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Using Pollinator Seed Mixes in Landscape Restoration Boosts Bee Visitation and Reproduction in the Rare Local Endemic Santa Susana Tarweed, *Deinandra minthornii*

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ABSTRACT: Restoration practices that enhance pollinator habitat can improve conservation outcomes, including support of pollinator-dependent plant species. Yet, limited background research has assessed the benefits of incorporating greater native forb diversity into larger-scale restoration operations to justify the often increased costs of pollinator seed mixes. This study examined changes in pollination services received by Santa Susana tarweed, *Deinandra minthornii*, a California-listed Rare (CR) endemic of the Santa Susana Mountains that were associated with a native forb seed mix used in a large-scale remediation program at the Santa Susana Field Lab (SSFL) in Los Angeles, California. A four-year study of pollinator community dynamics and services was conducted from 2011 to 2014 examining aggregations of *D. minthornii* near to and farther from restoration activities. We hypothesized that *D. minthornii* located closer to the areas seeded with the forb mixes would be visited by more pollinators and receive greater pollination services, resulting in increased seed viability. Pollinator exclusion experiments indicate *D. minthornii* to be highly dependent on pollinators for seed set (excluded seed viability = $4.1\% \pm 7.4$; open viability = $65.5\% \pm 19.5$). Populations located closer to pollinator-specific restoration seedings were visited by more bees and more bee types ($P = 0.00$), and showed a 30% higher seed viability when compared to populations located in unrestored areas (mean seed viability near = $62.20\% \pm 18.6$, far = $48.00\% \pm 11.7$). We encourage the use of regionally appropriate forb seed mixes in remediation scenarios to enhance pollination services.

Index terms: bees, pollinator dependence, rare species, restoration, seed viability

INTRODUCTION

Landscape restorations are often designed to restore the ecological services in cases where human actions or other biotic factors, such as invasive species, have degraded the capacity and function of the landscape. In the case of industrial lands, restoration actions most commonly include soil retention, erosion control preservation, and storm water run-off management—services previously performed by the local plant community (Costanza et al. 1998; Diaz et al. 2007). For larger landscapes typical of most industrial lands, the restoration of vegetative function commonly involves the use of native and nonnative grasses that establish quickly to support soil retention efforts and storm water run-off management activities. While grasses provide the indented soil retention and storm water run-off functions, unlike forbs, they do not provide pollination service support. Grasses are generally used because they are quick to establish, have a high success rate, are cost-effective, and require less technical knowledge for establishment than forbs. However, including a diversity of native plant species into restoration projects helps increase ecosystem services and supports a higher diversity and increased abundance of wildlife and birds (Davis et al. 2000).

Within natural landscapes, between 60 and 96% of angiosperm species are pollinator dependent (Ollerton et al. 2011),

indicating that successful restorations of ecosystem functions and services rely on providing and supporting pollinator populations (Tepedino 1979; Kearns and Inouye 1997), which in turn requires the presence of a diverse local flowering plant community (Terborgh 1986; Neff and Simpson 1993). Pollinators also play a critical role in the survival of threatened, rare, and endangered plant species, many of which are dependent on pollinators for reproduction, and therefore, highly dependent on intact landscapes that support pollination services (Biesmeijer et al. 2006). Pollination failure severely impacts rare plant survival, and is especially likely in systems where pollinator-dependent plants exist in an increasingly fragmented or isolated landscape with limited pollination services (Aguilar et al. 2006). Landscape restoration goals that promote pollination services should be a key consideration to aid in supporting conservation goals in these scenarios.

Many populations of rare plants and animals have been found within the boundaries of industrial areas with restricted human access (Greenwood and Gemmill 1978; Stein et al. 2008; Boice 2013). Santa Susana tarweed, *Deinandra minthornii* (Jeps.) B.G. Baldwin, is a California-listed rare (CR) (CNPS 2016) plant that grows in the Santa Monica Mountains between Ventura and Los Angeles counties in Southern California. Within the native and

historical range of *D. minthornii* is the Santa Susana Field Lab (SSFL), an aerospace research and development campus that was active from 1946 through 2006, when it was decommissioned (US EPA 2015). Throughout its history, SSFL was managed and operated by many entities, beginning with Rocketdyne, North American Aviation, and ending with The Boeing Company, which continues to own the land after ending research and development activities in 2006 (Sapere and Boeing 2005; Archeological Consultants, Inc., and Weitz Research, 2009). The Boeing Company leads restoration and rehabilitation activities at the SSFL.

The incorporation of flowering plant species into seed mixes can promote benefits to local plants and wildlife, including animal pollinators. The justification for pollinator enhanced activities is limited in the restoration literature. Examples of smaller-scale seeding and habitat-enhancing programs in agricultural landscapes show clear indications of increased pollinator species occurrence (Morandin et al. 2007; Morandin and Winston 2006), and in many cases, increased pollination services to nearby crops (Bullock et al. 2007; Kremen et al. 2007; Blaauw and Isaacs 2014; Isaacs et al. 2016). Land owner and restoration partner, The Boeing Company, engaged in supporting a test of alternative restoration practices, including pollinator community support through the seeding of diverse, regionally appropriate forb seed mixes, in order to evaluate the idea of enhanced seed mixes as part of standard practice.

