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Assessment of Conservation Reserve Program Enhancements at Contract Renewal: Impact on Monarch Butterfly (*Danaus plexippus*) Habitat

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Assessment of Conservation Reserve Program Enhancements at Contract Renewal:

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A Thesis Submitted in Partial Fulfillment

of the Requirements for the Degree of Master of Science

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Abstract

The monarch butterfly *(Danaus plexippus)* is a migratory species whose primary breeding range is the upper Midwestern United States. In 2022, the International Union for the Conservation of Nature listed the monarch as endangered due to milkweed and migratory habitat loss. One of the most promising opportunities for monarch recovery is to enhance habitat quality on private land currently enrolled in the USDA Conservation Reserve Program (CRP). In order to qualify for re-enrollment in the program and continuation of annual government payments, farmers must show adequate habitat quality or enhance their site by overseeding after burning, herbicide application, or tillage. I asked whether this process, as currently implemented, would succeed in improving monarch habitat. In summer of 2021, I assessed vegetation on seventeen farms in eastern Iowa using Daubenmire cover classes and counted milkweed stem density utilizing random transects. Six sites on four farms were required to enhance their vegetation to re-enroll; surprisingly, end-of-contract habitat quality was not closely related to the requirement to enhance. Enhanced areas at sites averaged just 17% of the area original sites. I observed a significant decrease in warm-season grasses and vegetative cover. The relative cover of forbs and non-native grasses, as well as milkweed stem density, were not affected, while warm-season grass relative cover on average decreased 31.12%. Early germinating wildflower species that were provided to farmers for overseeding were established on all sites, demonstrating that enhancement disturbances did open the plant community for new plant establishment. More time is needed to assess whether habitat value for monarchs improved, but preliminary evidence was mixed. By surveying 2-3 years after the enhancement, we may obtain a more

accurate picture of the outcome of the enhancements at each site. The study of private lands conservation programs has inherent limitations but is necessary for monarch butterfly conservation.

This Study by: Tristan L. Murphy

Entitled: Observing Expiring Conservation Reserve Program Field Enhancement Methods for Monarch Habitat Improvement

has been approved as meeting the thesis requirements for the

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Chapter 1: Introduction

Danaus plexippus Background and Migration

Danaus plexippus plexippus, commonly known as the monarch butterfly, is a migratory species of butterfly native to North America. There are two distinct monarch populations, an Eastern population found east of the Rocky Mountains and a Western population found west of the Rocky Mountains. Each year around March, the Eastern monarch butterfly population undertakes a nearly 3,500 km long migration from their overwintering sites in oyamel fir (*Albies reliogiosa)* forests near Mexico City to Canada (Momeni-Deaghi et al. 2021). As the butterflies migrate north towards the northern United States and southern Canada, it is estimated that the journey north takes place over three - four generations (Pyle, 2000). Their southbound migration is completed over several weeks by one generation.

As a migratory species, the monarch butterfly requires floral resources and the presence of milkweed (*Asclepias* spp.), their obligate larval host plant, along their journey. Monarch larvae feed on the leaves of the *Asclepias* where they were oviposited and ingest cardenolides present in the tissue of milkweed. The cardenolides are sequestered within the tissues of the monarch caterpillars and serve as a deterrent to predators (Brower et al. 1967). The presence of milkweed is so important to the monarch butterfly that the presence of *Asclepias* species determines their breeding distribution (Urquhart, 1960*)*. Without the presence of milkweed stems and appropriate habitats, monarch butterflies cannot breed and therefore the next generation of butterflies will not be able to continue the multi-generational migration. The eastern monarch migratory path encompasses a large swath of the Midwestern United States and as such, the monarchs rely heavily on appropriate habitats and milkweed resources in this region.

Monarch Butterfly and Milkweed Population Reductions

Historically, the overwintering sites in the Mexican fir forests contained many hectares of overwintering butterflies, peaking at nearly 21 ha in 1996 (Brower et al., 2011). The eastern monarch population is measured by estimating the area occupied by overwintering colonies in the oyamel fir forests during late winter (Rendón-Salinas et al. 2017). By 2011, this number had dropped to 4 ha which represents a nearly 80% decrease in the total area of overwintering colonies (Brower et al., 2011). Another study estimated that between 1997 and 2015, the monarch butterfly population decreased by 84% (Thogmartin et al. 2017). Due to this population loss, the monarch butterfly was predicted to be quasi-extinct with 11-57% certainty by 2036 (Semmens et al. 2016). Quasi-extinction refers to when an organism's population is so low that population increase is virtually impossible. Ecotourism, logging, and other variables at overwintering habitats have been identified as causes for some of the population decline. In addition to variables at overwintering sites, habitat loss in the Midwestern US migratory range has been identified as a main factor in part due to the large-scale agricultural activities in this geographic area (Brower et al. 2011).

Large scale herbicide usage in agriculture has contributed to the decline of milkweed resources, especially after 1996 with the introduction of herbicide tolerant crop varieties (Pleasants 2016). These varieties enabled the use of a broad-spectrum herbicide, glyphosate, for general weed control in row crops. Pleasants and Oberhauser (2012) estimate that from 1999 to 2010, there was a 58% population reduction of common milkweed stems in the midwestern United States. Ninety-eight percent of the loss has been in corn and soybean fields (Pleasants 2016). Pleasants (2016) estimated that the 58% milkweed population loss since 1999 equates to more than 850 million milkweed stems. A survey by the USGS in 2017 estimated that just 1.34 billion milkweed stems remain in the United States (United States Geological Survey 2017). The loss of 850 million milkweed stems is a significant population reduction, which must be regained partially or in full to sustain a healthy eastern migratory monarch population.

Monarch Conservation Efforts

As monarch overwintering populations have continued to decline, there has been increasing scientific interest in boosting milkweed populations, especially in the Midwest. In June 2014, a presidential memorandum created the White House Pollinator Health Task force (White House Pollinator Taskforce 2015). The goals of this task force were, in part, to increase monarch butterfly numbers to protect the annual migration; and to restore or enhance millions of acres of land for pollinators through combined public and private action.

The Task Force established a conservation goal of achieving an average of 6 hectares of overwintering colonies per year, which translates to approximately 225 million butterflies, by 2020. Oberhauser (2022) estimates 21 million monarchs are found in one hectare of overwintering habitat. Pleasants (2016) estimated that 425 million additional milkweeds were needed to support a healthy monarch butterfly population and 1.6 billion stems would be needed to reach the 6 ha overwintering population goal. Similarly, Thogmartin et al. (2017) estimated that between 1.3 billion and 1.6 billion stems would be needed to meet the 6 ha goal. Unfortunately, the size of overwintering colonies did not meet the 2020 goal of 6 hectares. In a Winter 2022 survey, only 2.21 ha of overwintering butterflies were recorded by the World Wildlife Foundation (Rendón-Salinas et al. 2023). There appears to be no peer reviewed literature estimating the number of new milkweed stems that have been added by conservation efforts since these targets were set.

