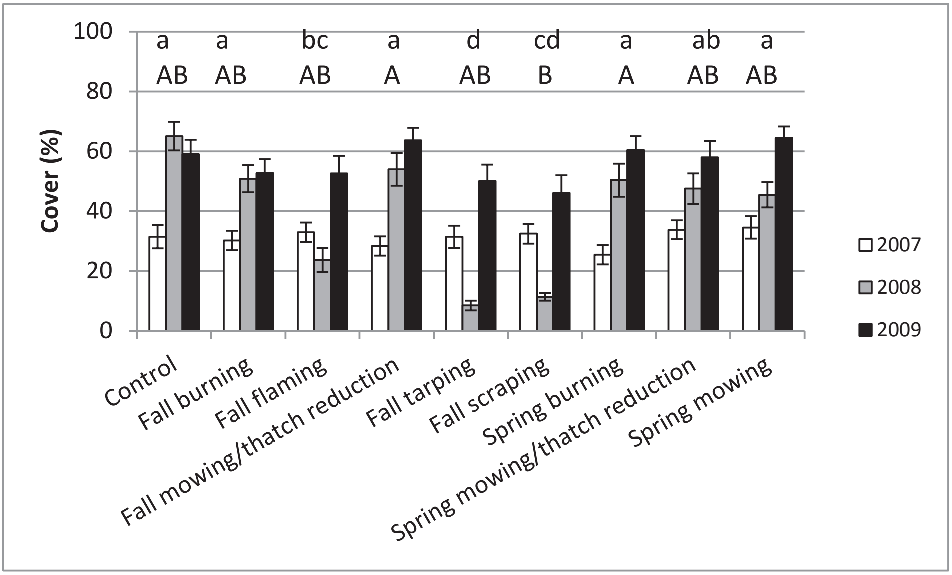

Figure 10.—Total non-native cover, *P*<0.0001 (2008); *P*=0.003 (2009). Error bars show ± 1 SE. Levels not connected by the same letter are significantly different. Lower case letters denote changes from baseline to Year 1 (2008); capital letters denote changes from baseline to Year 2 (2009).

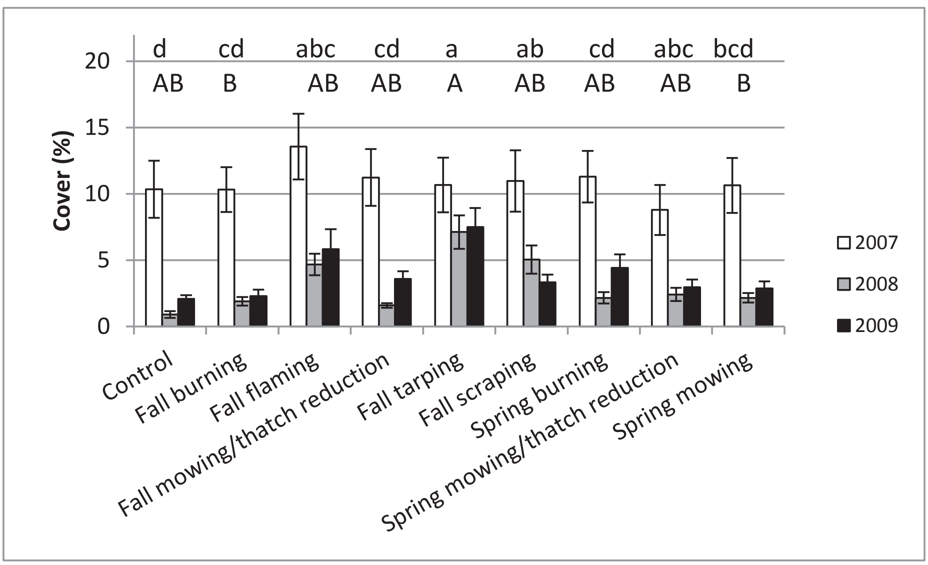

Figure 11.—Native annual and biennial forb cover, *P*<0.0001 (2008); *P*=0.068 (2009). Error bars show ± 1 SE. Levels not connected by the same letter are significantly different. Lower case letters denote changes from baseline to Year 1 (2008); capital letters denote changes from baseline to Year 2 (2009).