This study focused on the dependence of *D. minthornii* on pollinators and how the proximity to restored areas impacts seed viability. The goal of this study was to understand and assess the impacts that landscape-level restoration activities had on pollinator-plant systems and to provide relevant information to land owners and managers that would encourage the adoption of pollinator-supporting restoration techniques. As the reproductive biology of *D. minthornii* is not well understood, we also tested pollinator dependence through pollinator exclusion in order to better understand the full range of factors that

contribute to *D. minthornii* conservation and management. We monitored the effects that pollinator seeding restorations had on local pollinator occurrence and pollinator visitation to *D. minthornii*, and if increased insect pollinator visitation impacted seed viability. We tested the hypothesis that restoration seeding activities with regionally appropriate native forb seed mixes that provide habitat for pollinators increase the localized occurrence of floral visitors. Plant species nearer to restoration activities would experience high visitation rates from a more diverse community of pollinators. If these species were highly dependent on animal pollination vectors, nearness to restored pollinator habitat would also correlate to an increase in viable seed resulting from the distance-dependent increase in pollinator presence.

METHODS

Study Site and Species

The Santa Susana Field Lab (SSFL) is a 2850-acre campus approximately 48 km from downtown Los Angeles, California. The site is characterized by sandstone bluffs and boulders, oak woodlands, meadows, and mountain vistas (US EPA 2015). The site connects the Sierra Madre and Santa Monica Mountains, a wildlife corridor essential to migratory mountain lions and other wildlife. *Deinandra minthornii* is one of two rare California endemics that occur naturally at the site. The second, *Astragalus brauntonii* Parish (Braunton's milkvetch), is federally listed as endangered.

The site also has a rich cultural history; Native Americans inhabited the lands and left pictographs and other artifacts. In more recent times, SSFL was used as a rocket engine and energy research site, where ground breaking advancements gave birth to our modern space program (Archeological Consultants, Inc., and Weitz Research 2009). Due to its rich history, part of SSFL is included on the National Register of Historic Places. Research activities in space exploration technology and solar, nuclear, and sodium technologies resulted in low-level radioactivity

and residual chemical contamination at the site (Sapere and Boeing 2005). The Boeing Company has owned the site since 1996 and continues to lease portions of the property to the National Aeronautics and Space Administration and the Department of Energy. In 1996 the technical operation of the site began to wind down and the site's focus shifted to environmental remediation. Since 2007, Boeing has been working to clean up the site and comply with a consent order under the direction of the Department of Toxic Substances Control of California. Cleanup and remediation activities included the removal of soil down to bedrock in some areas (Sapere and Boeing 2005). The reinstallation of new soil, organic matter, and ground cover followed in order to restore water retention and run-off prevention functions to the landscape.

Santa Susana tarweed, *D. minthornii*, is a California endemic, State listed rare plant (CR) (CNPS 2016) that grows in a limited geographic region in the Santa Monica Mountains range between Ventura and Los Angeles Counties. The evolutionary history of tarweeds includes a historical adaptive radiation into xeric, subalpine habitats from more alpine regions in the Western United States (Baldwin and Wessa 2000). Tarweed species in California commonly grow in scrubby hillsides and grassland areas nearer to the coast, preferring Mediterranean climate patterns. *Deinandra minthornii* preferentially grows in disturbed areas and within cracks and sandstone boulders (CNPS 2016; Figure 1A), and is a highly fragrant, multistemmed perennial shrub that grows approximately 1-m in height and can reach over 3-m in diameter. Bright yellow flowers emerge in early July and flowering can continue into September. While the pollination system of *D. minthornii* remains unknown, other tarweeds are visited by a mix of pollinators, mostly bees (Ross 2012), and the floral color and morphology of *D. minthornii* is consistent with bee pollination. Aggregations of *D. minthornii* are located throughout the SSFL. Due to its listed status, the number of individuals at the site is monitored for size and change. In 2011, at the beginning of the study, the population of *Deinandra minthornii* documented at the SSFL was approximately

12,000, occurring across the 2850 acres (C. Dunn, pers. comm. with M. Galea, 24 May 2016). Candidate plants occurring within our study area that qualified as near and far from restoration activities numbered around 300 individuals scattered across six patches; 62 of these individuals were safely accessible for sampling and were included in our study.

Landscape Seeding

In late 2010, with the environmental remediation program in full swing, The Boeing Company approached the Pollinator Partnership (P2) to review their existing restoration seed mix and make suggestions on how it could become more pollinator friendly. P2 worked closely with The Boeing Company and its team of biologists to review the existing plant list and highlight included species that would be beneficial for pollinators and to suggest additions to the seed mix to enhance pollinator value. The result was a regionally specific, pollinator-friendly seed mix. It was applied in December 2010 using a combination of seed and organic mulching liquid that was hydraulically launched out of a hose attached to a vehicle, called hydroseeding. This mix can be considered a high-diversity mix when compared to minimum vegetation remediation standards for vegetative establishment for soil retention and storm water run-off management, which often comprises one or two grass species.

Six sites with clusters of five or more individuals of *D. minthornii* were selected from the total individual plants at SSFL to conduct bee visitation counts and pollinator exclusion experiments. The sites were identified as either near a seeded (restored) area (within 300 m of restoration seeding activity) or far from a restored area (more than 300 m away from seeding activities). The 300-m designation was chosen based on average maximum foraging distance by solitary native bees (Greenleaf et al. 2007).