Due to the scarcity of public land for addressing the breeding habitat needs of the monarch butterfly, the White House Task Force and other groups have focused on private lands conservation programs such as the Conservation Reserve Program (CRP). The Farm Bill of 1985 created the modern Conservation Reserve Program. Today, CRP is a common practice throughout the midwestern United States. In 2020, the CRP had 8,862,615.57 million hectares enrolled (Farm Service Agency 2020). Landowners that enter a contract to convert agricultural land to native grasslands or wetlands work closely with the USDA Farm Service Agency (FSA) and the USDA National Resources Conservation Service (NRCS) which provides guidance and cost-share assistance on planting and maintaining these converted fields. In exchange, the landowner is provided with a yearly payment. Landowners may enroll in practices such as CP42, which is designed for pollinator habitats, or CP25, which is commonly used for the restoration of prairies (USDA n.d.). All changes made to CRP contract sites must be in line with the initial conservation goal laid out at the start of the contract or the landowner may face the risk of contract termination (Conservation Reserve Program 2009). By having to conform to the existing contract, it is difficult to drastically change site quality for conservation purposes. This inability to change practices means that increasing habitat quality for monarch butterflies can only be done at contract reenrollment if farmers want to obtain cost share assistance. In order to qualify for re-enrollment in the program and continuation of annual government payments, farmers must show that their field maintains adequate habitat quality, or they must enhance their site by disturbing the existing cover and overseeding with an appropriate seed mix. Overseeding is the act of planting seeds into an existing community. A variety of disturbances are allowed, including burning, herbicide, and soil disturbance such as disking.

CP-25 is one of the most common types of CRP practice, with 951,769 acres (385,167 ha) enrolled across the US (44,327 hectares in Iowa) and, along with CP-42, has much higher vegetative quality standards than other practices (Farm Service Agency 2020). This large amount of land enrolled in the CRP CP-25 program may provide an excellent opportunity to restore milkweed stems and increase floral resources on private land. The land currently devoted to row crops is highly unlikely to become an appropriate habitat for monarch butterflies in the future, and likewise industrial areas will not revert to appropriate habitats. Although planting milkweed is growing in popularity, the potential for new habitat creation on public land and within urban areas is estimated to be very limited (Thogmartin et al. 2017). Therefore, the best opportunity for creating new habitat will come from willing landowning participants, through programs like the CRP's CP-25 and CP-42 practices. Because renewal or mid-contract management are the only times to increase habitat quality under these contracts, we wanted to understand the effects that these renewal methods have on the availability of resources for monarch butterflies and whether or not they can increase milkweed resources.

CRP Conservation Practices for Contract Renewal

After landowners decide they would like to re-enroll their contract, they must submit a bid outlining their desired financial compensation and plans to improve quality (USDA 2013). The USDA will then renew the contracts that have the highest environmental benefit to dollar spent ratio. In order to maintain the quality of existing CRP plantings at mid-contract or contract renewal, a local NRCS office may inspect the property and assess whether the original goals of the contract are being met using a vegetative survey (USDA 2013). Depending on the outcome of that inspection and the vegetation present, they may renew the contract as is, or require landowners to "enhance" it, namely they must introduce a significant disturbance, change the structure of the vegetative community, and overseed with additional plant species to have a more successful bid for re-enrollment (USDA 2013). Commonly allowed practices to "enhance" the site include prescribed burning, herbicide application, and tillage (USDA 2013). Practices are not standardized and vary by state. NRCS County offices may all interpret vegetation quality and allowable these practices differently. I was unable to locate a published protocol for inspection or a rationale for making enhancement decisions. Based on conversations with landowners and NRCS technical staff in eastern Iowa, we believe that they may conduct a windshield survey (i.e. view from a public road), or at most a rapid assessment (wandering survey). A designated enhancement practice and seed mix must be approved by each landowner's respective NRCS office, and the choice is probably related to the individual landowner's capacity to carry out a given practice.

After these enhancements are applied, farmers will apply an overseed mix. While NRCS guidance allows enhancement practices, they do not explicitly state reasoning and seem to infer that by disturbing the vegetative community and removing weeds that seed mixes will have greater success in establishing (USDA 2013). As renewal is the only time that habitat quality can be enhanced, it is crucial to understand the effects that enhancements have on vegetative communities and monarch butterfly resources. By observing sites that undergo these changes, we can gather data on how to best utilize the areas that we have for monarch conservation efforts. The effectiveness of these methods for improving renewing CRP contracts has not been researched and our study aims to fill these gaps in knowledge.

Research Objectives and Hypotheses

The purpose of this study is to examine and compare non-native grass, warm-season grass, forb coverage, and milkweed density before and after the application of enhancement practices in 10-15 year old expiring and renewed CP-25 fields. To accomplish this, surveyed vegetation in 10-15 year old expiring CP-25 fields, before and in the year after enhancement. We focused on three broad categories of vegetation in addition to milkweed stems: warm season grasses, non-native cool season grasses, and all nectar bearing forbs. These variables are easily identifiable characteristics that we suspect land managers are utilizing in management decisions, and they represent most of the plant community (85.9% of cover for all sites surveyed in 2021). Warm season and non-native grass composition are likely to influence the success of overseeding. And milkweed stem density and nectar bearing forb availability are important characteristics for monarch butterfly conservation. Examination of these variables will provide important information to scientists and policy makers about the current monarch habitat afforded by 10 to 15-year old CP-25 contracts and how that quality may change after implementation of contract management methods. I will also examine the consistency of enhancement recommendations by comparing site vegetation between renewed and non-renewed sites visited in 2021. Understanding what drives the decision for enhancement and whether that has the potential for positive or negative ecological effects on monarch butterflies is crucial. These findings may be used to inform NRCS management decisions and further scientific research.

Chapter 2: Materials and Methods

Site Selection and CRP Enhancement Processes

Site location, spatial data, and landowner contact information for 1,268 expiring CRP CP-25 contracts in Iowa were provided by the United States Department of Agriculture Farm Service Agency. I selected sites based on existing CRP contracts that were 1-3 years from expiration with plans to renew and contacted potential landowners to see if they would agree to participate in our study. Contracts were ranked based on being within driving distance of the University of Northern Iowa (120 km), time of expiration, and on willingness to participate. From this list of sites, 17 sites were selected. The decision for enhancement is made at the local county NRCS office in collaboration with the landowner. We had no access to information regarding how sites were inspected or evaluated, how new contracts were created, how or why enhancements were chosen, the size of the enhanced area, or how seed mixes were chosen for overseeding.