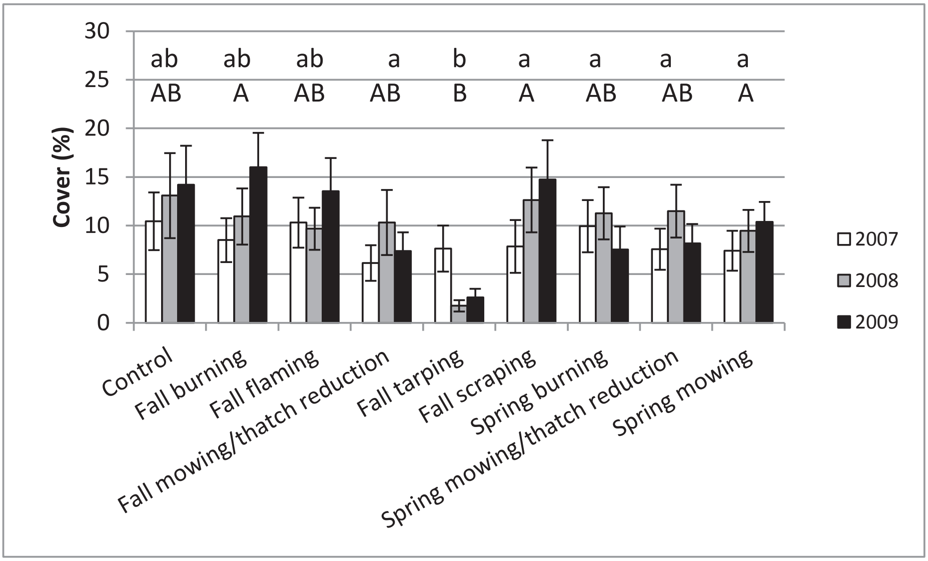

Figure 12.—Native perennial grass cover, *P*=0.0012 (2008); *P*=0.0018 (2009). Error bars show ± 1 SE. Levels not connected by the same letter are significantly different. Lower case letters denote changes from baseline to Year 1 (2008); capital letters denote changes from baseline to Year 2 (2009).

Discussion

By all measures, fall scraping, fall tarping, and fall flaming stood out as the most effective methods for increasing the number of Presidio clarkia at Inspiration Point. These three treatments were most successful in increasing one-year density in seeded clarkia plots. Fall scraping enhanced clarkia populations in the unseeded plots, although at much lower total numbers compared with seeded plots. In Year 1, these three treatments were also most successful in reducing annual grass cover and decreasing nonnative plant cover — standard measures of habitat suitability for a native forb such as the clarkia. Along with other treatments, they also significantly increased bare ground in Year 1. Plots treated with the three most successful treatments were visually identifiable in both years by their low cover of annual grasses.

Two years after treatment, some effects were muted. Only fall scraping had significantly more bare ground and less annual grass in all blocks. Effects persisted in the critical parameter of clarkia density; fall flaming and fall tarping were significantly different from the control, with fall scraping also showing an increase, albeit not significant.

Perhaps most important, clarkia persisted in newly introduced areas. While disturbance was key to establishing this ruderal species, clarkia persisted after other parameters returned to their original state. After only two years, it is not yet clear how long clarkia will persist before requiring additional disturbance; this is being studied further.

Post-germination treatments most successful.—Although other studies have shown spring treatments to be useful for reducing annual grass and thatch and increasing native forbs (Weiss 1999, 2002; Naumovich et al. 2009), that was not the case in this study. With spring treatments, annual grasses recovered too quickly to allow clarkia recruitment. Treating in late fall, after the annual grasses had germinated, appears critical for this site.

Fall treatments that did not address the flush of newly germinated annual grasses were less successful. The fall fire was conducted before the rainy season and subsequent grass germination. The fall mow with thatch reduction took place after germination, but it was designed to reduce thatch, not to affect germinated plants. These results are a significant departure from other studies, and reflect the critical importance of timing for weed control treatment. These findings all demonstrate the importance of assessing the suitability of treatments for any given location.