Deinandra minthornii Pollinator Exclusion and Seed Sampling

Pollinator exclusion devices were used to (1) assess pollinator dependence, and (2)

to compare seed viability for plants near restored areas and plants far from restored areas. In the first year of study (2011), the pollinator exclusion device included simple polyester pantyhose pulled over a portion of the plant's stem and secured with a plastic zip tie. This methodology proved sufficient for pollinator exclusion, but resulted in a smaller seed sample size as only about 10 floral heads could be contained in each pantyhose. In years two (2012), three (2013), and four (2014) of the study, we employed the use of 5-gallon elastic rimmed paint filtration bags from the Cary Company (PEMU150M C5 5 GAL ELASTIC TOP, Part Number 21WII5). For additional structure, metal stakes were pounded into the ground next to branches of *D. minthornii*, and then the five-gallon elastic rimmed paint filtration bags were pulled over the branches. The bottoms of the bags were secured with zip ties and duct tape. This setup prevented pollinators from accessing the flowers, but still allowed sun to reach the plant and air to circulate. Figure 1B shows a typical installation of the pollination exclusion bag. In years two, three, and four, the 31 pollinator exclusions were installed across five of the six identified sites of clusters of plants. The number of exclusion devices per site varied between four and 10, depending on the number of individuals at each of the identified six sites. Additionally, despite trying numerous methods of installation, including hammering and drilling, the number of exclusion devices varied based on the ability to install them on the individuals, as the plants often grow out of sandstone boulders. Staked exclusions could not be installed at Site 5 due to the rocky substrate.

When seed heads that were not bagged showed signs of natural dispersal, an indication of mature seed development, we collected the contents of the bagged branches as well as an additional sample of similar size from an unbagged region of the same plant. Entire floral heads were collected in the field and placed in labeled bags. The bagged and unbagged samples from each site were pooled for analysis, resulting in two samples from each of the five sampling sites (bagged and unbagged, plus one unbagged sample from Site 5),

for a total of 11 samples. *D. minthornii* aggregations are distributed in limited numbers throughout the SSFL landscape and the total accessible number of plants within our study area contains approximately 300 individuals. The 11 samples represent 62 individual plants assessed per year (an equal number of bagged and unbagged plants). The natural distribution of aggregations throughout the landscape allowed for only three paired, spatially independent sample comparisons to be made. Statistical methods were adjusted accordingly to deal with the small sample size. The bagged and unbagged samples from each site were pooled because the site was the replicated sample unit. The samples from 2011 were hand cleaned by gently separating seeds from other vegetative material. For years 2012–2014, the 11 samples were cleaned of chaff and other nonseed material by gently shaking the material through a strainer several times. A visual assessment was made to determine if all of the seed was separated from the chaff and ready for shipment.

The samples were then sent to the Oregon State University Seed Lab (OSU Seed Laboratory, 3291 SW Campus Way, Corvallis, OR 97331), where a tetrazolium chloride (TZ) test for seed viability was conducted on a minimum of 200 seeds per seed sample collected from 2011, 2012, 2013, and 2014. Due to the small size of the 2011 sample, only pollinator dependence (bagged vs. unbagged) was assessed across the SSFL. For 2012, 2013, and 2014, samples of unbagged and bagged seeds from each site were analyzed independently. The results of the TZ test are reported in terms of percentage viable seed from the total sample (Appendix).

Pollinator Visitation Rates

The visitation rates of various pollinators to *D. minthornii* were documented using frequency of visitation counts. A standardized sampling protocol was used for all four field seasons (2011–2014). During morning sampling (0900 to 1200), two random plants at each of the six *D. minthornii* sites were selected. Each of the two field researchers monitored a single plant for five minutes, documenting all