Of the original 17 sites, only four sites were chosen to be enhanced by the NRCS and landowners at renewal (Table 1). The four 2021 sites were split into six separate CP-25 contracts in 2022 that ranged from 1.54% to 89.2% of the original site sampled in 2021 (Tables 1-2). The reasoning for the site size reduction is unclear. Figures 2-5 show the spatial layout of the enhanced sites. The enhancement methods for each site are shown on Table 1. The chosen overseed mixes were applied after enhancement, but the timing is unknown. Landowners were provided with a "bump-up" seed mix containing five species (*Chamaecrista fasciculata, Dalea purpurea, Monarda fistulosa, Desmodium canadense, Heliopsis helianthoides*) to be planted in addition to the seed mix they selected to overseed their sites at enhancement. A "bump-up" seed mix is additional seed that restoration practitioners add to the primary seed mix to further customize the seed mix to match site conditions or increase the provisioning of ecosystem services. In our case, we chose “sentinel” species that could be easily detected due to their early, reliable germination and distinctive seedling characteristics. Seed amounts provided varied as some seed mixes contained these species already and needed more or less than others to meet our established seeding rates. Final seeding rates in PLS seeds m^{-2} were as follows: *Dalea purpurea,* 53.8, *Desmodium canadense,* 2.1, *Chamaecrista fasciculat,* 10.8, *Heliopsis helianthoides* ,5.4, and *Monarda fasiculata,* 43.0.

Enhancement practices create disturbance to promote establishment of an overseed mix chosen by the landowner and local NRCS office. Creating disturbance in the soil and removing vegetative competition allows seeds to have access to sunlight, water, and other nutrients. The landowner has several options for enhancement practices, and wide latitude in how they are accomplished in terms of timing and intensity. General practices are burning, tillage and herbicide application. Burning is a common practice employed in CRP contracts. Burning removes litter, suppresses shrubs and other woody vegetation, and promotes the growth of established plants. Fire in grasslands can also maintain or increase biodiversity while limiting the intrusion of woody species of trees (Veldman et al. 2015). Limiting tree invasion while also promoting biodiversity is an important function in managing CRP contracts. Tree invasion can lead to habitat loss and degradation. In CRP fields, burning is either conducted in the warm or cool season, depending on the desired outcome for the vegetative community. Burning in the spring targets cool-season plants and burning in the summer targets warm-season plants. Fire disturbances have been shown to provide potential to provide corridors and habitat for migrating monarchs when plant availability is limited (Baum et al. 2012). Burning also removes much of the plant litter from the existing vegetation and allows better light penetration for seedling establishment.

Disking is the process of disturbing soil using a disk. Disking disrupts root systems of plants, which can lead to more effective establishment of seed mixes. Unfortunately, this process can also easily lead to the establishment of non-native grasses such as *B. inermis*. As most farmers have access to a disc implement, this is a very common method for site enhancement.

Herbicide application is also a common method to change vegetation structure. Herbicide application "increases wildlife habitat value by suppressing grasses, inhibiting woody plant growth, reducing the accumulation of plant residue, and increasing sunlight penetration to the ground" (CRP Required Management Practices n.d.). Herbicide application is also commonly used as a method to prepare sites for contract renewal, as it kills almost everything at a site which gives a good opportunity to vastly alter the vegetation.

Vegetation sampling

Random points were created within the site shapefiles utilizing ArcPro and served as starting points for transects. These randomly generated points were uploaded to Garmin GPS units for location in the field. Each point was applied a random bearing between 0 and 359 and every other point was assigned the opposite bearing. Vegetative composition was measured in 100 1-m^2 quadrats (0.5 m × 2 m) using parallel transects. Quadrats were placed every 5 m of the transect starting at the randomly generated point. The length of the transects varied based on how far I could measure at each site without hitting the edge, but none exceeded 100 m in length. The total length of transects for each site was 500 m. Quadrats and transects were not reused again the following sample season. For sites undergoing enhancement, this process was repeated to generate a new random sample in 2022.

Field assistants underwent a rigorous three-week training in plant identification, which allowed us to identify plants to species level using vegetative characteristics. All plants over 10 cm in height were identified to species level except in cases where the identification was not possible in the field. Every 10 m along the transect using the tape measure as a guide, the percent cover of all plants presents in the 0.5 m^2 quadrat was recorded using the Daubenmire cover class system (Figures 6-7) (Daubenmire 1959). In 2021 bare ground and litter were not included in the cover classes but they were measured in 2022. In these cases where identification was not possible, I collected samples in a plant press and identified them later in the lab. Milkweed stems were identified to species and counted if present every 5 m in a 1 m^2 quadrat. These methods were repeated for sites surveyed in summer 2022. Sampling occurred in June and July of the respective year.

To evaluate the establishment of our bump-up seed mix, we counted the seedlings of the six species utilizing a 0.125 m^2 quadrat and the same transect method as 2021 and 2022. For each site, 50 quadrats were sampled. The sampling was completed in July 2022.

Data Organization and Analysis

Data Organization

Species-level data were grouped into four groups of interest: warm-season grasses, non-native grasses, nectar bearing forbs, and milkweed stems. These groups are easily identifiable and surveyable characteristics that land managers can utilize in management decisions. NRCS officials likely do not conduct as rigorous or detailed of vegetation surveys due to the sheer numbers of fields they must evaluate. Although we had identified all plants to species level, I chose to organize my data in a way that surveyors could utilize in the future and still have accurate measurements of functional groups within contracts. These groups of interest represent most of the plant community (85.9% of relative cover for all sites surveyed).

Warm-season grass species included A*ndropogon gerardii*, *Schizachyrium scoparium, Sorghastrum nutans, Bouteloua curtipendula, Panicum virgatum, Spartina pectinata,* and *Sporobolus compositus.* I selected the species listed previously as they are commonly occurring warm-season grasses within CRP fields and prairie remnants. Warm-season grasses are generally a significant portion in tallgrass ecosystems and understanding how this part of the vegetative community may change after enhancement is important for improving monarch resources.

Non-native grass species included *Bromus inermis, Elymus repens, Dactylis glomerata*, *Bromus tectorum, Bromus japonicus*, and *Phalaris arundinacea.* These species are commonly occurring non-native grasses in eastern Iowa. Some of these species are highly aggressive and can gradually exclude other species. As such, *Poa pratensis* is not included in this group.

Forb cover was characterized as all nectar bearing forbs, as they provide pollinator resources. Commonly observed forbs in our survey included *Solidago canadensis, Helianthus maximus, Heliopsis helianthoides, Monarda fistulosa,* and *Chamaecrista fasciculata*. I chose to include all species summed together in one variable because I was interested in general availability of nectar resources for the monarch.

Milkweed stem counts include all *Asclepias* species observed in the field (*Asclepias syrriaca, Asclepias incarnata, Asclepias tuberosa, and Asclepias verticillata*). *Asclepias* species stems were summed together as they all represent host plants that monarchs may utilize in their northward migration.