Seeding effectiveness.—Where active seeding did not occur, a low but statistically significant number of clarkia was present in fall scraped plots where the plant had initially been absent, indicating the treatment may have stimulated a dormant seedbank. It was not surprising to find the clarkia had difficulty recruiting on its own, since California native forbs are often seed-limited (Seabloom et al. 2003).

Where active seeding did occur, the three successful treatments increased clarkia density regardless of whether it had been present initially. These results suggest that efforts to introduce clarkia into unoccupied areas should include both habitat treatment and active seeding. Given a limited number of seeds available for planting, increasing the distribution of clarkia into areas with very low or no numbers should be a higher priority than seeding densely occupied areas.

Active management of an endangered species.—At Inspiration Point, clarkia will likely require ongoing management to address the continuous threat of invasive species. Gains from management treatments are expected to be short-term as annual grasses reinvade treated areas.

This experiment addressed the concern that some habitat treatments might be inappropriate in areas occupied by clarkia because of the threat to existing individuals of that species. Despite the fact that the most successful treatments took place during the growing season, our results show that the species responded positively to fall scraping, fall flaming, and fall tarping, when it was thought that the forb might be vulnerable to treatment. While some clarkia individuals may have been harmed by the treatments, overall habitat and density were both improved.

Site-specific studies.—Regional experiences and the literature suggested that all of the experimental treatments would reduce thatch and increase bare ground (Weiss 1999, 2002; Naumovich et al. 2009), and many were also expected to decrease annual grass (Brown and Smith 2000, Tu et al. 2001, Moore 2004, DiTomaso and Johnson 2006). For example, a single spring mow with thatch reduction in the serpentine grasslands at Edgewood Natural Preserve (about 45 km south of the Presidio) significantly reduced annual grass and thatch for three years, leading to an increase in native forb cover (Weiss 2002). A spring burn on Tulare Hill (about 100 km south of the Presidio) had similar results, although the effect lasted only two years (Weiss et al. 2010).

Many of these treatments did not prove effective at this study site. The relatively cool and wet weather at Inspiration Point lengthens the grass-growing season, making it more difficult to exert control with a single treatment. Indeed, other researchers have found burning and grazing to be less successful in coastal grasslands as compared with valley grasslands (Hatch et al. 1999). While the less successful treatments could likely be adjusted to be more effective on the site (i.e., mowing several times per season), the discovery of three techniques that work so well to establish clarkia and its preferred habitat eliminates the need to find other solutions.

Grasslands are known for spatial and temporal variability (Hobbs et al. 2007). It is possible that responses to treatments could be specific to the phenology and weather of the years in which they were performed. Precipitation was below average during the study period (37.7 to 47.9 cm compared with an average of 56.7 cm; Table 1). A similar study of *Clarkia franciscana* at Redwood Regional Park in Oakland, about 30 km east of the Presidio, showed that clarkia numbers were closely related to total precipitation from 2008–2013 ($r^2 = 0.90$) (Naumovich et al. 2014). While enough data are available to yield informed management decisions, it is important to recognize the role of annual variability and climate change in affecting plant communities. It is possible that treatment results would be different in a year of greater rainfall. Observations of treatments conducted in wetter years after this experiment was completed have shown similar, but unmeasured, results.

Pragmatism.—As with all active management programs, pragmatism is as important as efficacy in the selection of appropriate habitat treatments. Land managers at the Presidio consider the three most effective treatments in this study to be practical for use in this small, urban habitat fragment.

Experimental comparisons of alternative management techniques allow managers to make the best decisions. For MacDougall and Turkington (2007), the discovery that mechanical treatments resulted in cover increases to native flora and decreases to exotics that mimicked the responses to burning led them to recommend limiting the use of fire, which was physically and politically risky in their rural savannah ecosystem. In this study, the burn treatments were logistically difficult, even when confined to the burn boxes. On this site, however, burning proved less effective than other treatments and, thus, could be abandoned. Testing alternative grassland disturbance regimes can be useful in small or urban areas where classic methods such as grazing and prescribed fire may be neither pragmatic nor effective.

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