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Plant Composition And Turnover In Great Plains Conservation Reserve Program Grasslands

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PLANT COMPOSITION AND TURNOVER IN GREAT PLAINS CONSERVATION RESERVE PROGRAM GRASSLANDS

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ABSTRACT

The Conservation Reserve Program supports grassland reconstruction practices that vary in the number (richness) and identity of species added to enrolled sites. Although the program is administered at the federal level, the methods and species pools used to reconstruct these grasslands have changed over time and vary across the United States. Additionally, while the goal is to augment site species pools with desired species, there is some question as to what extent the prescribed practices result in a diverse species pool over the long term given the immense non-native propagule pressure that can exist on these sites. Unfortunately, no large-scale assessments exist of how seeded and observed species change among CRP sites. With this study I assessed program wide patterns in which species are seeded and how this translates to which species occur in a suite of grasslands throughout the Great Plains by comparing species similarity, richness, and turnover. Additionally, I examined the target and nontarget ranges of the top five most frequently seeded species by mapping their seeded and observed locations. Plant surveys were conducted in 109 CRP sites by walking a 50 m × 50 m square in each field and recorded each new plant species encountered within 1 m of transect. The observed dataset was compared with seeding information provided by local NRCS field offices. Through these surveys we recorded 302 species observed in CRP grasslands and through contract seeding information recorded 166 species that were intentionally seeded on the ground. There was no effect of target species richness on non-target species richness. However, observed target species richness increased as target species richness increased. As age increased, richness difference increased between new and old sites, while species richness decreased. Our findings suggest that

practitioners select target species based on a longitudinal gradient, which does influence observed species composition among sites. But observed species also had a latitudinal effect on variation in species composition, which is likely caused by local propagule pool presence and target species establishment success. Finally, geographic range varied among seeded and observed range for blackeyed Susan (*Rudbeckia hirta* L.). I conclude my thesis with a reflection on the more complex parts of the project and reasoning for some of the choices made throughout. From my work it is clear that changes are needed in seeding and management practices to increase seeded species retention and abundance and how local weed species are considered and managed in CRP sites.

CHAPTER 1

PLANT COMPOSITION AND TURNOVER IN GREAT PLAINS AND PACIFIC NORTHWEST CONSERVATION RESERVE PROGRAM GRASSLANDS

Introduction

Grassland reconstruction is the process or action of recreating grasslands on sites formerly dominated with perennial grassland cover. Not to confuse it with restoration, which is the process of improving intact grasslands that have been degraded primarily because of invasive species and livestock use. The reconstruction process typically involves site preparation, seed augmentation, and subsequent management steps and has been standardized and implemented by many non-profit and government organizations for large-scale application across the United States (Packard and Mutel 2005, Congress 2014, Török et al. 2021). One such program is the United States Department of Agriculture (USDA) Farm Service Agency (FSA) Conservation Reserve Program (CRP), established in 1985 to increase marginal agricultural land productivity and address natural resource concerns on enrolled lands including soil erosion, soil quality degradation, and habitat degradation (Congress 2014, Johnson and Monke 2019). Recent studies on CRP lands have found that establishing sites with a more diverse seed mixture improves soil and water quality, but plant diversity often declines over time and these effects can be geographically variable (Martin and Wilsey 2006, Baer et al. 2009, Huang et al. 2013, Martin and Wilsey 2015). This decline in plant diversity could be due to local, often non-native, propagule pressure on establishment, environmental conditions upon implementation, and/or lack of or ineffective management. A few smaller studies address these issues (Grimsbo Jewett et al. 1996, Baer et al. 2002, Baer et al. 2009), but there are minimal programmatic wide assessments of what species are seeded, where they currently occur, and how they vary with respect to local species outside of seeding. With this study, I aimed to analyze geographic variation in target species, species that are known to be sown on CRP sites, and nontarget species, species not known to be seeded on CRP sites. I aimed to assess species similarity, richness difference and species replacement vary between target and nontarget species pools.

Grassland reconstruction

Grassland reconstruction was introduced to western science in the 1940's by Aldo Leopold, whose goal was to improve grassland productivity and biodiversity and reintroduce wildlife habitat on degraded agricultural lands (Aldo Leopold Foundation 2016). Since that time, grassland reconstruction has become nearly prescribed in its application. We went from hand collecting seed on a case-by-case basis to an industry with entire businesses devoted to seed supply and restoration practices that vary by region (Török et al. 2021). While the industry and capabilities around grassland reconstruction have improved over time, this process still fundamentally includes site preparation, species augmentation, and management steps (Packard and Mutel 2005).

Site preparation actions prepare the seed bed through tillage and weed management practices to increase the likelihood of plant species establishment. Common tillage practices range from light-duty cultivating to heavy-duty harrowing, thus minimizing deep plowing commonly associated with row crop production. This soil disturbance increases microsites for seed germination and can enhance seedling establishment (Hobbs 1989, Hölzel and Otte 2003, Hofmann and Isselstein 2004, Edwards et al. 2007, Farrell et al. 2021). However, these efforts often bring buried, less desirable seeds and propagule to the surface (Packard and Mutel 2005). Weeds, species that are considered undesirable or unwanted, can use the new microsites and resources and potentially outcompete the desired sown species. This is where weed management comes into play, which aims to remove pressure from belowground plant propagules and decrease potential for standing weed vegetation. Weed management is best conducted using a combination of several practices – mowing, hand removal, herbicide, and fire (Gibson-Roy et al. 2010, Török et al. 2012, Humphries et al. 2021).

After site prep is seed augmentation. Practitioners select plant species after considering the aim of restoration and site physical conditions. Within the seed mixture, it is often advised that practitioners maximize functional diversity with the inclusion of warm and cool season grasses, sedges, legumes, and forbs. Often species selected include those with annual (used to enhance seedling establishment and decrease soil erosion), biennial, and perennial growth forms and that often have different flowering phenologies to increase and maintain diversity (Young et al. 2009, Smith et al. 2010, Török et al. 2011, Kaulfuß et al. 2022). With that, practitioners aim to source seed that could include native cultivars, local ecotypes, or wild harvested seed in a process that is ultimately based on species availability, management and landowner preference, and seed cost (McKay et al. 2005, Török et al. 2011, Bucharova et al. 2017b, Ahlering and Binggeli 2022). Seeds are considered local when they are sourced from near the site or from an area with a similar climate, which could allow for greater adaptation to site conditions than nonlocal seed, while seeds are considered nonlocal when they are not co-occurring within the designated region (Joshi et al. 2001, Raabová et al. 2011, Breed et al. 2013, Bucharova et al. 2017a, Bucharova et al. 2017b, Harrison 2021). In some cases, practitioners may intentionally use nonlocal seed sources to enhance gene flow as a climate change mitigation strategy (Vitt et al. 2010, Larson et al. 2021, McKone and Hernández 2021). However, seed sourcing ultimately comes down to the practitioner and what they deem fit for the goal of the restoration. From there, practitioners identify how and when seed should be sown. Seed can be sown in many ways, either through broadcasting, drilling, or a mixture of both methods (Packard and Mutel 2005, Török et al. 2011). It is important to note that unlike crop species, some native species are subject to states of dormancy, which controls germination and regulates the persistence of seed through unfavorable conditions until favorable conditions are available for establishment (Baskin and Baskin 2014, Kildisheva et al. 2020). So, the choice of when to sow seeds, whether it be in the growing or dormant season, should be guided by an understanding of what would best maximize species germination and establishment, to the extent that this is known about the selected species. Sowing during the dormant season, which is usually fall, is common with cool season grasses and forbs, and has shown best results through broadcasting, whereas sowing warm-season grasses during the growing season by drill has more promise in establishment (Larson et al. 2011, Applestein et al. 2018). Once the site has been planted, the next step is managing that site.

Management practices provide the last key factor that affects grassland reconstruction success. Management practices include, but are not limited to, fire, mowing, shrub and tree removal, invasive species control, and grazing by livestock (Török et al. 2021). These practices can decrease competition from invasive species, help maintain a diverse species pool, increase seed dispersal, and decrease woody species growth. Grazing, mowing, and fire increase plant colonization sites and reduce litter and canopy height to increase plant species richness and diversity (Bissels et al. 2006, Bonanomi et al. 2006, Billeter et al. 2007). However, because grazing can be highly selective it could increase unwanted species and decrease native species (Török et al. 2011). In contrast, fire is not selective on what it burns and the season in which the grassland is burned can affect the plant diversity and richness. Meyer and Schiffman (1999) found that fall and late-spring burns increased native plant diversity and richness and decreased nonnative, unwanted species. Early-spring burns may also increase plant diversity by increasing perennial forbs and sedges and decreasing cool-season grasses (Smith et al. 2010). Depending on the management practice implemented, species persistence can vary within a site. Coulson et al. (2001) found that there is increase in seed dispersal through mowing/haying rather than grazing, but mow time is critical in dispersal and species establishment depending on their life history. To ensure that these practices are beneficial, Török et al. (2021) advocated that plantings should be assessed on the desired structure, composition, function, resilience, and stability in restored or reconstructed grasslands.

The greatest challenge to reconstruction is the establishment of unwanted, mostly non-native, species from the local propagule pools. Over time it is common to see sites degrade, which increases the likelihood of invasion by nonnatives (Martin and Wilsey 2012, 2014, Kaul and Wilsey 2021). This is because, as sites increase in age, seeded species retention tends to decrease and sites are subject to propagule pressure from the surrounding landscape that tends to cause an increase in nonnative species and cover over time (Rojas-Botero et al. 2022). The intensity of this pressure can be site specific, seed mix specific, or species specific with some species having an increased persistence over time (Larson et al. 2017). For example, former agricultural fields can have increased nutrients from past site management that increase nonnative presence (Lockwood et al. 2005, Carr et al. 2019). There are a few ways to decrease the effects of propagule pressure. One way is the increase the use of species that are highly competitive themselves, so that they outcompete nonnative populations (Rojas-Botero et al. 2022). Another is to increase species diversity within seed mix, to decrease weedy, unwanted species establishment and increase site diversity (Török et al. 2011, Barr et al. 2017).

The range of nonnative and native species differ along a North to South latitudinal gradient (Martin and Wilsey 2015). They found that southerly latitudes have higher nonnative species turnover, but lower native species turnover, whereas northerly latitudes had higher native species turnover, but lower nonnative turnover (Martin and Wilsey 2015). Species turnover represents the differences in species composition between or among sites. It is important in understanding species richness patterns, and their subsequent influence on biodiversity and ecosystem stability (Chen et al. 2016, Bauer et al. 2023). For example, sites that have high species turnover might have more distinct, rare species distinguishing them from each other, whereas sites with low species turnover have more similar, less unique species between each other. Additionally, over time these ranges for native and nonnatives species are subject to change due to climate change. In a study conducted by Wilsey et al. (2018) on phenology between native- and exotic-dominated grasslands, the researchers found that with climate change the time in which exotic species have an earlier greening period and later senescence. These changes in growing season can affect plant phenology characteristics (*e.g.,* flowering date, maturity rate, growth rate) and vegetation composition and their subsequent effects on ecosystem function (Piao et al. 2007, Hu et al. 2010, Haggerty and Galloway 2011, Wolkovich and Cleland 2011, Khorsand Rosa et al. 2015, Shen et al. 2022). Understanding these differences in species ranges could guide future restoration projects in how they assemble and source their seed.