In order to examine change within the vegetative community, relative cover was utilized. Relative cover measures the cover of a species, or in this case a group of species, to other species within an area. By examining vegetation in relation to other vegetation, it is possible to examine how the vegetation changes in relation to each other after enhancements are applied. Relative cover allows a more direct comparison to be made without variation in absolute cover affecting the comparison. To determine relative cover, cover class midpoints were calculated for each quadrat at the species level. After the cover midpoints for quadrats were calculated by species, I then grouped the species included into the vegetation groups of interest together within each quadrat. Quadrat midpoint covers of the vegetation groups of interest were then averaged for each site to determine site coverage for the groups of interest and then scaled to 100%. Standard error for each group at each site was also calculated. After the raw data was grouped, relative cover was calculated by utilizing cover class midpoints of the raw data to estimate total quadrat and individual species cover at each site and then scaled to 100%. Q-Q plots were created to determine the normality of the areas of interest for each site. Box-Cox transformations were utilized for each area of interest's site averages to normalize data.

Absolute cover was utilized to examine how enhancements reduced vegetation and created bare ground. The method to determine relative cover was repeated without scaling to 100%. I did not group species into vegetation categories; all plants were considered to be vegetation.

Data Analysis

I compared the vegetation characteristics of sites that were required to enhance vegetation with those that were not using a Welch's t-test to accommodate unequal sample size and variances. I used the average relative cover site value for each vegetation group after the Box-Cox transformation was utilized to determine the best data transformation to achieve normality.

To examine the effect that enhancements had on vegetation, the average relative cover for each vegetation group in 2021 was subtracted from the 2022 value to find the change in relative cover. All enhancement types and their changes were included together in this one-sample t-test. The mean of six change values for each vegetation group was used to test the null hypothesis of no change in relative cover of the existing vegetation groups due to enhancement.

To determine the loss of total vegetation at each site, I subtracted the 2022 absolute cover value from the 2021 absolute cover value. Because bare ground was not measured in the 2021 sampling, no formal statistical analysis was possible. However, extensive observations during vegetation sampling suggest that bare ground was in the 0-5% cover class for the vast majority of quadrats at each site in 2021.

The reenrolled area at each site was a small proportion of the original area sampled in 2021, (Table 2) and we could not know in advance where enhancements would take place. Thus, direct comparison of 2021 and 2022 vegetation was problematic. Four sites had no quadrats sampled in the 2022 enhancement areas. Of 850 total quadrats in 2021, only sixty quadrats fell in the 2022 enhancement. However, since the placement of 2021 sampling transects was random, and standard deviations and coefficients of variation for relative cover classes were low (Tables 3-6), I made the assumption of site uniformity and proceeded to compare vegetation before and after enhancement.

To calculate seedling establishment by species of each site, I divided the observed number of seedlings by the number of seeds planted per m^2 in each quadrat and calculated a mean and standard error (N=100, 0.125m^2 quadrats at each site).

Chapter 3: Results

Vegetative Survey of Expired CP-25 Contracts

At the end of a ten to fifteen year contract, the 17 CRP sites averaged 41% relative cover for forbs (Table 4), 23% warm-season grass relative cover (Table 5), and 21% non-native grass relative cover (Table 6). Average milkweed stem density was 0.218 stems m^{-2} (Table 3).

There was substantial variation among sites for all vegetative characteristics. Relative forb covers ranged from 20% to 69.7% (Table 4); warm-season grass relative cover from 0.05% to 71% (Table 5); non-native grass cover from undetectable to 62% (Table 6). Milkweed stem density ranged from 0.006 stems m^{-2} to 0.830 stems m^{-2}.

Consistency of CRP Enhancement Recommendations

Prior to carrying out the study, I assumed that the decision to require enhancement would be related to some major deficiency in vegetation quality, such as a lack of nectar-bearing forbs or very high cover of non-native grasses. However, two of the three vegetation categories associated with high vegetation quality showed no significant difference. Average warm-season grass cover and forb cover did not differ between enhanced and unenhanced sites (Tables 4 and 5; $p = 0.298$ and 0.896, respectively). Also counter to expectations, non-native grass cover was *lower* at enhanced sites (Table 6; $p=0.00022$). In keeping with my expectations, the average milkweed stem density was 32% higher at non-enhanced sites than enhanced sites (Table 3; $p=0.043$).

Of the four sites that required enhancement, three applied enhancement treatments and overseeding to less than 6% of their original area (Table 2; Figures 2-5). Only one landowner overseeded the majority (89%) of their site.

Vegetative Survey of Newly Enhanced, First-year CP-25 Fields

After the sites were enhanced by landowners in 2022, vegetative characteristics varied from site to site. All six sites averaged 24.5% relative forb cover (range 2.30% - 48.2%; Table 7); 12.5% warm-season grass relative cover (range 0.11% to 33.6%, Table 8); and 3% non-native grass relative cover (range 0% to 8.39%, Table 8). Average milkweed stem density for all six sites was 0.100 stems m^{-2} (range 0 to 0.34 stems m^{-2}, Table 7). The sites with the lowest relative forb coverage (Site 4 & Site 5) had herbicide applied, while the two highest sites (Site 1 & Site 2) were enhanced with spring burning. The highest relative cover for non-native grasses was observed at Site 1 which was enhanced with a spring burn, while the lowest site (0% cover observed) underwent fall and spring herbicide application.

Site Changes from 2021 to 2022

In 2022 after enhancement treatments I observed large and consistent reductions in absolute cover of vegetation within the area that was enhanced ($p<0.01$; Table 9). Bare ground, which is normally less than 5% in eastern Iowa CRP fields on typical soils (personal observations) but was not measured in 2021, averaged 67% in 2022 at the newly enhanced sites. Changes in relative cover of forbs and non-native grasses groups were insignificant. Milkweed stem density did not change after enhancement. Only the relative cover of warm-season grasses was significantly reduced by an average of 31% (Table 9).

Seedling Establishment

Figure 8 shows the establishment rate of the five sentinel species provided to each landowner. In mid-summer 2022, most of the sentinel wildflower species were established on all sites. Early establishment rates (seedlings per seed planted x 100) varied from 0.01-30%, however *Heliopsis helianthoides* was only observed at one site and in small numbers.

Chapter 4: Discussion

Quality of CRP for Monarch Habitat at End-of-Contract

The potential for CRP to contribute to monarch recovery depends on how good the habitat quality is already. If there is substantial room for improvement, then end-of-contract enhancement processes could play a major role in boosting the availability of milkweed stems and nectar plants. The quality of CRP fields for monarch breeding and migration at the end of their ten- or fifteen-year contract was higher than expected. The average relative forb cover for all sites in 2021 was 41%, which was the highest percent cover of any vegetation group measured. The abundance of forbs in end-of-contract CRP fields may provide excellent nectar resources for monarch butterflies on their migration.