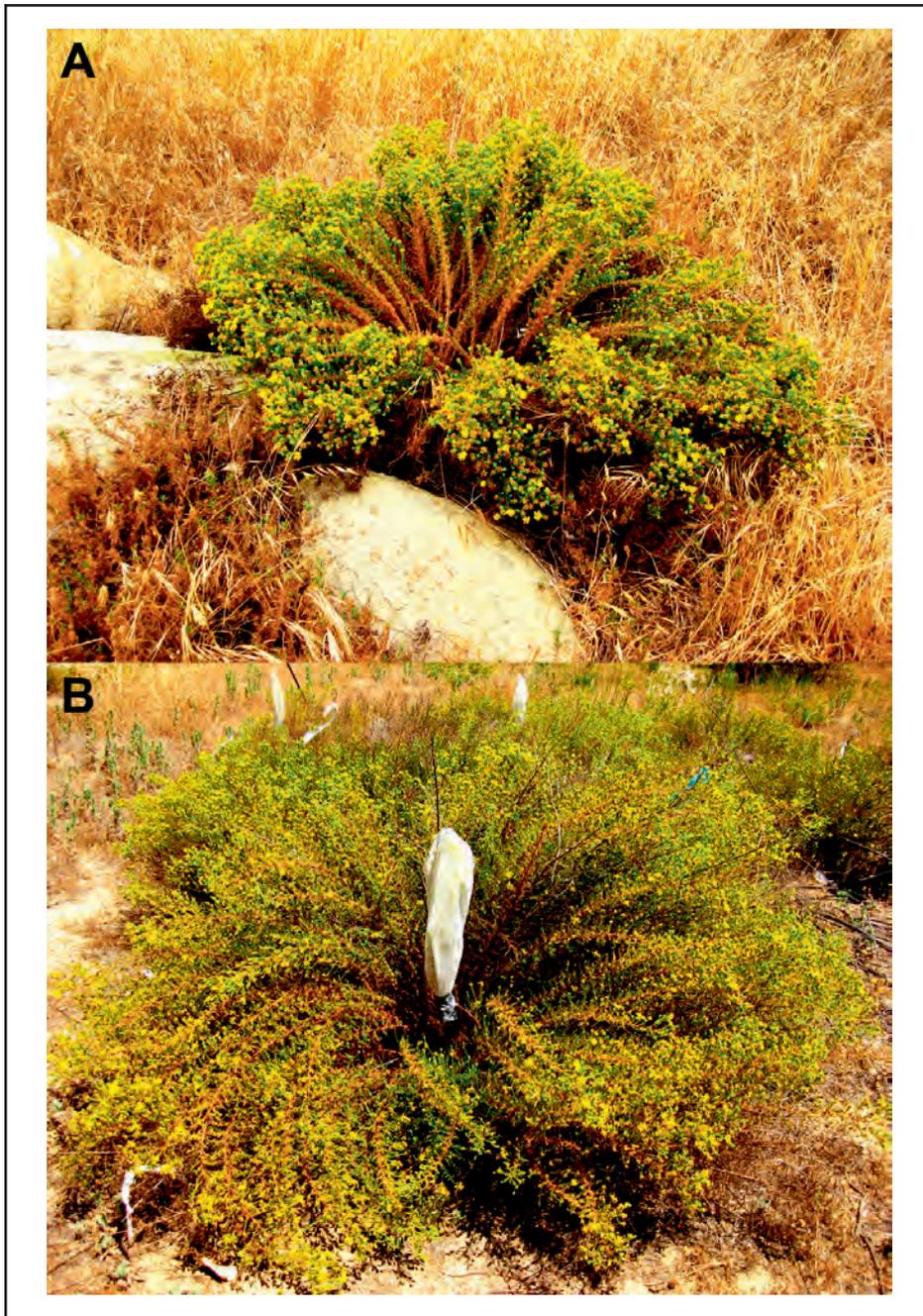


Figure 1. (A) Field image of *Deinandra minthornii* growing on a rocky outcropping at the Santa Susana Field Lab. (B) Pollinator exclusion device comprised of a 5-gallon paint straining bag secured to a metal stake. Photo credits: Chris Dunn.

pollinators visiting *D. minthornii*. After five minutes, the researchers switched plants and collected data from the second plant for an additional five minutes. The procedure was repeated (using the same randomly selected sample plants) in the afternoon (1200 to 1500). This accounted for a total of 40 minutes of visitation data collection per site per sample day.

Visitation data were collected when *D. minthornii* began to bloom (early July) and continued until the bloom period was complete (mid-September). Bees visiting *D. minthornii* were visually identified using the following categories: honey bee (*Apis mellifera* L.), yellow-faced bumble bee (*Bombus vossenskii* Radoszkowski), sweat bee (*Halictus* spp.), small sweat bee

(*Lasioglossum* spp.), green sweat bee (*Agapostemon* spp.), leaf cutter bee (*Megachile* spp.), long-horned bee (*Melissodes* spp.), potter bee (*Anthidium* spp.), mining bee (*Andrea* spp.), small carpenter bee (*Ceratina* spp.), and orchard bee (*Osmia* spp.). The 2014 sample season occurred during a category D4 Exception Drought in the project region of Southern California (US Drought Monitor Map Archive 2016). Sampling efforts continued throughout the year, but 2014 data were not used in the final analysis as they did not represent typical phenology patterns of pollinator occurrence.

Statistical Methods

We compared the pollinator dependence of *Deinandra minthornii* by contrasting the seed viability of all open pollinated seeds to all bagged seeds across three sample years (2011–2013; $n = 18$) using a two-tailed t -test ($\alpha = 0.05$). Samples from 2014 were not included in the final analysis due to extreme drought conditions that impacted plant development and bloom. The effect of proximity to restoration activities on seed viability was compared between samples using the Wilcoxon and Kruskal-Wallis tests ($\alpha = 0.05$), as our sample size was relatively small in this comparison (paired $n = 3$) and did not fit the assumptions of use for a t -test. The visitation rates of various pollinators to *D. minthornii* located near to and farther from restoration activities from 2011 through to 2013 were compared with t -tests. Again, data from 2014 were not included in the final analysis due to drought conditions. Comparisons were made for each individual bee type observed as well as for total richness and abundance of the pollinator community. Correlations between the frequency of bee visitation and seed viability were also investigated using linear regression models in order to determine if increased pollinator visits to *D. minthornii* could explain seed viability trends. All statistical analyses were carried out in R (R Core Team 2012).

RESULTS

Deinandra minthornii was significantly pollinator dependent, with seed viability

of pollinator-excluded flowers displaying a mean of 4.1% (± 7.4), while flowers open to pollination had a mean viability of 65.5% (± 19.5) (Figure 2). This difference was statistically significant (two-tailed t -test, $P < 0.000$).

Comparisons of seed viability between populations of *D. minthornii* located near to restoration activities versus ones located away from restoration activities indicated a 30% increase in seed viability at sites closer to restoration (near = 62.20 ± 18.6 , far = 48.00 ± 11.7 ; Figure 3). This difference was not determined to be significant at the 95% confidence level (Kruskal-Wallis $P = 0.1006$; Wilcox $P = 0.1336$); however, this lack of significant difference is likely due

to a naturally small sample size of limited individual plants.