The biggest need for grassland reconstruction efforts comes in the aftermath of grassland conversion for agriculture production. Conversion to row-crop production reduces landscape diversity and results in soil degradation (Lin et al. 2011, Tang et al. 2019), which poses significant challenges for returning a site to a grassland state. To address this need to improve ecosystem services and functions in the aftermath of agricultural production, many non-profit and government organizations have institutionalized programs to guide the grassland reconstruction process. In the United States this includes the Conservation Reserve Program (CRP), which addresses soil, water, and plant natural resource concerns in agricultural landscapes. There are also other programs similar in concept to CRP around the world, such as Landcare Australia, European Union (EU) Common agricultural policy, and Natura 2000 (Kleijn and Sutherland 2003, Wilson 2004, Moon and Cocklin 2011). The EU common agricultural policy is unique in that it is comprised of multiple programs that address ecological services that have since declined due to agriculture, land-use intensification, deforestation, and so forth (Sutherland 2002, Wade et al. 2008). Through these EU programs, around half of all taxa (*e.g.,* birds, arthropods and plants) increase in richness, but some of these programs fail to attain their education and training aims (Aughney and Gormally 2002, Kleijn and Sutherland 2003, Kleijn et al. 2004). Other studies have also shown the same increased trend in wildlife activity and biodiversity, as above (Swetnam et al. 2004, Knop et al. 2006, Barral et al. 2015). As for the Landcare Australia group, they are a non-profit, grassroots organization that aims to improve biodiversity, build resilience in Australia's food and farming systems, and create stronger communities (Wilson 2004). Participation by landowners is based on the level of biodiversity offered by Landcare, their potential change in property rights, and landowner benefits for enrollment (Moon and Cocklin 2011). With these programs, there is still a need to understand how the programs are applied at landscape scales, especially the link between local and regional diversity (Wade et al. 2008).

The Conservation Reserve Program

The United States Conservation Reserve Program is a federally funded program established with the 1985 Food Security Act and administered by the US Department of Agriculture (USDA) Farm Service Agency (FSA). The program has received continued support from renewals of the Agricultural Improvement Act, otherwise known as the Farm Bill, every five to six years since establishment (Congress 2014, Johnson and Monke 2019). Since inception, CRP has become the largest private-lands conservation program in the United States. Its original aims were to control erosion and stabilize overly used agricultural land through the addition of perennial cover. As the program grew, CRP added more natural resource concerns to its repertoire from improving water quality to increasing wildlife habitat. The program has many benefits for the environment and contract holders. Contract holders are paid per acre on a yearly basis for participation in the program. Contracts run for a period of 10-15 years and require that enrolled land is removed from agricultural production and augmented with pre-determined species dependent on the Conservation Practices (CP) implemented. The CRP program has supported over 40 Conservation Practices that range from planted shelter belts to established perennial grassland cover on enrolled lands (Congress 2020). Decisions as to which practices are chosen for a particular contract are made by the contract holder in conjunction with local field offices and are based on the natural resource concerns for the focal parcel (Onianwa et al. 1999, Atkinson et al. 2011, Wachenheim et al. 2018, FDCE 2020). For my purposes, I focused on CRP practices that involve reconstructing grasslands (Table 1; selection process described below) over large parcels of land.

Current Studies and Findings

Limitations on species availability and management processes can affect species presence and persistence in restoration programs (Baer et al. 2009). Sowing fields with lower species diversity mixes or with species that have limited resistance capabilities, increases the probability of invasive or non-target species presence (Baer et al. 2009). In a study conducted by Piper et al. (2007), they found that higher species diversity mixes lead to an increase in target species presence and a decrease in invasive/nontarget species. But this is not always the case for CRP sites. Because CRP fields were recently used for agricultural practices, they are subject to higher densities of nonnative/invasive species that compete with the desired target species on the site (Grimsbo Jewett et al. 1996). Not only does the presence of nonnative species in the local pool increase turnover and affect establishment on the landscape, but what is seeded and how it is seeded does too. Most CRP fields are seeded with a combination of grasses and forbs. Though the rate at which they are seeded varies between functional groups. Recent studies have found that over time, native grass composition increases, but forb composition decreases, since grasses are seeded at a higher rate than forbs (Baer et al. 2002, Baer et al. 2009, Bach et al. 2012). The fluctuation over time in species is affected by the success of seeding establishment, which in turn is affected by the local propagule pool.

In summary, what goes into a site is subject to field office decisions, seed availability, and landowner decisions. While it seems prescribed in nature, there are few programmatic wide assessments of what goes on the landscape and what establishes within the context of the CRP program. This is important for planning future iterations of the program and planning in the face of climate change.

Specific aims

I aimed to understand how plant composition and species turnover differ among sites in the Conservation Reserve Program grasslands throughout the Great Plains. More specifically, I examined how target species (known to be sown on CRP sites based on contract seed documents) and nontarget species (not known to be seeded on CRP sites) pools compare in species similarity, richness, and turnover among sites. I hypothesized that target species composition will differ in between regions with more pollinator habitat (CP42) sites and those with less-species rich Conservation Practice mixes. I also hypothesized that nontarget species pools will have high turnover and low similarity among regions, since each region is subject to different environmental factors and species propagule pools. Additionally, I hypothesized that target species will have higher similarity and less turnover among regions than nontarget species pools. Intentionally seeded species are fairly prescribed mixes, while local species pools arise from local propagules from each area/region. I additionally examined the target and nontarget ranges of the top five most frequently seeded species. I hypothesized that there will be a range shift between the target and observed ranges for the most frequently seeded species. Since most Conservation Practice mixes are fairly prescribed in terms of species composition, this could lead to some species being seeded outside their ranges.

I used Principal Components Analysis (PCA) and linear regression analyses to visualize and test for age and geographic (*e.g.*, latitude, longitude) effects on species presence/absence matrices. I also use SDR (species similarity (S), richness difference (D), and species replacement (R)) framework to quantify and partition components of beta diversity associated with species overlap, gain, and loss between sites in target, observed, observed target, and observed nontarget datasets (Podani and Schmera 2011, Legendre 2014, Tóth et al. 2017, Podani et al. 2018).

Findings from this study will increase our knowledge on plant species persistence and similarity among regions to inform future programmatic recommendations on plant species to use in the CRP program.

Methods

Site Selection

We selected and repeatedly sampled 256 CRP sites. We selected our sample sites from the list of all active and pending USDA- FSA CRP contracts obtained from the Natural Resource Conservation Service Headquarters in Washington, DC in February 2021. This information included shape files for every CRP parcel and supporting metadata with contract details pertaining to the practices used, reenrollment status (if known), and contract expiration dates. We queried this database (Table 2) for sites that met desired practice type and geographic details.

Conservation Practice selection

For the purposes of this project, we focused on large, most round parcels with a past cropping history that involved at least one of seven CRP Conservation Practices associated with establishing and maintaining perennial grassland cover. These included CP1, CP2, CP4D, CP10, CP25, CP42, and CP38E (Table 1), all of which are commonly used throughout the Great Plains and Pacific Northwest. While all address soil erosion, wildlife habitat, and water quality concerns, these practices differ slightly based on their main objectives which range from supporting pollinator communities to increasing perennial cover in areas with rare and declining habitats. Most of these practices involve seeding bare soil sites with a supplemental seed mixture. The plant species selected for each parcel is determined through state, county, and producer input with some limitations depending on the practice (Table 1). Landowners determine how and when the seed is applied to the ground (*e.g.*, broadcasting, drilling) and are guided to manage the sites through herbicide applications and mid-contract biomass removal practices (*e.g.*, burning, disking, interseeding). Mid-contract management practices are in place to improve plant community composition and diversity, provide early successional habitat for some wildlife species, provide habitat for declining species, and to help remove nonnative and woody species (Agriculture 2012, Stubbs 2014). Aside from mid-contract biomass management, producers are not to disturb the established vegetation for the duration of the contract.

Geographic selection

We focused on CRP sites within four geographic regions of high concentration of grassland CRP contracts (Figure 1). These included the Northern Plains (NP), Central Plains (CP), Corn Belt (CB), and Pacific Northwest (PNW). These regions roughly corresponded with natural geographical breaks in enrollment patterns associated with the focal practices and areas of high commodity production and increased likelihood of returning to commodity production. Our Northern Plains region included North Dakota, South Dakota, and western Minnesota. The Central Plains region included Kansas, Nebraska, and eastern Colorado. The Corn Belt region included Iowa, northern Missouri, and western Illinois. The Pacific Northwest region included eastern Washington, northeastern Oregon, and western Idaho. To reduce potential travel time among sites and to ensure site access, we further limited the candidate site dataset to sites within 50 m of primary and secondary roadways using ArcGIS (ver. 10.8.1, ESRI, Redlands, CA). With these procedures, we narrowed down the number of candidate sites from 601,405 to 11,169 parcels (Table 2).

Candidate site selection

We further selected candidate sites within each of the four geographic regions based on provided site enrollment history (yes/no reenrollment), contract end date, size, and shape with an aim to identify the largest, most circular sites across all potential site ages within each geographic region. Newly enrolled sites are those with potentially no prior history of perennial grassland cover. Reenrolled sites had at least 10 to 15 years of prior history in perennial grassland cover (depending on the practice), but because the contract system does not account for multiple reenrollments these sites could have an even longer history in perennial grassland cover. We calculated site age (known years in perennial grassland cover) based on the contract details provided with each parcel (contract end date; yes/no reenrollment) and used this age as a conservative estimate for the site selection process.

To assess parcel shape, we calculated the Polsby-Popper Shape Index based on the area (A) and perimeter (P) for each parcel (i) whereby:

Polsby-Popper Shape Index = $4\pi A_i / P_i^2$

The Polsby-Popper Shape Index (hereafter, shape index) is ratio of the area of the parcel to area of a circle whose circumference is equal to the perimeter of the parcel and ranges from 0 to 1 where 0 is the least compact and 1 is the most compact (Polsby and Popper 1991). After we calculated the shape index, we developed a priority index for each parcel as a sum of the standardized natural log transformed area and standardized shape index. We then ranked parcels based on this priority index within each age (from 1 to 35) and geographic region group where the highest ranking was assigned to the largest, most circular parcel at each age (yearly) in each region (CB, NGP, SGP, PNW). This approach prioritized sites with potentially lesser edge effects (*e.g.,* sites that are more compact with smoother edges and a rounder shape) over those with potentially greater edge effects (*e.g.*, wide only in one direction or more convoluted in shape) within our site selection process.

To ensure that we sampled as uniformly as possible across all available ages, we selected the top 27 sites in each age (continuous; 0 to 35) × region (*e.g.,* Corn Belt, Southern Great Plains, Northern Great Plains, Pacific Northwest) category as candidate sites. Because not all age classes were represented in each region, we supplemented this list with additional selections as needed and generated a list of 1,644 parcels that represented the largest, most circular grassland CRP parcels of each age in each region. Once we had final candidate sites selected, we contacted contract holders for permission to sample the sites through a combination of email and postal mail methods. Contract holders were provided options to respond via Qualtrics survey, email, or phone. At that time, we also asked if they could verify the site CRP enrollment history and we updated the age records for each site as appropriate. From this permission process, we accumulated 256 parcel approvals out of the 1,644 parcels contacted, giving us a 15% approval rate (see Figure 2). Once we had permission, we contacted the regional NRCS offices to obtain the seeding details and confirm stand ages to the extent that this information was available in the records. I obtained this information for 109 sites all within the Great Plains. These sites form the basis for the analyses presented in Chapter 2.

It is important to note that we did not include specific practice type (of the seven in the reduced dataset; Table 2) in our candidate site selection process. We did this for several reasons. First, not all practices were equally represented across all site ages across all regions (*e.g.*, CP10 discontinued after 2011). Secondly, we did this to ensure that the sites selected represent the range in plant community composition that exists on large block CRP grasslands through each geographic region, irrespective of the programmatic and human decision-making limitations on the contract (Atkinson et al. 2011, Congress 2014, 2020). Once sites were selected and permission confirmed, we traveled to them in 2021 and 2022 to record species composition (details described in the specific methods in Ch 2). We used these datasets as the basis for assessing the intentionally seeded and local/observed species pools across the study region.