The ten to fifteen-year-old sites had only 23.35% warm-season grass cover (Table 5), which was lower than I had expected. However, CRP sites commonly undergo mid-contract management which could have reduced the cover of warm-season grasses.

I expected to see high relative covers of non-native grasses at the end of contracts due to the aggressive nature of these grasses. *Bromus inermis* and *Phalaris arundinacea* are highly invasive and difficult to remove once established, often being more competitive than native grasses (Palit et al. 2022). If left unchecked, these grasses are capable of completely overtaking tallgrass prairie communities. In our 2021 survey, average coverage of non-native grasses was 21.59%.

Milkweed availability varied from site to site, with some sites having no milkweed and some sites having high stem densities. Our seventeen sites averaged 0.218 milkweed stems m^{-2}. I was surprised to find milkweed density to be this high as *Asclepias* spp were generally not included in CP25 seed mixes prior to the increase in public awareness of monarch decline (L. Jackson personal communication). Kaul and Wilsey (2019) observed a density of 212 stems/ha in conservation plantings and 1,274 stems/ha in roadside plantings, while our study estimated 2,180 stems/ha in CP-25 conservation plantings. Lukens et al (2020) observed a mean density of 1,390 milkweed stems per hectare in conservation grasslands. The Iowa Monarch Conservation Consortium included CP contracts as agricultural areas and in a report from 2022, they estimated there are an estimated 9,444,591 milkweed stems in 302,216 acres of agricultural habitat including both conservation grasslands and row crop fields. This is a density of only 77.22 stems/ha (Iowa Monarch Conservation Consortium 2022). Such differing estimates may mean that milkweed stem density in conservation grasslands is highly variable from site to site, and we do not yet have an accurate estimate of milkweed availability. Alternatively, the present study's high sampling intensity may reveal much more milkweed than previously estimated. If the latter is true, then more rigorous, and time-consuming milkweed surveys are warranted to accurately assess milkweed resources and develop appropriate conservation targets.

Enhancement of Expiring CRP at Reenrollment

The impact of enhancing existing CRP fields for greater monarch habitat value will depend on several processes. First, only fields that are truly of low habitat quality at the end of contract should be selected for enhancement. If only a portion of the field is going to be enhanced, it should be an area of particularly low habitat quality. Second, the enhancement practice chosen by the landowner must successfully shift existing vegetation to more bare ground and to vegetation that is not very competitive which may allow for better establishment of overseeded species while also minimizing forb and milkweed loss.

In order to utilize the CRP to its maximum potential to increase monarch habitat, the lowest quality of the initial 17 sites would have been chosen for enhancement. Evidence for this was mixed. Milkweed stems were statistically higher at unenhanced sites (Table 3) which is beneficial for monarch restoration, but the quality of other vegetative characteristics at the unenhanced sites was either the same or worse than the enhanced sites. The sites that were required to enhance had higher average warm-season grass covers (36.5%) than the sites that were not required to enhance (19.3%) (Table 5). The average non-native grass cover was significantly lower at sites that required enhancement (7.04%) compared to those that were not selected to be enhanced (26.1%). High levels of non-native grasses can lead to a decrease of vegetative diversity over time and eventually result in the site being overtaken by these species. Disturbing a site with a well-established non-native seedbank and bud bank may also degrade habitat quality. Non-native grasses outcompeting nectar-bearing forbs and milkweed is also a concern. Some unenhanced sites had lower milkweed density and higher non-native grass covers than the enhanced sites did.

Based on the trends for enhancement that we observed, these sites which had lower milkweed and non-native grass covers should have been enhanced as well, but were not. This suggests that there is either no standard vegetative characteristic examined by NRCS offices, or that standards vary from office to office. A lack of enhancement consistency for a program as large as the CRP is detrimental to conservation efforts not only for the monarch butterfly, but also to other endangered species. If low monarch habitat quality sites are not being enhanced while high quality sites are, as the present study observed (Tables 3-6), monarch habitat and resources will not be increased to the extent of conservation goals.

Assuming that the correct sites are chosen, the enhancement methods must remove competing vegetation and leave desirable vegetation like milkweeds and forbs as well as provide an opportunity for seed mixes to establish. The enhancements I observed resulted in significant decreases of total vegetative cover and warm season-grasses. Bare ground increased from an informally observed 0-5% before enhancement, to an average of 69.77%. Warm season grass decreased an average of 32%, and total vegetation decreased an average of 32.04% after enhancement (Table 9). These changes may promote successful establishment of overseeded species by removing competition. While an increase in milkweed density and forb cover would be ideal, observing no significant change in their relative abundance is still a positive outcome as this means these beneficial habitat elements were not diminished relative to grass cover (Table 9). All species included in the bump-up mix that we provided landowners established on at least one site. Seedling establishment ranged from 0.01-30%, demonstrating that these enhancement methods created sufficient disturbance to facilitate new recruitment of nectar-bearing forbs. This may lead to higher quality habitat for monarch butterflies in future years.

While these results are somewhat promising, it is important to note that they applied to only a small (<6%) proportion of their entire field at three of the four farms sampled (Figure 2-5). The areas chosen for enhancement were all close (<100 m) to a road or dwelling; there is no record of whether the area was of particularly low vegetation quality.

Study Limitations

Because my study was observational and had no replication for individual enhancement methods, it is not possible to make claims about the effectiveness of any of the enhancement methods. Each site had different enhancements applied by different people using different equipment on different days. Herbicide application may have differed in mixture composition, strength or application rate, explaining the inconsistencies of that application on reducing cover. The timing of sampling may have also affected the results as seedlings may not have sprouted at this time. Plant establishment takes time, so sampling directly after enhancements are made may not show the true vegetative characteristics of a site as all seedlings may not be established or annual plants are overly representative. By surveying 2-3 years after the enhancement, we may obtain a more accurate picture of the outcome of the enhancements at each site.

Because I did not have access to the landowners' plans for enhancement, I sampled the entire site in 2021. In most cases the enhanced areas were a small portion of the original site, and by chance were not well represented in the pre-enhancement survey. Given the process of making determinations of enhancement and signing contracts at the NRCS county office level, it may not be possible to obtain that crucial information ahead of time in an on-farm setting. To avoid these problems, it would be necessary to establish a replicated, randomized experiment in a dedicated research environment, in which we can control the location of sampling areas before and after and test the value of different enhancement practices. The study of private lands conservation programs has inherent limitations and constraints but is necessary for monarch butterfly conservation.