There were some significant differences in the visitation rates of bees to *D. minthornii* populations near and far from restoration activities. In particular, bee abundance (mean occurrence per count near = 8.669, far = 6.012; $P = 0.000$) and richness (mean occurrence per count near = 1.756, far = 1.481; $P = 0.048$) were significantly higher at sites nearer to restoration activities (Table 1). Honey bees were the most common visitors to *D. minthornii*, regardless of proximity to restoration activities, however honey bee numbers were significantly higher at near sites compared to far sites (mean occurrence

per count near = 6.681, far = 4.191; $P = 0.00$). Native bees showed a similar trend, with more visits recorded at sites nearer to restoration; however, these results were not significantly different (mean occurrence per count near = 1.988, far = 1.821; $P = 0.609$). The composition of common bee visitors did vary between near and far sites (Figure 4). *Megachile* spp. dominated at far sites and *Melissodes* spp. dominated at near sites. Bumble bees (*Bombus* spp.) were significantly more common at near sites compared to far sites (near = 0.253, far = 0.037; $P = 0.005$). Linear regression models for bee visitation rates and seed viability did not display any significant trends for individual bee groups or total bee abundance at the 95% confidence level.

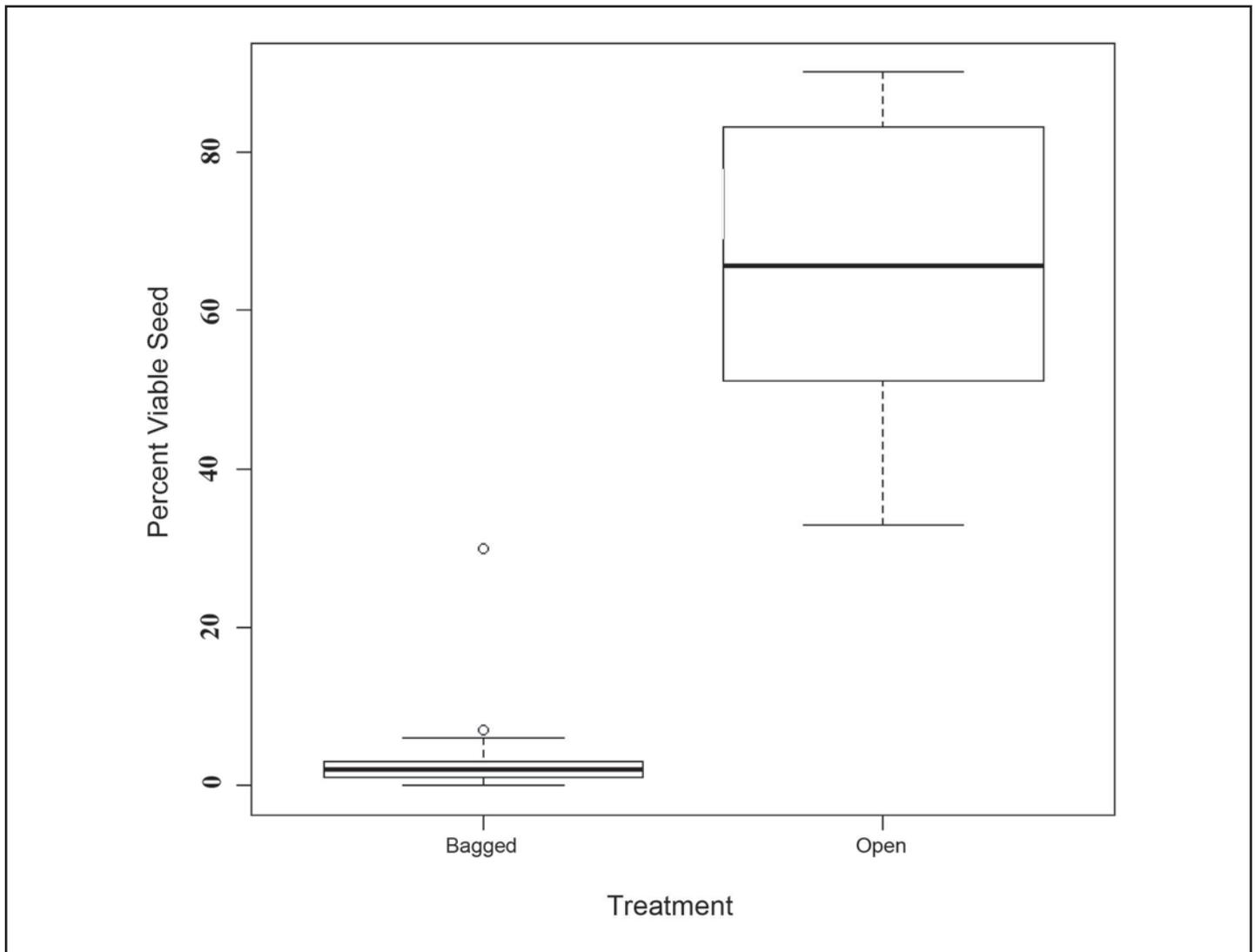


Figure 2. Mean seed viability in *Deinandra minthornii* open to pollination and excluded from pollinators (bagged) determined through TZ tests.