Summary

To reiterate, I aimed to understand how plant composition and turnover differed among sites in the Conservation Reserve Program grasslands at a national scale. With that, I also aimed to examine the target and nontarget ranges of the top five most frequently seeded species. In short, we used CRP to address these and developed a process to select 256 ideal sites for the project (*e.g.*, region, state, age, site size and shape, distance from road) in four geographic regions – Northern Great Plains, Central Great Plains, Corn Belt, and Pacific Northwest. I further explain in Chapter 2 how I sampled and used these sites to address this aim through PCA and SDR analyses.

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Table 1: Summary of the seven Conservation Practices (CP) associated with the USDA-CRP program that establish or maintain perennial grassland cover on qualified cropland and addressed within this study (Agriculture 2012, Stubbs 2014). PLS = Pure live seed

Practice Code	Practice Name	Purpose	Notes
CP1	Establishment of Permanent Introduced Grasses and Legumes	Establish new or maintain existing cover of introduced grasses and legumes	
CP2	Establishment of Permanent Native Grasses	Establish new or maintain existing cover of native grass species	
CP4D	Permanent Wildlife Habitat	Establish new or maintain existing wildlife habitat cover	Can include woody vegetation
CP10	Grass Already Established	Used for land that already has established grass cover upon contracting	Not offered after March 14, 2011
CP25	Rare and Declining Habitat	Restore the functions and values of approved critically endangered, endangered, and threatened habitats	Specifications determined at the state level.
CP42	Pollinator Habitat	Establish habitat to support a diversity of pollinator species	Limited to 10 acres/tract with 0.50-acre min. Must contain at least 9 pollinator-friendly wildflowers, legumes, and/or shrubs. Must include at least one early, mid, and late season blooming species and no more than 50% native grasses based on PLS/ft^2
CP38E	State Acres for Wildlife Enhancement (SAFE) - Grass	Apply practices to eligible lands where the habitat can be restored and maintained as determined by the state developed standard	For our purposes, only considered sites where CP2, CP4D, CP10, CP25, or CP42 was used

Table 2: Summary of site selection process, providing information on number of states and parcels at each step. We first queried the national FSA CRP database for sites that met desired practice and geographic details. From there, we reduced the site list to sites 50 m from primary and secondary roadways. Lastly, we identified the largest, most circular sites within each age class.

Site set	States	Parcels
All CRP contracts	44	601,405
Target large-block grassland practices	12	501,796
Target Geographic States	12	372,079
Target Geographic Regions	12	311,876
Major Roadway Proximity (50 m)	12	11,169
Candidate site list	12	1,644
Final sites	12	256

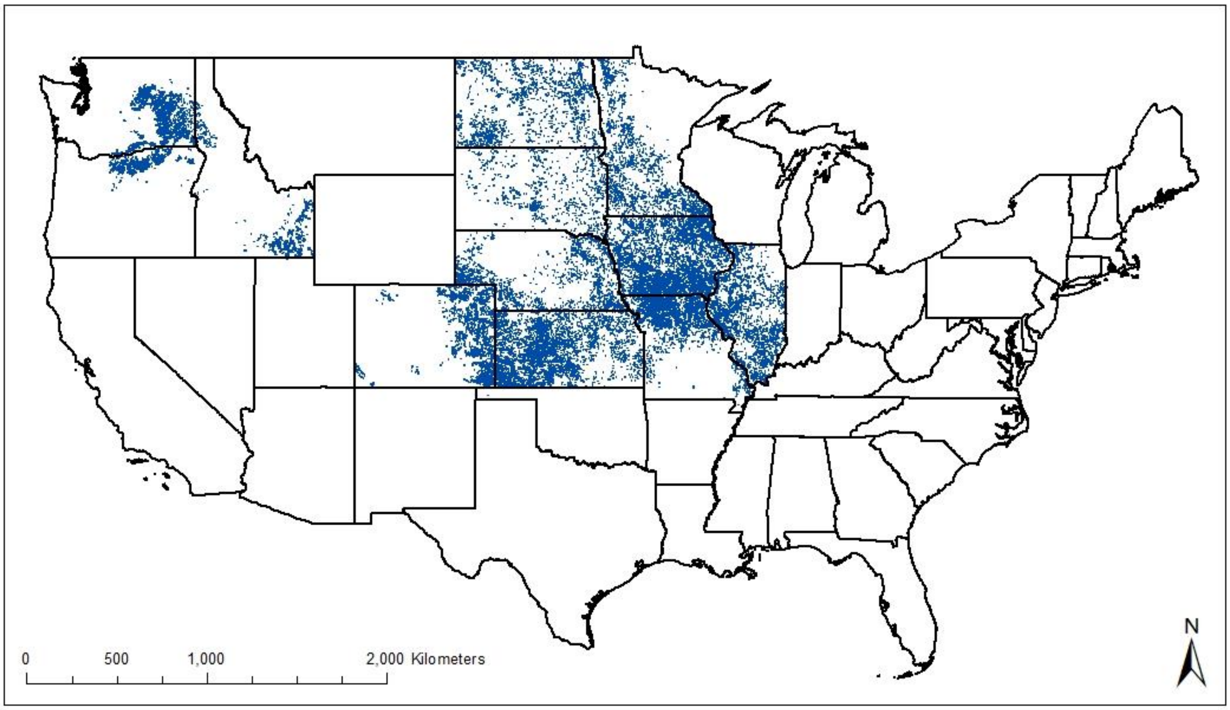

Figure 1: Map of CRP sites in the 12 study states, as of February 2021, to show natural breaks in CRP enrollment in the four geographical regions studied. Regions include the Pacific Northwest (Washington, Oregon, Idaho), Southern Great Plains (Kansas, Nebraska, Colorado), Northern Great Plains (North Dakota, South Dakota, Minnesota) and Corn Belt (Iowa, Illinois, Missouri).

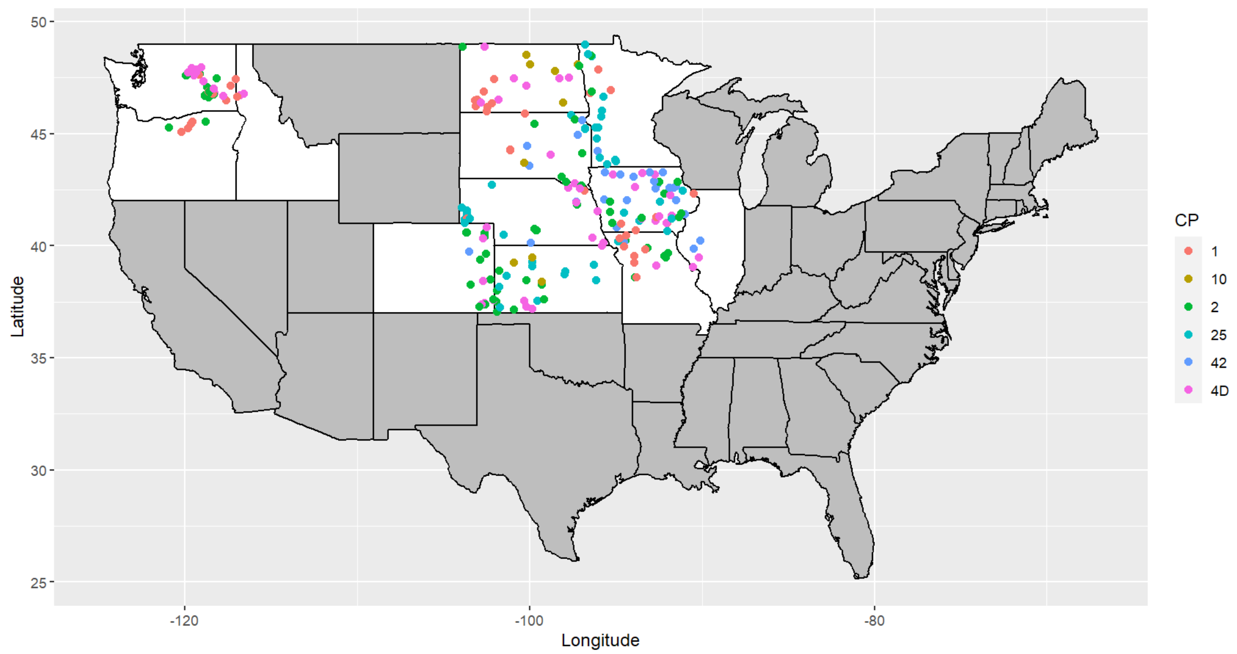

Figure 2: Map of CRP sites sampled in 2022 colored by Conservation Practice (CP).

CHAPTER 2

SOWN AND OBSERVED SPECIES DISTRIBUTIONS AMONG GREAT PLAINS CONSERVATION RESERVE PROGRAM GRASSLANDS

Abstract

The Conservation Reserve Program supports grassland reconstruction practices that vary in the number (richness) and identity of species added to enrolled sites. Although the program is administered at the federal level, the methods and species pools used to reconstruct these grasslands have changed over time and vary among geographic regions across the United States. Additionally, while the goal is to augment the site species pools with native grassland species, there is some question as to what extent the prescribed practices result in a diverse species pool over the long term given the immense non-native propagule pressure that can exist on these sites. Unfortunately, no large-scale assessments exist of how seeded and observed species change among CRP sites. With this study we assessed program wide patterns in which species are seeded and how this translates to which species occur in a suite of grasslands throughout the Great Plains. We recorded plant species occurrence along a 200 m transect in 109 CRP fields distributed across nine states in summer 2022. We recorded which species were seeded within each site from supplied contract documents. There was no effect of target species richness on non-target species richness. However, observed target species richness increased as target species richness increased. As age increased, richness difference increased between new and old sites, while species richness decreased. A composition analysis suggested that practitioners select target species based on a longitudinal gradient, which does influence observed species

composition among sites. But observed species also had a latitudinal influence on variation in species composition, which is likely caused by local propagule pool presence and target species establishment success. Finally, geographic range varied among seeded and observed range for black-eyed Susan (*Rudbeckia hirta* L.). In summary, changes are needed in seeding and management practices to increase seeded species retention and abundance and how local weed species are considered and managed in CRP sites.

Introduction

Grassland reconstruction has an inherent human dimension element that is rarely addressed. Although there is no shortage of plant species on the landscape to colonize and fill newly abandoned agricultural fields (Meiners et al. 2001, Cramer et al. 2008), most are introduced, or considered problematic weeds and not reflective of pre-agriculture plant communities. Indeed, it follows that a basic premise of restoration ecology is that because of significant species loss from landscapes, sites presumably need augmentation to reintroduce species and restore function (Packard and Mutel 2005). Reconstruction requires decision making about what to seed, how to seed, and when to seed, which is mostly an art and product of practitioner's experiences (Packard and Mutel 2005, Ahlering and Binggeli 2022). These decisions and experiences are crucial to a successful reconstruction. Sites seeded at the wrong time with nonnative or less diverse seed mixes are subject to invasion of undesired species and lower establishment success (Bakker et al. 2003, Fischer et al. 2013, Applestein et al. 2018). That is why in this study, I aim to understand how species similarity, richness, and replacement varied within target (what was intentionally seeded in fields) and nontarget (species not documented as seeded; local species pool) species pools in Conservation Reserve Program (CRP) grasslands. I also aimed to analyze how the geographic distributions of the top five most frequently seeded species varied between where they were seeded and observed in CRP fields.

The Conservation Reserve Program

The Conservation Reserve Program is a federally funded program established with the 1985 Food Security Act and administered by the US Department of Agriculture (USDA) Farm Service Agency (FSA). It aims to control erosion, improve water quality, increase wildlife habitat and stabilize overly used agricultural land through the addition of perennial cover. Contracts require that enrolled land is removed from agricultural production and augmented with pre-determined species depending on the Conservation Practices (CP) implemented (Congress 2014). These Conservation Practices vary in the number of species that are sown, with some mixes having five species and others having 35 species. The CRP program has supported over 40 Conservation Practices that range from planting shelter belts to establishing perennial grassland cover on enrolled lands (Congress 2020). Decisions as to which practices are chosen for a particular contract are made by the contract holder in conjunction with local field offices and are based on the natural resource concerns identified for the focal parcel (Onianwa et al. 1999, Atkinson et al. 2011, Wachenheim et al. 2018, FDCE 2020). For this study, we limited the CP practice to seven of the 40 possible practices, which pertained to establishing perennial grassland cover (Table 1).