Tables and Figures

Table 1. Site number conversion for 2021 sites to 2022 sites

Site 2021 Number	*Site 2022 Number*	*Site Enhancement*
1	1	Spring Burn
2	2a	Spring Burn
2	2b	Fall and Spring Tillage
3	3	Fall and Spring Herbicide
4	4a	Fall Herbicide, Fall Tillage
4	4b	Fall and Spring Herbicide, Fall Tillage

Table 2. Sites surveyed in 2021 and 2022 (n=21) showing Iowa county, plant date, site size in hectares for 2021 and 2022, and Conservation Practice (CP) enrolled for 2022. All sites are CP-25

Site	*County*	*2021 Size (ha)*	*Year planted*	*2022 Size (ha)*	*Proportion of Original Site*
1	Bremer	14.7	2016	0.817	5.55%
2a 2b	Winneshiek	38.9	2007	0.600 0.637	1.54% 1.63%
3	Fayette	2.69	2006	2.4	89.2%
4a 4b	Floyd	12.5	2007	0.310 0.300	2.48% 2.40%
5	Winneshiek	4.26	No Data		
6	Hardin	2.27	2011		
7	Winneshiek	0.94	2011		
8	Fayette	0.85	No Data		
9	Fayette	5.76	2011		
10	Butler	8.86	No Data		
11	Poweshiek	12.8	2001		
12	Iowa	35.1	2007		
13	Iowa	17.5	2007		
14	Iowa	27.2	2007		
15	Iowa	19.7	2007		
16	Iowa	29.7	2006		
17	Floyd	21.6	No Data		

Table 3. Mean (SE) milkweed (*Asclepias* species) stem density prior to enhancement, at four sites that required enhancements to reenroll, vs. thirteen sites that did not require enhancement to reenroll. For each site, n=100 0.5m^2 quadrats. Welch's t-test p= 0.043

Enhancement	*Mean*	*SD*	*CV*	*No Enhancement*	*Mean*	*SD*	*CV*
1	0.006	*1.63E-03*	2.71E-01	5	0.040	2.23E-03	5.57E-02
2	0.330	*4.88E-03*	1.48E-02	6	0.460	6.84E-03	1.49E-02
3	0.180	*8.63E-03*	4.79E-02	7	0.110	2.97E-03	2.70E-02
4	0.230	*9.48E-03*	4.12E-02	8	0.220	6.36E-03	2.89E-02
				9	0.020	9.90E-04	4.95E-02
				1	0.330	4.81E-03	1.46E-02
				11	0.090	2.26E-03	2.51E-02
				12	0.180	4.74E-03	2.63E-02
				13	0.080	2.33E-03	2.92E-02
				14	0.120	2.88E-03	2.40E-02
				15	n/a	n/a	n/a
				16	0.480	1.65E-02	3.43E-02
				17	0.830	2.43E-03	2.93E-03
Average	**0.186**		**9.37E-02**		**0.246**		**4.42E-02**

Table 4. Mean (SE) percent relative cover for nectar bearing forbs prior to enhancement, at four sites that required enhancements to reenroll, vs. thirteen sites that did not require enhancement to reenroll. For each site, n=100 0.5m^2 quadrats. Welch's t-test p= 0.8963.

Enhancement	*Mean*	*SD*	*CV*	*No Enhancement*	*Mean*	*SD*	*CV*
1	48.6	*11.31*	0.23	5	66.7	*9.33*	0.14
2	21.7	*9.05*	0.42	6	50.6	*6.51*	0.13
3	48.1	*9.69*	0.20	7	69.7	*12.23*	0.18
4	47.6	*5.37*	0.11	8	58.2	*6.92*	0.12
				9	55.1	*9.05*	0.16
				10	23.2	*0.43*	0.02
				11	40.1	*11.03*	0.27
				12	32.7	*8.70*	0.27
				13	23.8	*7.92*	0.33
				14	37.8	*0.70*	0.02
				15	20.0	*7.79*	0.39
				16	30	*11.04*	0.37
				17	23.4	*0.21*	0.01
Average	**41.5**		**0.24**		**40.8**		**0.18**

Table 5. Mean (SE) percent relative cover for warm-season grasses prior to enhancement, at four sites that required enhancements to reenroll, vs. thirteen sites that did not require enhancement to reenroll. For each site, n=100 0.5m^2 quadrats. Welch's t-test p= 0.29

Enhancement	*Mean*	*SD*	*CV*	*No Enhancement*	*Mean*	*SD*	*CV*
1	10.39	*11.10*	1.07	5	25.49	*23.12*	0.91
2	71.06	*56.92*	0.80	6	13.45	*9.33*	0.69
3	19.94	*18.60*	0.93	7	9.52	*19.02*	2.00
4	44.67	*13.44*	0.30	8	24.51	*19.23*	0.78
				9	14.15	*6.60*	0.47
				10	31.95	*18.31*	0.57
				11	27.28	*25.39*	0.93
				12	0.05	*0.49*	9.04
				13	1.04	*7.57*	7.29
				14	16.44	*23.83*	1.45
				15	45.55	*48.44*	1.06
				16	12.98	*18.60*	1.43
				17	28.49	*19.30*	0.68
Average	**36.4**		**0.775**		**19.2**		**2.1**

Table 6. Mean (SE) percent relative cover for non-native grasses prior to enhancement, at four sites that required enhancements to reenroll, vs. thirteen sites that did not require enhancement to reenroll. For each site, n=100 0.5m^2 quadrats. No non-native grasses detected at site 4. Welch's t-test p=2.2E-4

Enhancement	*Mean*	*SD*	*CV*	*No Enhancement*	*Mean*	*SD*	*CV*
1	23.28	*27.86*	1.197	5	0.56	*4.48*	8.074
2	1.66	*11.53*	6.962	6	26.04	*24.66*	0.947
3	3.22	*13.22*	4.109	7	8.27	*17.61*	2.129
4	n/a	n/a	n/a	8	7.55	*6.64*	0.880
				9	19.55	*21.78*	1.114
				10	28.82	*22.20*	0.770
				11	18.32	*33.23*	1.814
				12	41.32	*54.59*	1.321
				13	62.36	*64.28*	1.031
				14	35.42	*39.67*	1.120
				15	23.81	*50.20*	2.109
				16	43.48	*58.41*	1.343
				17	23.39	*30.48*	1.303
Average	**9.33**		**4.08**		**26.0**		**1.84**

Table 7. Average monarch resources including nectar bearing forb relative cover (n=100 $0.5m^2$ quadrats) and milkweed stem density after enhancement applied (n=100 m^2 quadrats).