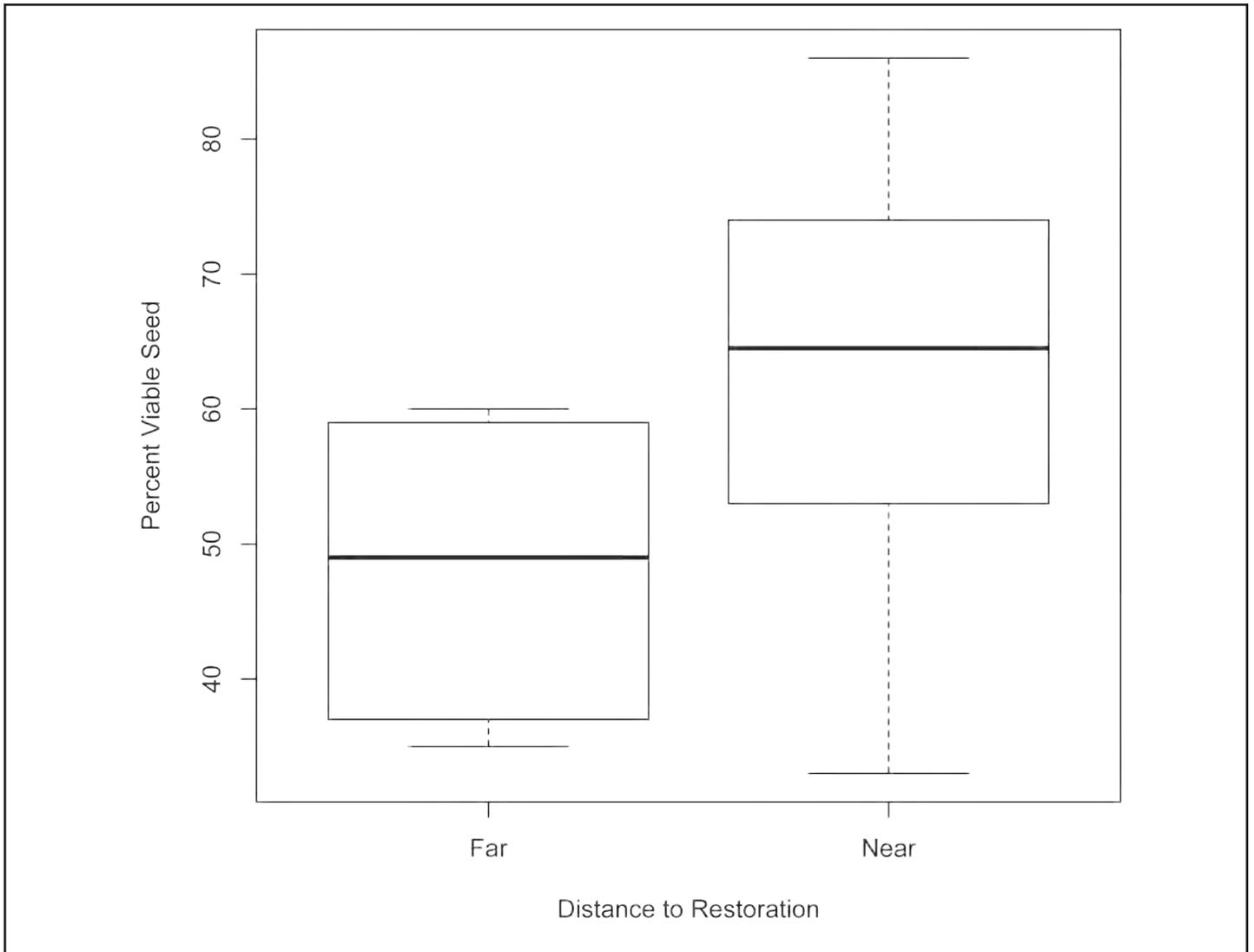


Figure 3. Difference in mean seed viability from *Deinandra minthornii* plants in populations near to and far from restoration activities. Although viability is 30% higher near to restoration activities, this difference is not statistically significant due to small sample size.

Seed viability was significantly positively correlated to visits by *Megachile* spp. at the 90% confidence level ($R^2 = 0.2677$; Adj. $R^2 = 0.1863$ $F = 3.29$; $DF = 1,9$; $P = 0.100$), meaning that *Megachile* spp. may be functional pollinators of *D. minthornii*.

DISCUSSION

Supporting Plant–Pollinator Relationships in Restoration

Deinandra minthornii exists in a sparse and resource-limited landscape where one reproductive strategy is to attract a wide range of pollinators. Populations of *D.*

minthornii nearer to restorations received more visits than those located farther from areas seeded with restoration mixes. Nearness to restoration showed a correlation to higher seed viability and it can be concluded that *D. minthornii* benefitted from being nearer to restored landscapes that were seeded with regionally appropriate native forb seed mixes.

Our assessment of reproduction in *D. minthornii* showed that this rare plant is dependent upon pollinators for reproduction and produces almost no viable seeds in their absence. This dependence on pollinators puts *D. minthornii* in the same category as the majority of temperate and

xeric plant species (Ollerton et al. 2011). Our observations indicated that, indeed, *D. minthornii* was visited by a mix of pollinators, but the dominant visitors, and likely the key pollinators of this species, are bees. The richness of native bees did not differ significantly between populations near and far from restoration; however, there was some variability in community composition. Some bee groups were only documented to visit *D. minthornii* near restoration sites, such as bumble bees. Although bumble bees may have been more common foragers on *D. minthornii* nearer to restoration activities, their occurrence may have been driven by overall landscape-level increases in resource avail-

Table 1. Mean pollinator visitation rates of individual bee groups, as well as mean bee community abundance and richness, to *Deinandra minthornii* at sites near to and far from restoration seeding activities. Bold numbers indicate significant differences (ttest; $P < 0.05$).