Human dimensions

CRP and similar programs are implemented by county based NRCS personnel to help rebuild natural resources within abandoned agricultural fields. A prevailing assumption is that sites will filter what seeded species establish based on local conditions of the site and time of seeding (Kiehl et al. 2010, Kaul and Wilsey 2021). Most texts/sources recommend species for mesic or xeric conditions (Packard and Mutel 2005, Kramer and Havens 2009, Broadhurst et al. 2015) and that is primarily the extent to which mixes are tailored for a location. Realistically, what goes into a seed mixture is determined by input and experience from all parties. This includes NRCS and FSA staff, but also any non-profit biologists (*e.g.*, Pheasants Forever, Ducks Unlimited) helping to implement these programs. With many practices having a bias to common species that are readily available and relatively cost efficient, which limits species diversity and seeding rates (Broadhurst et al. 2015). The USDA will pay for a percentage of the cost of seed mixes and the installment of those mixes with the payment being no more than 50 percent of actual or average cost (Congress 2014). But the species list itself is at the discretion of the contract holder depending on the practice.

Species selection

Species selection is controlled by many factors, one being the specific aim of the reconstruction practice. Depending on the practice species used can be native or nonnative. It is recommended that native species be used over nonnative, since nonnative species may outcompete native species leading to change in diversity and composition of restored grasslands (Bakker et al. 2003, Fischer et al. 2013). Species used in seed mixes should also include a mixture of grasses, forbs, and legumes (Packard and Mutel 2005). Studies have shown that increasing functional group diversity can decrease the undesired, weedy species and provide greater productivity (Pokorny et al. 2005, Piper et al. 2007, Garrett and Gibson 2020).

Seed sourcing

This is all predicated on seed availability. The seed needs to be sourced and supplied. Some areas require locally adapted sourced seed, but with climate change the extent to which they are adapted to current local conditions might be limited, while other areas do not require local seed (McLachlan et al. 2007, Galatowitsch et al. 2009, Breed et al. 2018, Ahlering and Binggeli 2022). Local assumes that the seed is locally adapted, which presumably will increase plant success. However, with climate change these local adaptations might be limited (Hufford and Mazer 2003, McKay et al. 2005, Kramer and Havens 2009, Vander Mijnsbrugge et al. 2010, Breed et al. 2013). Non-local seed could have characteristics suitable for the effects of climate change, but they could also not be successful if seed characteristics are not suitable to the local biome (Vitt et al. 2010, McKone and Hernández 2021). Because climate change can affect what seed establishes and survives in a changing environment, local seed might not have the traits (*e.g.,* drought tolerance, dormancy duration, growth rate) ideal for success, whereas non-local seed would be more appropriate with having characteristics, such as drought tolerance, shorter or longer dormancy periods, and faster or slower growth rates (Balazs et al. 2020, Ahlering and Binggeli 2022). Combining local and non-local seed is projected to be common in future restorations due to climate change effects (Balazs et al. 2020, Harrison 2021). This is commonly referred to as assisted gene flow (Vitt et al. 2010, McKone and Hernández 2021), allowing for gene flow within seeded species current range (Aitken and Whitlock 2013, Breed et al. 2013, Bucharova et al. 2017b, Bucharova et al. 2019).

Implementation

Once species are selected and sourced, establishment is subject to site preparation, seeding method, and site management approaches. Site preparation includes, but is not limited to, tillage and weed management. Disturbing the site through tillage increases microsites for seed germination and improves seedling establishment, while weed management helps remove competition from unwanted species (Hobbs 1989, Hölzel and Otte 2003, Hofmann and Isselstein 2004, Edwards et al. 2007, Gibson-Roy et al. 2010, Farrell et al. 2021, Humphries et al. 2021). Once the site is prepared, seeds are either broadcast or drilled onto the landscape. But these methods influence grassland restorations in different ways. Although broadcasting and drilling have similar effects on establishment, broadcasting can affect survivorship and emergence of heterogeneity (Bakker et al. 2003, Yurkonis et al. 2010). A study conducted by Applestein et al. (2018), found that broadcasting increases native establishment and is more consistent than drilling. Along with seeding method, practitioners consider at what rate to sow seed and when to sow seed. The rate at which seed is sown, varies on the aim of the restoration and practice guidelines. Sowing seed at an increased rate can increase target species abundance and reduce unwanted species but can be limited by seed availability (Bakker et al. 2003, Applestein et al. 2018). The timing of when you seed also affects seedling establishment and species composition. Many species seeded in grassland restorations require a cold scarification attained through fall seeding, while the rest germinate in spring. After grassland restorations are seeded, it comes down to the management regime to maintain species diversity. This can range from fire to grazing to mowing, but they all affect grassland restoration differently. Grazing, mowing, and fire can increase native species and reduce litter, which ultimately increases species richness and diversity (Bissels et al. 2006, Bonanomi et al. 2006, Billeter et al. 2007). For a successful restoration, timing and persistence are key to accomplishing the projected aims of the program.

Species establishment

It is unclear how seeding decisions and management practices translate to what exists on the ground. We know that grassland restorations generally decline in diversity and target species composition because of interactions with species in local propagule pool and lack of sufficient management (Bakker et al. 2003, Mangla et al. 2011). It is important to note that native and nonnative species pools vary in their turnover on a latitudinal gradient going South to North (Martin and Wilsey 2015). Southerly latitudes had a higher turnover in nonnative species, but lower turnover in native species, whereas northerly latitudes had higher turnover in native species, but lower turnover in nonnative species (Martin and Wilsey 2015).

These differences in turnover between latitudes could be attained from something quite different than how sites change and differ over time but might ultimately come down to cost. There is a very significant cost to seeding, there simply might not be a return on the investment (Török et al. 2011). Cost and aim of restoration can reflect the diversity of seed mixes with the cheapest, low diversity mixes used to benefit certain wildlife goals or expensive, high diversity mixes aimed at increasing community species abundance and maximize richness (Manchester et al. 1999). The difference though lies in the outcome of these low and high diversity mixes. High diversity mixtures tend to result in more species rich and less invaded plantings, while low diversity mixtures tend to result in less species rich and more invaded plantings (Lepŝ et al. 2007, Piper et al. 2007, Török et al. 2011).

All of this affects the final function of the restored grassland – especially when there are aims to rebuild habitat and soil health (Török et al. 2021). So, this begs the question of what is a reasonable and effective expectation for species establishment in CRP? Recent studies conducted in CRP, found that grasses increase, while forbs gradually decrease over time (Baer et al. 2002, Bach et al. 2012). This is not the only characteristic of these sites. Grimsbo Jewett et al. (1996) found that since CRP sites were once agricultural fields the density of nonnative/weedy species are higher, leading to increased competition with intentionally seeded species.

In addition, climate change may affect species distributions as time goes on. Climate change affects many things from average precipitation to seasonal temperature (Loarie et al. 2009, Trenberth 2011, Dai et al. 2018), but we need to understand how it will influence species' ranges. Every species has what is called a climate envelope that defines the conditions and geographic location under which it can currently exist (Hijmans and Graham 2006, Magness and Morton 2018). But with climate change, where the climate envelope/range exists on the landscape could shift through effects on species establishment success, overall growth, and phenology (Parmesan and Yohe 2003, Root et al. 2003, Craine et al. 2011). One step in understanding this range shift could be to see if species are occurring in the same space where they are seeded.

Specific aims

With this study we assessed program wide patterns in which species are seeded and how this translates to which species occur in a suite of grasslands throughout the Great Plains. We posed four main questions: By what component do target and observed species compositions vary (*e.g.,* species similarity, richness difference, species replacement)? How does age since enrollment affect species similarity, richness difference, and species replacement? How do seeded and observed species richness correlate with one another? What area are species seeded versus observed? For seeded species, I hypothesized that they would have high similarity and high richness difference between sites. Because CRP is seeded with relatively similar mixes that contain like species. As for observed species, I hypothesized that there will be high turnover, the change in species composition between sites, and low similarity between sites since each site is subject to different environmental factors and local propagule pools. Then, I hypothesized that as age of enrollment increases, species similarity will decrease, and species replacement will increase (higher turnover). The presence of local propagules, which mainly consists of nonnative/weedy species, causes competition leading to decrease in seeded species pool. As for where species establish, I hypothesized that there will be a shift in where species were intentionally seeded to where they are observed for all the top five intentionally seeded species. This means that seeded species will most likely not establish in all sites that it was seeded in, resulting in a shift in species range.

Methods

Study sites

We sampled 109 CRP sites (Figure 1) selected from the CRP enrollment database (USDA-FSA, Washington DC, Feb 2021) following methods described in Chapter 1. Briefly, we queried the database for sites that incorporated large block grassland conservation practice types (Table 1) and met geographic detail requirements (state, region, shape, and size). Geographic requirements included sites within nine selected states and three study regions (*e.g.*, Corn Belt, Northern Great Plains, Central Great Plains). From there, we selected sites that were 50 m from primary and secondary roadways, allowing for optimal site accessibility. Compact sites with smooth edges and rounder shapes were selected over wide only in one direction or more convoluted in shape sites to limit edge effect. The top sites by age for each region were then selected. Once we had final candidate sites selected, we contacted contract holders for permission to sample the sites through a combination of email and postal mail methods.

Seeding documents

We requested documents pertaining to management history, seed information, and site history from county NRCS field offices. We summarized contract data from the 109 CRP sites distributed throughout the Great Plains that spanned a 35-year enrollment history. For sites with available seeding information, we recorded which species were seeded to create a target species list for each site. If sites had either a history of interseeding or used of cover crop, we included those species if they were within the sites. From the files we requested we compiled two graphs that represent the distribution of Conservation Practices by state and by age (Figure 2).

Field surveys

We surveyed each site between June and August 2022 from South to North to control potential phenology differences as much as possible. Plant surveys were conducted by walking a 50 m × 50 m square in each field, each side of the 50 m × 50 m square was walked in one of the cardinal directions (*e.g.,* North, South, East, West). Along each side, we recorded each new plant species encountered within 1 m of that transect. The starting point for this survey was located at a previously designated coordinate 50 m from the road and adjacent field to minimize edge effects. Additionally, it was in an area of the site that was representative of vegetation present. If we were unable to identify plant species in the field, they were collected for later identification. This observed dataset was compared with the target species dataset, as specified by seed documents, to analyze species similarity, species replacement and richness difference between sites.

Data analysis

Species datasets were defined as target species and observed species, with the observed dataset further separated into two datasets – observed target species and observed nontarget species (Appendix A). Target species were species that were known to be seeded in a site based on contract documents that we received. We additionally noted if species used and encountered are considered native, introduced or both in the lower 48 states of the United States (plants.USDA.gov). Observed species are species that we recorded in the field and were classified as either observed target species or observed nontarget species. Observed target species are species observed within a site that were known to be seeded (*e.g.,* target species) based off contract seeding documents. Observed nontarget species are species observed within a site that were not seeded in CRP fields based off contract documents and are a part of local propagule pool. We separately defined target and non-target species for each site because some species that naturally occur on the landscape are still seeded (*e.g.,* alfalfa (*Medicago sativa* L.), Intermediate wheatgrass (*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey) and Red clover (*Trifolium pratense* L.)).

We ranked target species and observed species occurrence across the CRP sites and graphed the rank abundance curves using the ggplot2 package in R v3.4.1 (Wickham 2016, R Core Team 2022). The top five target species – Black-eyed Susan (*Rudbeckia hirta* L.), Purple prairieclover (*Dalea purpurea* Vent.), Sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), Little bluestem (*Schizachyrium scoparium* (Michx.) Nash) and Big bluestem (*Andropogon gerardii* Vitman) were used in our species range analysis described later.