Site	*Enhancement*	*Forb cover*	*SE*	*Milkweed stems m^{-2}*	*SE*
1	Spring burn	48.2	*0.18*	0	*0.00E+00*
2a	Spring burn	22.6	*0.20*	0.34	*1.40E-03*
2b	Fall and spring tillage	32.8	*0.42*	0.05	*2.60E-04*
3	Fall and spring herbicide application	2.30	*0.78*	0.14	*8.76E-04*
4a	Fall herbicide application and tillage	9.20	*0.38*	0.30	*1.19E-03*
4b	Fall and spring herbicide application, fall tillage	31.7	*0.23*	0.05	*3.90E-04*
Average		**24.5**		**0.10**	

Table 8. Average relative covers for warm-season and non-native grass cover in 2022 after enhancement applied (n=100 0.5m^2 quadrats). No non-native grasses detected at site 3.

Site 2022	*Enhancement*	*Warm-season Grass Cover*	*SE*	*Non-Native Grass Cover*	*SE*
1	Spring Burn	11.5	*2.82*	8.39	*2.01*
2a	Spring Burn	33.6	*4.16*	1.01	*0.72*
2b	Fall and Spring Tillage	0.11	*0.12*	0.79	*1.28*
3	Fall and Spring Herbicide Application	4.42	*1.74*	0	n/a
4a	Fall Herbicide Application and Tillage	7.80	*1.93*	6.13	*1.66*
4b	Fall and Spring Herbicide Application, Fall Tillage	17.5	*3.37*	0.79	*0.21*
Average		**12.5**		**2.85**	

Table 9. Changes in absolute and relative vegetation cover from 2021 to 2022 after enhancements applied.

			Absolute Cover					***Relative Cover Change***		
Site	*2021 All Vegetation*	*SD*	*2022 All Vegetation*	*SD*	*Vegetation Change*	*Bare Ground Change*	*Warm Season Grasses*	*Non-native Grass*	*Forbs*	*Milkweed Stem Density Change*
1	78.3	6.78	55.4	6.85	-22.9	76.4	1.13	-14.89	-0.30	-0.006
2a	57.2	4.61	21.0	4.09	-36.2	28.2	-37.37	-0.65	0.90	0.01
2b			49.6	7.71	-7.6	64.8	-70.95	-0.86	11.20	-0.13
3	62.5	5.76	7.4	2.65	-55.1	97.6	-15.52	-3.22	-45.90	-0.09
4a	75.5	10.00	41.4	7.99	-34.1	56.0	-36.87	6.00	-38.40	0.26
4b			39.2	7.82	-36.3	95.6	-27.12	1.00	-15.80	-0.41
AVG	67.7		35.7		-32.0	69.77	-31.12	-2.10	-14.72	-0.06
SE					8.42		*9.93*	*2.85*	9.41	0.05
t-test					3.80		3.13	0.74	1.56	1.31
p-value					**0.003**		**0.026**	0.494	0.179	0.245

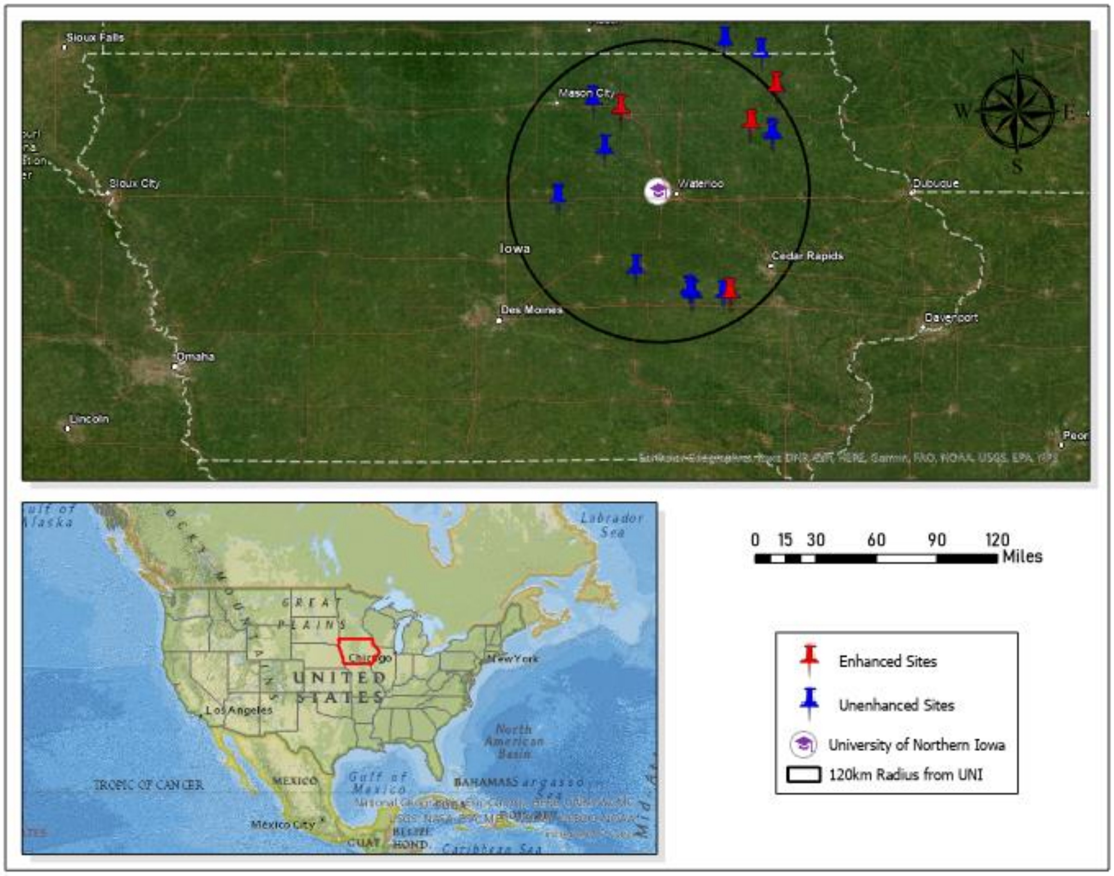

Figure 1. Site map showing the sampling area and sites surveyed in summer 2021. (Imagery © 2017 Maxar)

Figure 2. Site map for Site 1 showing initial contract (yellow outline) and 2022 enhancement (red outline). (Imagery © 2017 Maxar)

Figure 3. Site map for Site 2a and 2b showing initial contract (yellow outline) and 2022 enhancement (red and blue outlines) (Imagery © 2017 Maxar)

Figure 4. Site map for Site 3 showing initial contract (yellow outline) and 2022 enhancement (red outline) (Imagery © 2017 Maxar)

Figure 5. Site map for Sites 4a and 4b showing initial contract (yellow outline) and 2022 enhancements (red and blue outline) (Imagery © 2017 Maxar)