	<i>Apis mellifera</i>	<i>Andrena</i> spp.	<i>Anthidium</i> spp.	<i>Bombus vossenski</i>	<i>Cervina</i> spp.	<i>Agapstemon</i> spp.	<i>Halictus</i> spp.	<i>Lastiglossum</i> spp.	<i>Megachile</i> spp.	<i>Melissodes</i> spp.	<i>Osmia</i> spp.	Abundance	Abundance - Native	Richness	Richness - Native
far	4.191	0.000	0.321	0.037	0.154	0.049	0.389	0.043	0.401	0.340	0.086	6.012	1.821	1.481	0.790
near	6.681	0.006	0.181	0.253	0.060	0.139	0.313	0.060	0.452	0.470	0.054	8.669	1.988	1.765	1.000
<i>P</i> -value	0.000	0.319	0.196	0.005	0.148	0.071	0.532	0.611	0.696	0.273	0.466	0.000	0.609	0.048	0.107

ability. Being colonial foragers, they tend to track resource patterns in the landscape and have been documented to occur in higher numbers at denser floral resources (Heinrich 1979). Bumble bees may also have been visiting *D. minthornii* in higher numbers during its bloom period because it was one of a few resources offering pollen and nectar in the late summer. The same is likely true for feral honey bees foraging in the landscape, which, like bumble bees, have food requirements throughout the year and track resources over a larger landscape area (Rivera et al. 2015), or employ what is known as adaptive foraging (Valdovinos et al. 2010). Honey bees represented the largest proportion of visitors (more than 70% of bee visits both near and far from restorations were *Apis mellifera*), but are unlikely to be the functional pollinators of *D. minthornii*. Leaf cutter bees in the genus *Megachile* might be the most functional pollinators of *D. minthornii*, as our analysis of seed viability as a function of specific bee group visitation showed a trend of increased viability with increased visits from leaf cutters. Furthermore, leaf cutter bees may provide the correct mechanical transfer of pollen; this theory would need to be investigated further though an analysis of floral and pollinator morphometrics.

Landscape fragmentation is one of the greatest threats to pollinator services (Hadley and Betts 2011). Pollinators have the ability to move through a landscape, but their movement and presence is dictated by the spatial distribution of habitat (Steffan-Dewenter et al. 2002; Heard et al. 2007; Steffan-Dewenter and Westphal 2008) and their biological characteristics (Greenleaf et al. 2007). At the landscape level, this is represented by changes in species composition and general patterns of occurrence (Brosi et al. 2007; Jha and Vendermeer 2009). At the site-specific level, pollination services have been shown to be impacted in both wild (Potts et al. 2003; Brosi et al. 2007) and managed landscapes (Kremen et al. 2007; Winfree et al. 2007) when fragmentation and distance to habitat increase.

Habitat restoration activities that focus on pollinators need to consider the specific composition of local, native plants in

order to be successful. Providing a floral resource base that is not preferred or used by the local community of bees, in effect maintains fragmentation and dissociation in this portion of the ecosystem. While the area of habitat created may appear significant and physical distances may seem connected, the ecological connections necessary for functional ecosystems may not be there. Plant-pollinator systems are complex. Overlap and the use of multiple plant species by bees is the norm and has been determined in many recent studies through the development of pollination networks (Burkle et al. 2003), with single-species connections being much less common (Waser et al. 1996; Vazquez and Aizu 2003). Increases in plant community richness do not guarantee corresponding linear increases in support for local pollinator communities; plant-pollinator networks have been noted to be more commonly asymmetrical (Vazquez et al. 2007) and saturations of pollinator community richness can be achieved with fewer plants when modeled on high-level local interaction data. Some plant species serve as magnet species that attract a diversity of bees, while others are required to support unique and important members of the local pollinator community (Johnson and Steiner 2000; Wojcik et al. 2008). Developing and sourcing restoration seed mixes that include a higher percent of regionally appropriate forbs was shown in this case to support pollination services. This strategy, although more costly and reliant on specialized technical information, has significant biological benefits.

Practical Justification

Industrial land restoration efforts in the form of native plant seeding had a dramatic, positive impact on rare species reproduction. Seed viability tests showed increased average seed viability associated with proximity to restored landscapes. Increased seed viability, combined with data indicating trends of increased pollinator visitation nearer to restoration seedings, suggests that *D. minthornii* benefited from restoration activities.