To understand the relationship between target richness and observed target and non-target richness, we conducted a linear regression analysis. We used lm() function in basic R v3.4.1 for this analysis (R Core Team 2022). Then, ggplot2 package in R v3.4.1 was used to plot this analysis (Wickham 2016, R Core Team 2022). This analysis addresses the question: Is species loss and invasion consistent across the target richness gradient?

To explore patterns of species turnover in the target and observed species datasets, we conducted a pairwise comparison using partitioned beta diversity metrics – species similarity (S), richness difference (D), and species replacement (R) (Podani and Schmera 2011, Tóth et al. 2017, Podani et al. 2018). Species similarity (S), also known as Jaccard's similarity, is the species shared among sites (a) and divided by the total number of species present among all sites (n): $S_{Jac} = \frac{a}{n}$ (Podani and Schmera 2011, Legendre 2014, Podani et al. 2018). Richness difference (D) is the species that are different among sites. The number of species in each site (b = site 1 richness, c = site 2 richness) are subtracted from one another, then divided by total number of species among sites (n): $D_{rel} = \frac{|b-c|}{n}$ (Podani and Schmera 2011, Legendre 2014, Podani et al. 2018). Species replacement (R) is the minimum number of unique species among sites: $R = \frac{2\min\{b,c\}}{n}$ (Podani and Schmera 2011, Legendre 2014, Podani et al. 2018). Species replacement can also be calculated by taking $1 - S - D = R$, since S, D and R sum to 1. We visualized the SDR values for each pairwise site comparison in Simplex space with the ggtern package in R v3.4.1 (Hamilton and Ferry 2018, R Core Team 2022).

We also analyzed how species similarity (S), richness difference (D), and species replacement (R) change over time. We performed an SDR analysis that compared a site's target species to the site's observed species composition and graphed the outcome using the ggplot2 package in R v3.4.1 (Wickham 2016, R Core Team 2022). This analysis generated a dataset that contained species similarity, richness difference, and species replacement values that were used in a linear regression. We used lm() function in basic R v3.4.1 for this analysis (R Core Team 2022). Linear regression helped us to understand how these metrics change as sites age.

We conducted a Principal Components Analysis (PCA; PC-ORD, ver. 7, MjM Software Design, Gleneden Beach, OR) to identify the main axes of variation in species presence-absence matrices (McCune and Mefford 1999). The matrices used were target species, all observed species, observed target species, and observed nontarget species. These matrices contained species that were in ≥5% of sites, species that were in ≤5% of sites were removed. From there, we assessed to what extent age, latitude, longitude, soil moisture, bulk density, pH, Julian day of sampling, electroconductivity (EC), aggregate stability, vegetation biomass, and percent sand, silt and clay were correlated with the main axes of compositional variation. We also conducted a Multi-Response Permutation Procedures (MRPP) analysis to test practice and state effects on composition within each dataset.

With the top five most frequently seeded species, we conducted a species range analysis to compare their target and observed species range. We used the ggmap package in R v3.4.1 to map target and observed species ranges (Kahle and Wickham 2013, R Core Team 2022). From there, we calculated the average latitude and longitude for the target and observed species range to give us their centroids. We conducted two sample t-tests to analyze the differences in target and observed latitude and longitude for all five top target species using t.test() function in basic R v3.4.1 (R Core Team 2022).

Results

Species abundance and composition

In all, 166 species were seeded across the 109 sites studied. This includes native and introduced species. Introduced species seeded were most often Intermediate wheatgrass (*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey) and Red clover (*Trifolium pratense* L.) and seeded under CP25 (Rare and Declining Habitat) program. The top five most frequently seeded target species were Black-eyed Susan (*Rudbeckia hirta* L.) (68%), Purple prairieclover (*Dalea purpurea* Vent.) (67%), Sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.) (60%), Little bluestem (*Schizachyrium scoparium* (Michx.) Nash) (57%) and Big bluestem (*Andropogon gerardii* Vitman) (53%) (Figure 3a). We recorded 303 species when visiting the sites, 75 of which were from the target species pool. The top five observed species were Smooth brome (*Bromus inermis* Leyss.) (66%), Kentucky bluegrass (*Poa pratensis* L.) (61%), Big bluestem (*Andropogon gerardii* Vitman) (57%), Common milkweed (*Asclepias syriaca* L.) (53%) and Little bluestem (*Schizachyrium scoparium* (Michx.) Nash) (49%), two of which fell under the top five target species (Figure 3b).

Although sites that were intentionally seeded with more species had higher target species richness ($y = 0.324x + 15.1$, $R^2 = 0.2344$, $F_{1, 107} = 32.76$, $p < 0.001$; Figure 4), only two sites contained all target species and no sites contained more than 17 target species despite efforts to create communities with > 40 target species. There was no effect of target species richness on non-target species richness ($y = 0.0632x + 14.3$, $R^2 = 0.01248$, $F_{1, 107} = 1.352$, $p = 0.248$; Figure 4). However, observed target species richness increased as target species richness increased ($y = 0.26x + 0.775$, $R^2 = 0.5421$, $F_{1, 107} = 126.7$, $p < 0.001$; Figure 4).

Species turnover

Pairwise comparisons of species similarity, species replacement, and richness difference varied between target and observed species pools. The target species pool was characterized by high richness difference and species replacement among sites (Table 2, Figure 5a). In the observed species pool, species similarity was lower and species replacement was higher across sites than in the target species pool (Table 2, Figure 5b). The observed target analysis resulted in similar findings as the target species analysis, with only the species similarity decreasing slightly (Table 2, Figure 5c). Unlike the observed target analysis, the observed nontarget species were similar to the combined observed species analysis, meaning that the driving factor in that dataset was the observed nontarget dataset (Table 2, Figure 5d). It is important to note that species similarities (S_{jac}) for observed target and observed nontarget species were similar.

Age effect on beta diversity

We also asked how time since seeded in CRP affected species similarity, richness difference, and species replacement between target species and observed species (Figure 6). As age increased, richness difference increased between new and old sites, while species richness decreased. Species replacement was constant over time (y = 0.00461x + 0.25, R^2 = 0.00725, $F_{1, 107}$ = 0.7814, p = 0.379). Species similarity (y = -0.00262x + 0.198, R^2 = 0.06207, $F_{1, 107}$ = 7.082, p = 0.00899) and richness difference (y = -0.002x + 0.552, R^2 = 0.04011, $F_{1, 107}$ = 4.471, p = 0.0368) decreased over time.

Species composition analyses

We used PCA ordination to visualize variation in species composition within the target, observed, observed target, and observed nontarget species presence/absence matrices. The main axis for target species PCA explained 21.937% of variation among sites, while the second axis accounted for 9.496% variation (Figures 7a, 8a, 9a). Longitude was correlated with the first axis (Table 3; Figure 7a). Longitude was also correlated with the first axis in the PCA's of the observed, observed target, and observed nontarget species matrices (Table 3). Species composition in the North Dakota sites was notably defined by introduced species and the use of CP1 practice (*e.g.*, alfalfa (*Medicago sativa* L.), intermediate wheatgrass (*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey)), yellow sweetclover (Melilotus officianalis (L.) Lam.)), while Iowa predominantly used broader, more diverse species mixes, such as CP42 (Figures 8a and 9b). Similar to the target species matrix, the observed target species PCA (PC1 = 16.279%, PC2 = 6.412%) showed CP42 practices varied from other practices, and Iowa and North Dakota species composition varied from one another (Figures 7c and 8c). But unlike the target species matrix, plant biomass (main axis) and percent silt (second axis) were correlated with the PCA axes (Table 3) for observed target species. However, this was not the case for the observed species and observed nontarget PCAs (observed species matrix: PC1 = 9.816%, PC2 = 5.874%; observed nontarget species matrix: PC1 = 9.614%, PC2 = 6.412%). Hulls for each CP practice within observed species and observed nontarget matrices overlapped meaning these sites were compositionally similar (Figure 8b, d). Additionally, the second axis in both the observed and observed nontarget species PCAs were correlated with latitude (Figure 7b, d).

Practices varied in species composition in the target species presence-absence matrix (MRPP analysis; Table 4, 5) but compared to observed target species matrix the practices that varied the most were CP42 and CP1. For example, conservation practices 2 and 42 differed from one another in observed target species matrix ($T = -4.913$, $A = 0.0127$, $p = 0.0028$). As for observed and observed nontarget species matrices, there were few differences among practices.

Kansas most frequently differed in composition from other states in observed and observed nontarget composition. Kansas most strongly varied from Illinois (observed species: T = -2.587, A = 0.0272, p = 0.0105; observed nontarget species: T = -1.862, A = 0.0226, p = 0.0462). For the target species matrix, North Dakota most strongly differed from Colorado (T = -3.760, A = 0.0757, p = 0.0039). Iowa differed in the observed target species matrix from Minnesota (T = -2.089, A = 0.0099, p = 0.0378), while Missouri differed the most from Iowa (T = -3.743, A = 0.0257, p = 0.0039).

Species range shifts

Only Black-eyed Susan resulted in a significant shift between the target species range and the observed species range moving west to the east (Table 6, Figure 10).

Discussion

We compared target species and observed species to identify how species similarity, species replacement, and richness difference differ between CRP sites and change over time. We also asked if species composition differed by state or practice and to what extent major axes of variation in species composition were correlated with latitude, longitude, and age for target, observed, observed target, and observed nontarget species pools. The variation in target pools was correlated with a longitudinal gradient and with practices that range in richness and species composition. This is due to seed mixes being moderately prescribed by the CRP program, but for the most part locally determined between the NRCS FSA staff, any non-profit assistants (Pheasants Forever, Ducks Unlimited, etc.), local soil conservation districts and contract holder, and experience with sites, region, soils, and seed availability. This largely determines to what extent plants can be used to affect conservation outcomes. Unlike the target species pool, variation in the observed species pool was correlated with longitude (PCA 1; Figure 7b, 8b) and latitude (PCA 2; Figure 7b, 8b). Neither of the main axes of variation in the target or observed pools were correlated with age.

In all, 166 species were seeded across the 109 sites studied. This included native and introduced species. Introduced species were most often Intermediate wheatgrass (*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey) and Red clover (*Trifolium pratense* L.) and seeded under CP25 (Rare and Declining Habitat) program. Seeding with nonnative species, such as these, can increase competition with other seeded species, which in most cases leads to a decrease in success of other target species establishment and an increase in invasion of nonnative, weedy species (Grimsbo Jewett et al. 1996, Bakker et al. 2003, Fischer et al. 2013).

Seed supply and seeded species documentation were notable issues encountered while reviewing contract documents. In some regions, there was a single supplier providing seed. For instance, the Corn Belt region had a lot of Pheasants Forever (Hopkinton, IA) mixes (*e.g.,* IA mainly), while Central Great Plains had a lot of Star Seed Inc. (Osborne, KS) mixes (*e.g.,* CO, NE, KS). In some cases, where tags were supplied, seed originated from many locations and was not necessarily local. There are mixed views in the literature on seeding local (*e.g.,* collected within the same state/geographic region) vs. non-local seed in the literature. Many have argued a need to source seed locally since those seeds are presumed to be adapted to the local environment (Balazs et al. 2020, Harrison 2021, Ahlering and Binggeli 2022). However, others are exploring using non-local and local seed as a means of assisted gene flow, to combat climate change (Vitt et al. 2010, Aitken and Whitlock 2013, Breed et al. 2013, Bucharova et al. 2017b, Bucharova et al. 2019, McKone and Hernández 2021). However, the use of non-local seed in the CRP contracts I reviewed is most likely a response of suppliers getting the seed from wherever they could source it, not an intentional climate change mitigation decision. On top of where the seed is coming from, there needs to be more consistency in reporting on which species are being used. Some species, reviewed through contract documents, were labelled differently than what they were or were given a local common name, confirmed after contacting seed companies used. For example, one company listed Mexican hat (*Ratibida peduncularis* (Torr. & A. Gray) Barnhart) as a species seeded in their CRP mixes, but it was upright prairie coneflower (*Ratibida columnifera* (Nutt.) Wooton & Standl.) that was seeded.