Figure 6. Transect sampling utilizing quadrat and transect to sample vegetation

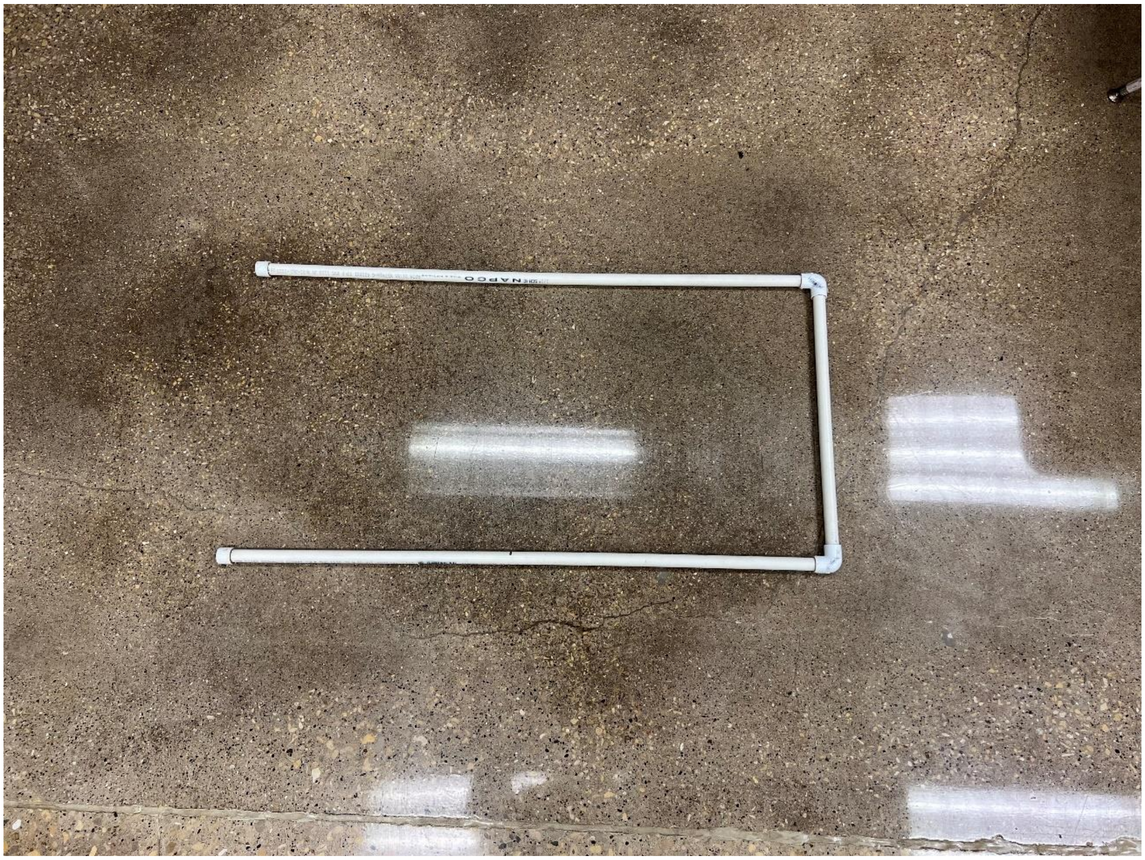

Figure 7. 0.5 m² sampling quadrat utilized in 2021 and 2022 sampling.

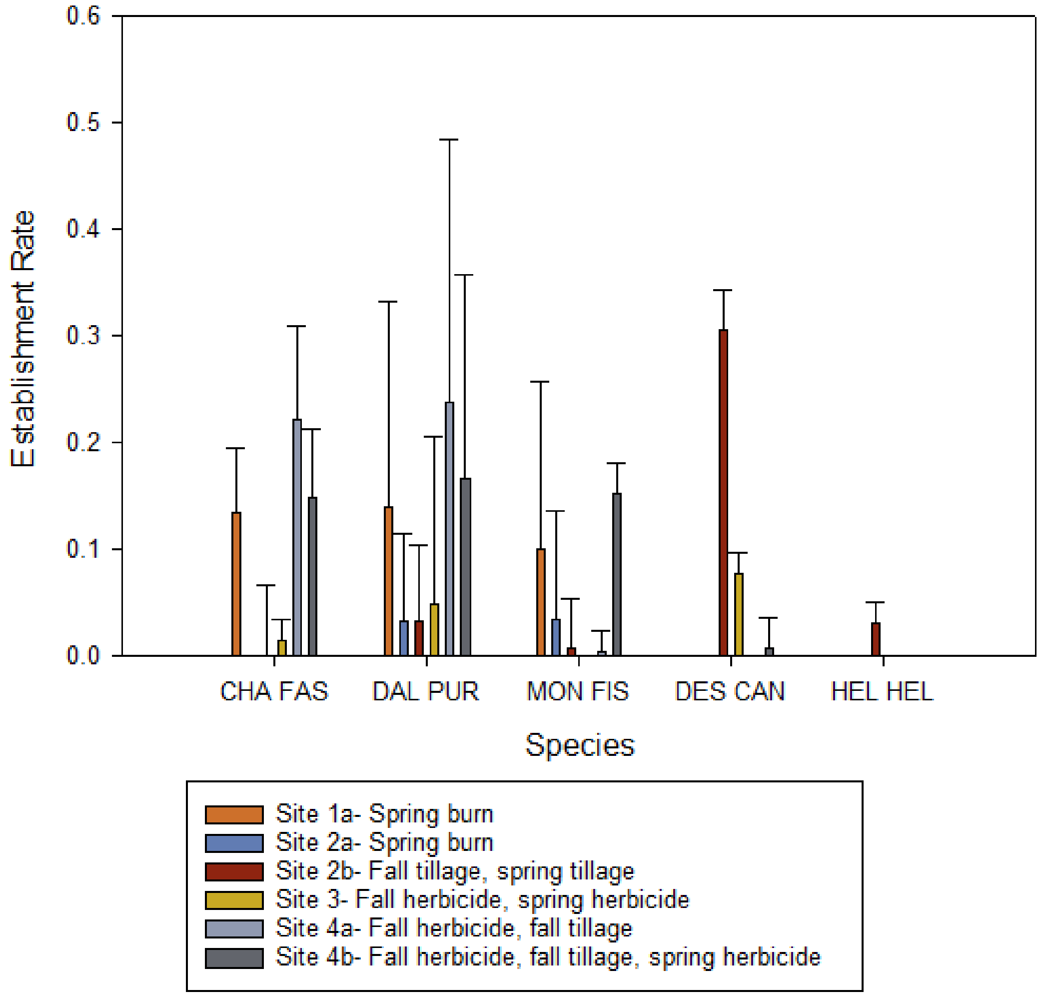

Figure 8. Establishment rates of bump-up seed mix dispersed after enhancement. Five species (*Chamaecrista fasciculata*, *Dalea purpurea*, *Monarda fistulosa*, *Desmodium canadense*, *Heliopsis helianthoides*) were included in the seed mix. The x-axis has the first three letters of genus and species while the y-axis represents the percentage of seeds germinated from the amount seeded in the seed mix.

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