With some planning and forethought, general restoration practices such as seeding

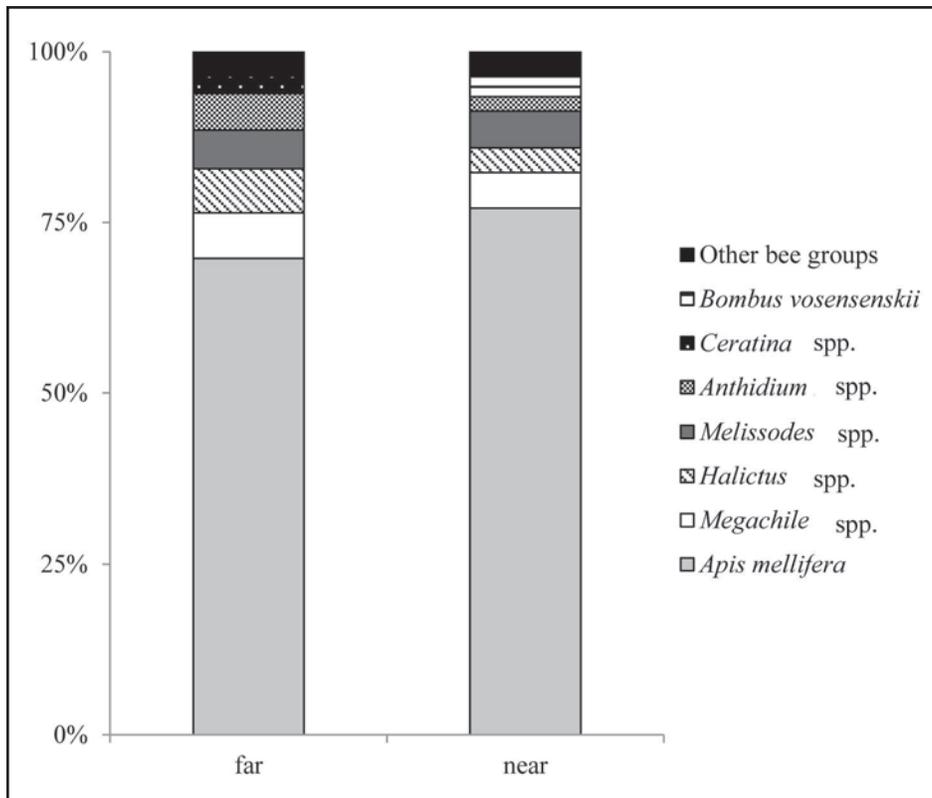


Figure 4. Composition of common bee visitors to *Deinandra minthornii* growing near to and far from restoration activities.

for soil stabilization can be modified to benefit pollinators. Plants are an essential functional component of any landscape, as they remove up to 50% of human CO₂ emissions, provide 80% of the world's population with their primary source of healthcare (Hawkins 2008), create erosion buffers, and filter nutrients from storm-water run-off (Roman et al. 2001; Brauman et al. 2007). A diverse set of plants that are not restricted to grasses, or species currently commonly commercially available, can provide these ecological services. In fact, many local native forbs couple pollinator benefits with these ecological services. In wild landscapes, plants structure ecosystems and provide diverse food to wildlife.

Developing seed mixes is an important first step to many restoration projects. In order to increase floral resources for pollinators, an assessment of existing seed mixes needs to be conducted. By including a high percent of forb species, there will be benefits to local plants and wildlife. While commercial availability is often limiting, it is important to incorporate as many native

plant species into the mix since high plant diversity can increase arthropod diversity (Siemann et al. 1998; Diaz et al. 2007), the abundance of wildlife, and reverse the decline in a number of bird populations (Davis et al. 2000). Additionally, ecosystem functionality cannot be maintained with a few carefully selected species (Hector et al. 2001). Using native species has been shown to help reduce exotic annual species (Cox and Anderson 2004), a particularly important consideration in any restoration project, but especially so when considering the fire regime of areas in drought. Plant diversity can help maintain the natural fire regime and improve wildlife habitat (Main and Richardson 2002), which is often limited in such regions. All of these factors are important to consider when developing a pollinator-friendly seed mix.

The enhancement of pollinator communities should be considered more heavily and more commonly when seed mix species selections are made for restoration activities. We have shown that you can increase pollinator occurrence by seeding

more forbs into targeted restoration areas. We recommend the modification to seed mixes to introduce more pollinator-attractive forbs to boost pollinator occurrence. Encouraging innovative stewardship action that can help outline successful novel approaches to restoration in natural landscapes is a positive strategy when working with restoration partners that have flexibility in their restoration plans and budget. Generating more data on enhanced pollinator communities through restoration seedings has the potential to shift common trends in the restoration industry.

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Appendix: TZ (tetrazolium chloride) test results from 2012 through to 2014 conducted on seeds taken from SSTP located near to and far from restoration activities. Bagged vs Open indicates if pollinators were allowed to freely visit bloom (b=pollinators excluded, o=open to pollination). Viable seeds are noted as a percentage of the total sample. A notation of nd indicates that no data were collected from that sample, either due to low sample size or damage in the field.

Site Number	Year	Viable Seed (%)	Location	Bagged vs Open
1	2012	7	near	b
2	2012	3	near	b
3	2012	1	near	b
4	2012	1	far	b
5	2012	nd	far	b
6	2012	2	far	b
1	2012	58	near	o
2	2012	74	near	o
3	2012	71	near	o
4	2012	60	far	o
5	2012	37	far	o
6	2012	59	far	o
1	2013	30	near	b
2	2013	1	near	b
3	2013	1	near	b
4	2013	0	far	b
5	2013	nd	far	b
6	2013	2	far	b
1	2013	33	near	o
2	2013	86	near	o
3	2013	53	near	o
4	2013	35	far	o
5	2013	nd	far	o
6	2013	49	far	o
1	2014	6	near	b
2	2014	3	near	b
3	2014	1	near	b
4	2014	1	far	b
5	2014	nd	far	b
6	2014	3	far	b
1	2014	90	near	o
2	2014	87	near	o
3	2014	80	near	o
4	2014	77	far	o
5	2014	nd	far	o
6	2014	86	far	o