It is no surprise that there is variation in target richness due to differences in practice specifications. But once sites are established, does this go away? We found that the higher the target richness is, the higher the observed richness is within a site. But this richness gain is limited, only 17 species established at most, despite efforts to incorporate over 40 species at some sites. Multiple studies have found that an increase in functional group diversity within a seed mix causes a decrease in undesired/weedy species, while also creating greater productivity (Manchester et al. 1999, Pokorny et al. 2005, Piper et al. 2007, Garrett and Gibson 2020), but we did not find an effect of increasing richness on species recruitment from the nontarget species pools, though this could be cause of functional group abundance. Additionally with CRP's attempt to seed different seed mixes that have different species richness's across the Great Plains, we assumed that species variation between sites would be different between practices. This was not true based on our findings. Even though sites were seeded with different practices, with different aims, they ultimately did not differ from one another based off our observed data. This is most likely caused by local propagule pressure within sites, which can increase competition with the target species pool (Bakker et al. 2003, Mangla et al. 2011). This pressure can vary between regions by latitude, as found by Martin and Wilsey (2015).

We also analyzed how richness differed among sites, how species similarity changed and how species replacement changed. Sites were initially seeded to vary in what species were used and how many species were used based on the practice implemented, which lead to low similarity among sites, and moderate richness difference and species replacement. This was not the case for what we observed. We found that among sites there was very low similarity and high turnover, which was influenced by the observed nontarget species pool. High turnover is commonly associated with pressure from the local species pool that contains mainly undesired, weedy species that can outcompete the intended seeded species (Bakker et al. 2003, Mangla et al. 2011, Fischer et al. 2013). Because we knew that there was a change in similarity, species replacement, and richness difference between target species pool and observed species pool the next step was to understand if age influenced these changes within the site. Over time, species similarity decreased, and richness difference increased. This suggests that as sites get older the pressure from local propagule pools introduces new species that caused an increase in richness difference and decrease in species similarity between species intentionally seeded to what was observed. As sites age, species richness decreased from the influence of weedy species outcompeting native species and, in some cases, the limited diversity of the initial seed mix (Lepŝ et al. 2007, Lengyel et al. 2012).

From our analysis, we found that there is a mismatch between seeding and establishment that needs to be addressed. With climate change planning there is a lot of interest in rescuing species and moving them (Vitt et al. 2010, McKone and Hernández 2021, Ahlering and Binggeli 2022). For instance, within CRP black-eyed Susan (*Rudbeckia hirta* L.) showed a significant shift that reflected poor establishment in a particular state, which was Nebraska where they were intentionally trying to seed black-eyed Susan toward the western part of the state where it was not establishing/seen. There were also other sites that were within Nebraska that we sampled but did not receive seeding information on. Even in those sites, black-eyed Susan (*Rudbeckia hirta* L.) was not observed. This might be a seeding issue, sample time issue and/or sampling structure issue.

All functionality aside, these issues need to be addressed because of the cost involved (Ahlering and Binggeli 2022). The most expensive species seeded was alumroot (*Heuchera richardsonii* R. Br.; Page County, IA; Seeding Plan sheet) but was one of the species that was never observed. This has financial implications. The five most common species range in price from $6.89 to $45.03 per pound while the rarest used species (alumroot (*Heuchera richardsonii* R. Br.)) at $16,209 per pound and the rarest observed species (heart-leaved golden alexander (*Zizia aptera* (Gray) Fern.)) at $9,349.20 per pound. CRP is investing money in these species, and we are not observing them on the ground. Studies have addressed this issue of what to seed and what species to seed together, it all comes down to seed availability, aim of restoration and how diverse of a mix is used (Török et al. 2011, Broadhurst et al. 2015). Practitioners and land managers can create many kinds of seed mixes, but the success of what they seed can come down to the overall composition of that mix, the availability of seed used, and management. Ahlering and Binggeli (2022) suggest that one way to increase availability of seed is through partnering with other collaborators, which in turn decreases seed costs.

Now with all of that said no doubt we need high diversity on the landscape (Loreau et al. 2001, Hooper et al. 2005, Eisenhauer et al. 2016), but the program may not be delivering on goals to create diverse plant communities, which we need in order to restore ecosystem functions on these landscapes. Our findings suggest that practitioners select target species based on a longitudinal gradient, which does influence observed species composition among sites. But observed species also had a latitudinal influence on variation in species composition, which is likely caused by local propagule pool presence and target species establishment success. Other studies have found latitudinal gradients in species turnover and composition with main influences directed by environmental factors such as temperature, day length, and soil nutrients (Bognounou et al. 2010, Reed et al. 2019, Nishizawa et al. 2022). We suggest that practitioners consider latitudinal variation when constructing seeding plans in CRP sites, so that what is chosen will have a higher establishment success in the future and can compete with local species pool. And when they choose the species to seed, they should consider species that are more common, since our observation of rare species was very minimal, and those species are usually the most expensive. In summary, changes are needed in seeding and management practices to increase seeded species retention and abundance and how local weed species are considered and managed during CRP establishment.

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Table 1: Summary of the seven large-block Conservation Practices (CP) associated with the USDA-CRP program that establish or maintain perennial grassland cover on qualified cropland and addressed within this study (Agriculture 2012, Stubbs 2014). PLS = Pure live seed.

Practice Code	Practice Name	Purpose	Notes
CP1	Establishment of Permanent Introduced Grasses and Legumes	Establish new or maintain existing cover of introduced grasses and legumes	
CP2	Establishment of Permanent Native Grasses	Establish new or maintain existing cover of native grass species	
CP4D	Permanent Wildlife Habitat	Establish new or maintain existing wildlife habitat cover	Can include woody vegetation
CP10	Grass Already Established	Used for land that already has established grass cover upon contracting	Not offered after March 14, 2011
CP25	Rare and Declining Habitat	Restore the functions and values of approved critically endangered, endangered, and threatened habitats	Specifications determined at the state level.
CP42	Pollinator Habitat	Establish habitat to support a diversity of pollinator species	Limited to 10 acres/tract with 0.50-acre min. Must contain at least 9 pollinator-friendly wildflowers, legumes, and/or shrubs. Must include at least one early, mid, and late season blooming species and no more than 50% native grasses based on PLS/ft^2
CP38E	State Acres for Wildlife Enhancement (SAFE) - Grass	Apply practices to eligible lands where the habitat can be restored and maintained as determined by the state developed standard	For our purposes, only considered sites where CP2, CP4D, CP10, CP25, or CP42 was used

Table 2: Results of pairwise comparison among sites using partitioned beta diversity metrics, species similarity (S_{jac}), richness difference (D_{rel}), and species replacement ($ß_{rel}$) (Podani and Schmera 2011, Tóth et al. 2017, Podani et al. 2018, Farrell et al. 2021), for target, observed, observed target, and observed nontarget species datasets.

Dataset	Species similarity (S_{jac})	Richness difference (D_{rel})	Species replacement ($ß_{rel}$)
Target Species	16.25	43.00	40.75
All Observed Species	12.49	25.24	62.26
Observed Target Species	9.99	40.81	49.21
Observed Nontarget Species	9.68	27.70	62.62

Table 3: Correlations of site environmental characteristics with the first two (1, 2) axes of compositional variation for PCAs of target, observed, observed target, and observed non-target datasets. We assessed the extent that age, latitude, longitude, soil moisture, bulk density, pH, Julian day, electroconductivity (EC), aggregate stability, vegetation biomass, and percent sand, silt and clay were correlated with the first and second axis in each PCA.

Variable	Target Species		Observed Species		Observed Target Species		Observed Nontarget Species	
	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2
Site Age	0.280	-0.045	-0.069	0.154	-0.175	-0.084	-0.109	0.047
Latitude	0.112	-0.163	0.073	0.624	-0.168	-0.130	-0.140	0.486
Longitude	-0.635	-0.106	-0.834	-0.107	0.553	-0.416	-0.717	0.240
Soil Moisture	-0.198	-0.050	-0.217	0.012	0.201	-0.265	-0.173	0.069
Bulk Density	0.005	0.086	0.088	-0.079	-0.047	-0.024	0.115	0.055
Julian Day	-0.127	-0.054	-0.175	-0.114	0.172	-0.237	-0.089	0.115
pH	-0.123	-0.062	0.009	-0.128	0.078	-0.069	0.061	0.044
EC	0.064	-0.112	0.005	0.183	-0.100	-0.114	-0.068	-0.133
Aggregate Stability	-0.280	-0.087	-0.248	0.015	0.216	-0.241	-0.182	-0.004
Percent Sand	-0.161	0.090	0.025	-0.216	0.110	0.091	0.102	0.076
Percent Clay	-0.124	0.016	-0.228	0.007	0.170	-0.247	-0.195	0.082
Percent Silt	-0.024	-0.111	-0.181	0.215	-0.025	-0.343	-0.198	-0.041
Plant Biomass	-0.313	-0.014	-0.263	-0.171	0.314	-0.180	-0.156	0.209

Table 4: Results from MRPP analysis testing effects of practice on plant composition for the target, observed, observed nontarget, and observed target species matrices. (* = p < 0.05; ** = p < 0.01; *** = p < 0.001)

Pairwise Comparison	Target Species		Observed Species		Observed Target Species		Observed Nontarget Species	
	T	A	T	A	T	A	T	A
25 v 1	-17.72	0.1327 ***	-7.111	0.0267 ***	-12.77	0.08382 ***	-1.922	0.0072 *
25 v 4D	-6.657	0.0311 ***	-3.451	0.0094 **	-2.8583	0.01247 *	-1.940	0.0055 *
25 v 2	-8.535	0.0396 ***	0.3458	-0.0009	-0.5688	0.0026	0.5163	-0.0015
25 v 10	-2.780	0.0240 *	0.5797	-0.0029	-0.2498	0.0017	0.0656	-0.0003
25 v 42	-15.70	0.0739 ***	-5.981	0.0144 ***	-6.6806	0.02544 ***	-3.829	0.0098 **
1 v 4D	-5.513	0.0564 **	-1.854	0.0088	-6.1474	0.05863 ***	-0.2024	0.0009
1 v 2	-12.24	0.1065 ***	-4.192	0.0186 **	-9.4745	0.1029 ***	-0.8208	0.0036
1 v 10	-3.153	0.0818 *	-1.391	0.0159	-3.0386	0.08627 *	-0.1423	0.0016
1 v 42	-18.15	0.1981 ***	-11.405	0.0484 ***	-15.77	0.1367 ***	-4.4076	0.0176 **
4D v 2	-3.686	0.0210 **	-0.0416	0.0001	-2.362	0.01424 *	0.5501	-0.0016
4D v 10	-0.706	0.0093	0.2452	-0.0016	0.1687	-0.0019	0.3078	-0.0018
4D v 42	-12.07	0.0755 ***	-7.640	0.0231 ***	-9.263	0.04570 ***	-1.5090	0.0046
2 v 10	-1.201	0.0113	0.6552	-0.0037	0.2088	-0.0025	-0.0808	0.0005
2 v 42	-17.11	0.1086 ***	-4.913	0.0127 ***	-7.293	0.03627 ***	-1.9393	0.0053 *
10 v 42	-6.614	0.0680 ***	-3.165	0.0142 **	-3.562	0.02637 **	-2.447	0.0125 *

Table 5: Results from MRPP analysis testing effects of state on plant composition for the target, observed, observed nontarget, and observed target species matrices. (* = p < 0.05; ** = p < 0.01; *** = p < 0.001)

Pairwise Comparison	Target Species		Observed Species		Observed Target Species		Observed Nontarget Species	
	T	A	T	A	T	A	T	A
NE v CO	-1.178	0.0164	-0.5345	0.0040	-0.6161	0.0071	-0.8221	0.0054
NE v KS	-8.784	0.0785 ***	-7.618	0.0317 ***	-3.929	0.0279 **	-9.573	0.0419 ***
NE v IA	-13.16	0.0581 ***	-13.89	0.0331 ***	-10.955	0.0430 ***	-12.93	0.0331 ***
NE v SD	-3.102	0.0289 *	-1.895	0.0105 *	-0.9961	0.0078	-2.832	0.0153 *
NE v MO	-1.745	0.0230	-3.939	0.0265 **	-4.5015	0.0501 **	-3.010	0.0186 **
NE v IL	-1.322	0.0220	-0.9440	0.0089	-1.326	0.01817	-0.7386	0.0064
NE v MN	-7.176	0.0540 ***	-7.729	0.0380 ***	-2.947	0.02043 **	-9.672	0.0476 ***
NE v ND	-15.94	0.1778 ***	-8.716	0.0368 ***	-10.507	0.0847 ***	-3.057	0.0120 **
CO v KS	-0.470	0.0149	-3.247	0.0285 **	0.1676	-0.0042	-3.256	0.0318 **
CO v IA	-3.276	0.0273 **	-6.413	0.0232 ***	-2.868	0.0202*	-5.599	0.0223 ***
CO v SD	0.4969	-0.013	-1.491	0.0288	0.1291	-0.0037	-2.459	0.0543 *
CO v MO	-2.568	0.0898 *	-2.934	0.0892 *	-2.405	0.1596 *	-2.672	0.0753 *
CO v IL	-1.954	0.0460 ***	-1.510	0.0601	-1.200	0.0265	-1.617	0.0676
CO v MN	-3.162	0.0586	-4.109	0.0513 **	-1.271	0.0234	-4.540	0.0616 **
CO v ND	-3.760	0.0757 **	-1.702	0.0181	-1.629	0.0438	-1.565	0.0173
KS v IA	-15.02	0.0905 ***	-19.76	0.0558 ***	-10.51	0.0525 ***	-18.19	0.0534 ***
KS v SD	-4.382	0.0714 **	-7.717	0.0578 ***	-2.338	0.0321 *	-8.027	0.0663 ***
KS v MO	-1.582	0.0435	-4.809	0.0404 ***	-3.581	0.0791 **	-2.925	0.0246 **
KS v IL	-0.409	0.0156	-2.588	0.0272 *	-0.1181	0.00363	-1.862	0.0226 *

Table 5: Cont.

Pairwise Comparison	Target Species		Observed Species		Observed Target Species		Observed Nontarget Species	
	T	A	T	A	T	A	T	A
KS v MN	-9.149	0.1235 ***	-10.88	0.0697 ***	-3.4602	0.0368 **	-11.28	0.0793 ***
KS v ND	-12.59	0.2120 ***	-14.07	0.0930 ***	-8.091	0.1153 ***	-10.51	0.0631 ***
IA v SD	-6.939	0.0443 ***	-7.636	0.0224 ***	-4.767	0.0264 ***	-5.812	0.0184 ***
IA v MO	-0.739	0.0057	-1.702	0.0055	-3.743	0.0257	-0.6930	0.0024
IA v IL	-0.799	0.0076	-0.3871	0.0016	-1.568	0.0133	0.0682	-0.0003
IA v MN	-7.541	0.0389 ***	-7.558	0.0187 ***	-2.089	0.0099 *	-7.154	0.0193 ***
IA v ND	-20.79	0.1555 ***	-21.52	0.0673 ***	-19.41	0.1214 ***	-12.45	0.0358 ***
SD v MO	-2.042	0.0561 *	-3.064	0.0475 **	-3.149	0.0990 **	-2.315	0.0360 *
SD v IL	-1.066	0.0353	-0.8093	0.0195	-0.5285	0.0177	-0.8491	0.0229
SD v MN	-3.679	0.0490 **	-2.725	0.0222 *	-0.8127	0.0106	-2.649	0.0250 *
SD v ND	-6.254	0.1021 ***	-2.5100	0.0188 *	-3.335	0.0507 **	-1.077	0.0087
MO v IL	0.3904	-0.017	1.291	-0.0222	-1.387	0.0921	1.379	-0.0271
MO v MN	-1.563	0.0290	-3.994	0.0379 **	-3.790	0.0786 **	-2.700	0.0249 *
MO v ND	-8.300	0.1915 ***	-7.352	0.0763 ***	-6.505	0.1890 ***	-4.369	0.0398 ***
IL v MN	-1.421	0.0339	-0.7116	0.0092	-1.126	0.0275	-0.6680	0.0089
IL v ND	-4.361	0.1129 **	-2.450	0.0309 *	-1.777	0.0632	-1.612	0.0203
MN v ND	-14.48	0.2504 ***	-9.807	0.0701 ***	-8.908	0.1245 ***	-6.766	0.0441 ***

Table 6: Results of two-sample t-test between target and observed latitude and longitude for all five target species. The top five species were Black-eyed Susan (*Rudbeckia hirta* L.), Purple prairie clover (*Dalea purpurea* Vent.), Sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), Little bluestem (*Schizachyrium scoparium* (Michx.) Nash) and Big bluestem (*Andropogon gerardii* Vitman).

Scientific Names	Latitude			Longitude		
	t	df	p	t	df	p
Rudbeckia hirta L.	-0.20203	111	0.8403	-2.9429	111	0.00396*
Dalea purpurea Vent.	-0.97276	96	0.3331	-0.25329	96	0.8006
Bouteloua curtipendula (Michx.) Torr.	0.46491	85	0.6432	1.2128	85	0.2286
Schizachyrium scoparium (Michx.) Nash	1.309	97	0.1936	0.93871	97	0.3502
Andropogon gerardii Vitman	-0.017534	101	0.986	-0.54977	101	0.5837

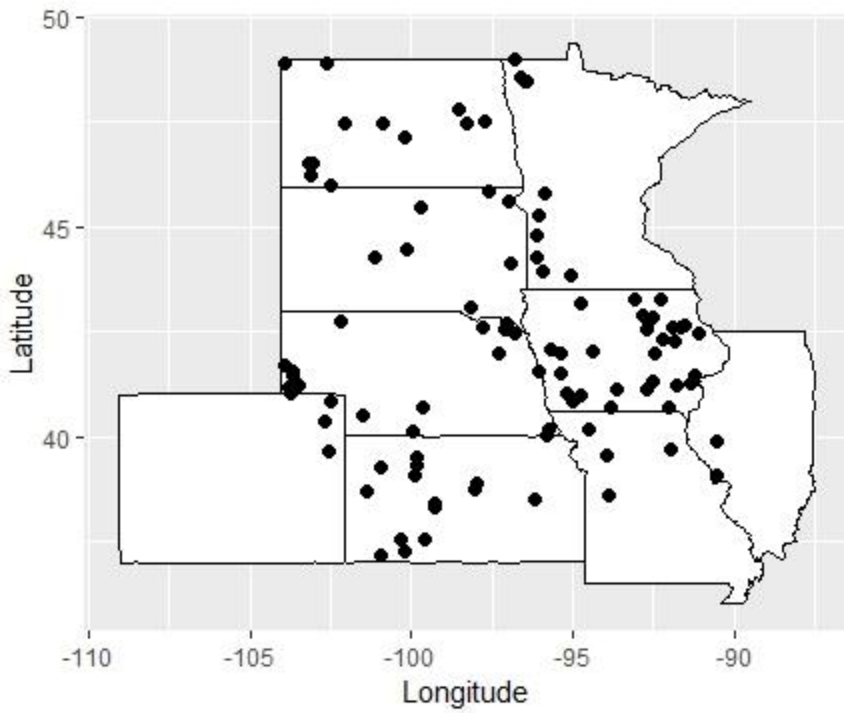

Figure 1: Map of the 109 CRP sites used in this study.

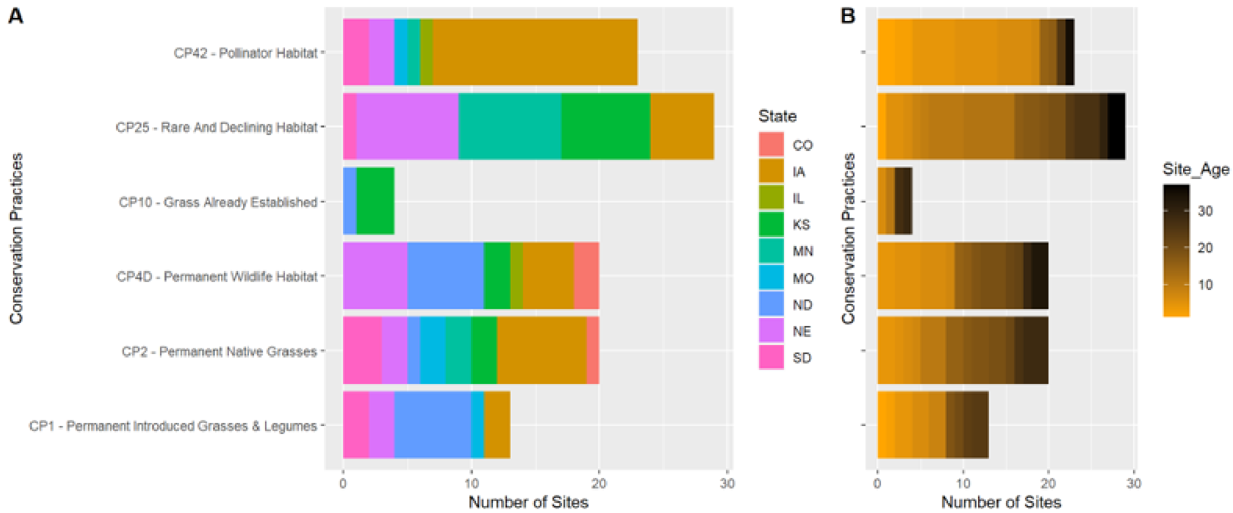

Figure 2: Distribution of Conservation Practices (CP) among study sites by (a) state and (b) age. Conservation Practices addressed within this study include CP1 (establishment of permanent introduced grasses and legumes), CP2 (establishment of permanent native grasses), CP4D (permanent wildlife habitat), CP10 (grass already established), CP25 (rare and declining habitat), and CP42 (pollinator habitat).

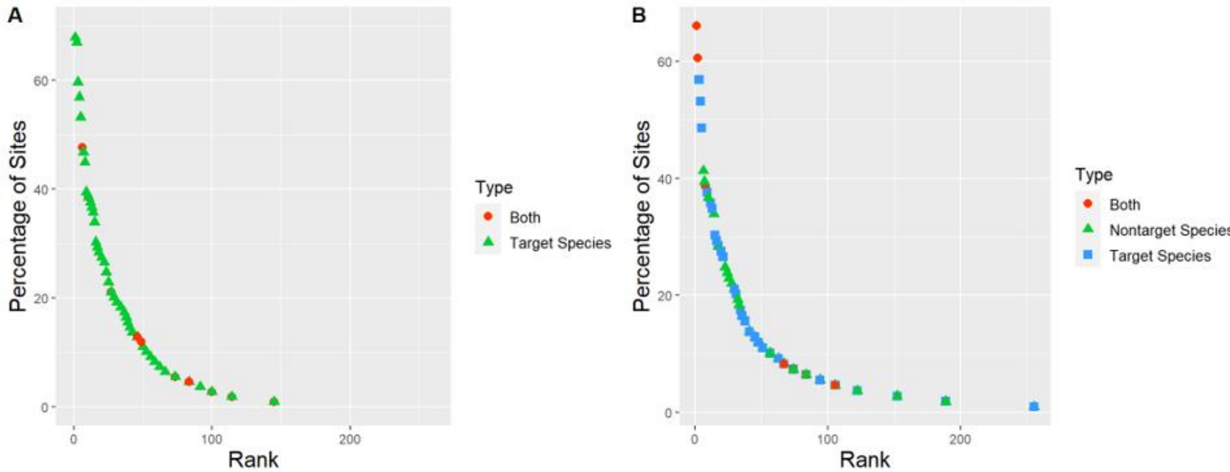

Figure 3: Percentage of sites species were (a) seeded and (b) observed by rank. Species on this graph are separated by target species or both. Target species are species seeded in CRP sites based off contract seeding documents. Species considered both are species that were seeded in CRP sites but are considered introduced or native/introduced by plants.USDA.gov and can establish without the need to be seeded.

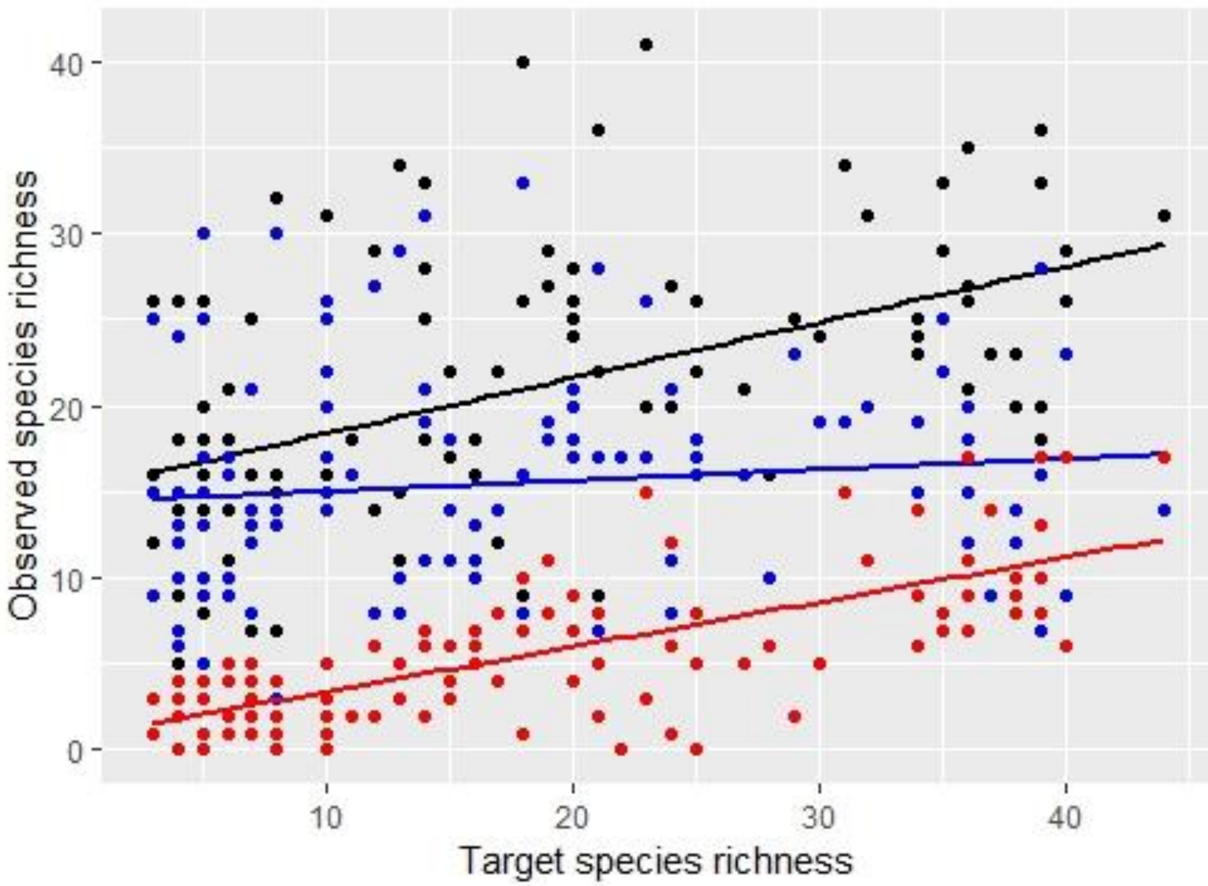

Figure 4: Effect of target species richness on observed and nontarget species richness. Sites seeded with more species had higher observed species richness (black; y= 0.324x + 15.1, R^2 = 0.2344, $F_{1, 107}$ = 32.76, p < 0.001). Target species richness did not affect non-target species richness (blue; y = 0.0632x +14.3, R^2 = 0.01248, $F_{1, 107}$ = 1.352, p = 0.248). Sites seeded with more species had greater target richness (red; y = 0.26x +0.775, R^2 = 0.5421, $F_{1, 107}$ = 126. 7, p < 0.001).

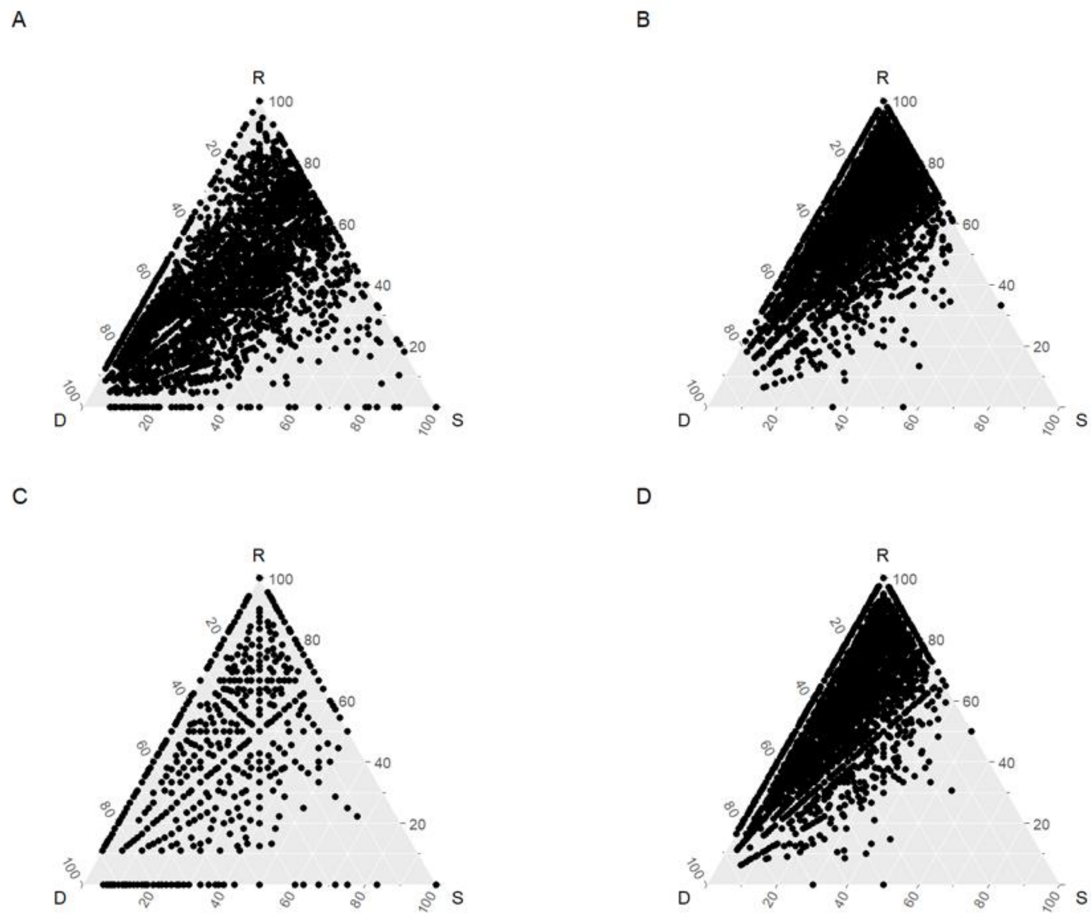

Figure 5: SDR (similarity (S), richness difference (D), and species replacement (R)) values graphed in simplex space for pairwise comparisons among CRP sites for (a) target, (b) observed, (c) observed target, and (d) observed nontarget species pools.

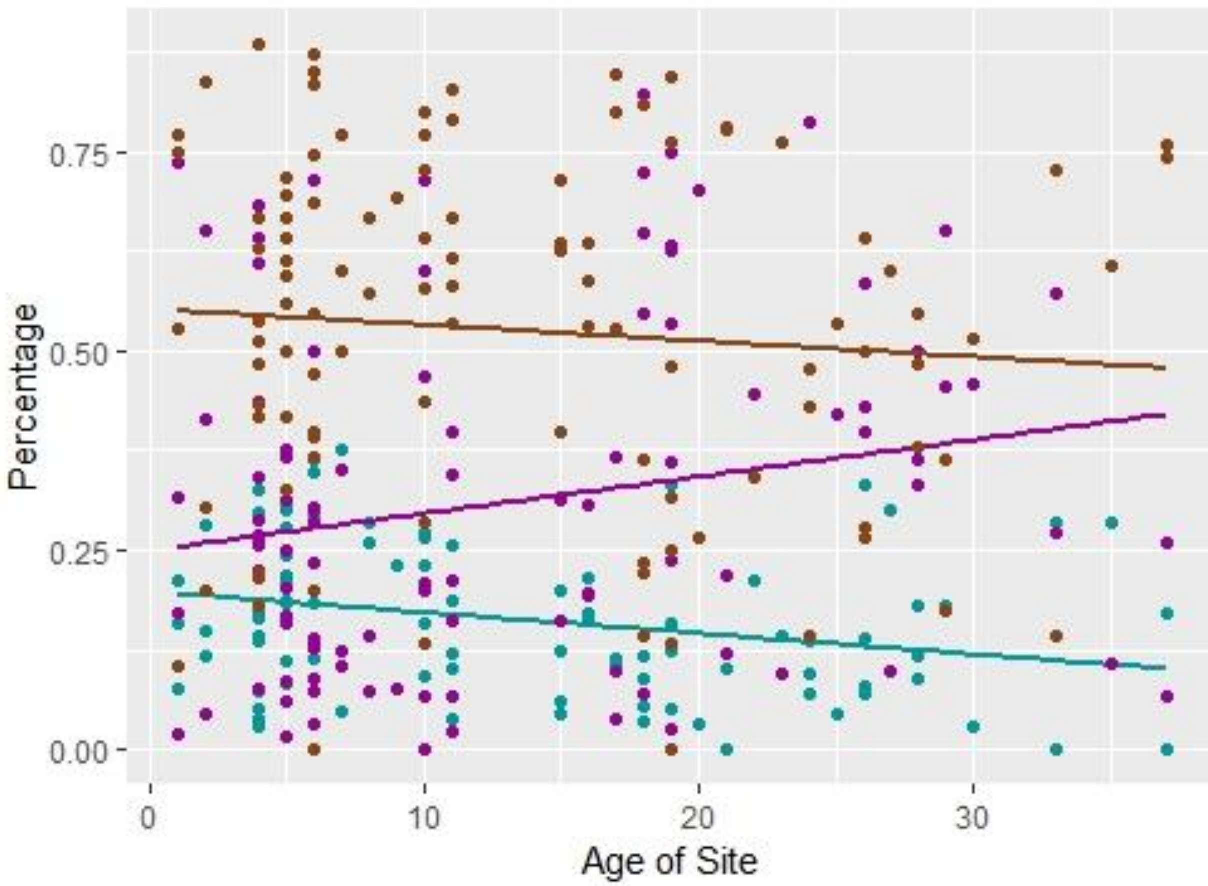

Figure 6: Effect of time in CRP on species similarity (blue), richness difference (purple) and species replacement (brown) between target and observed species pools. Species replacement was constant over time ($y = 0.00461x + 0.25$, $R^2 = 0.00725$, $F_{1, 107} = 0.7814$, $p = 0.379$). Species similarity ($y = -0.00262x + 0.198$, $R^2 = 0.06207$, $F_{1, 107} = 7.082$, $p = 0.00899$) and richness difference ($y = -0.002x + 0.552$, $R^2 = 0.04011$, $F_{1, 107} = 4.471$, $p = 0.0368$), on the other hand, increased over time.

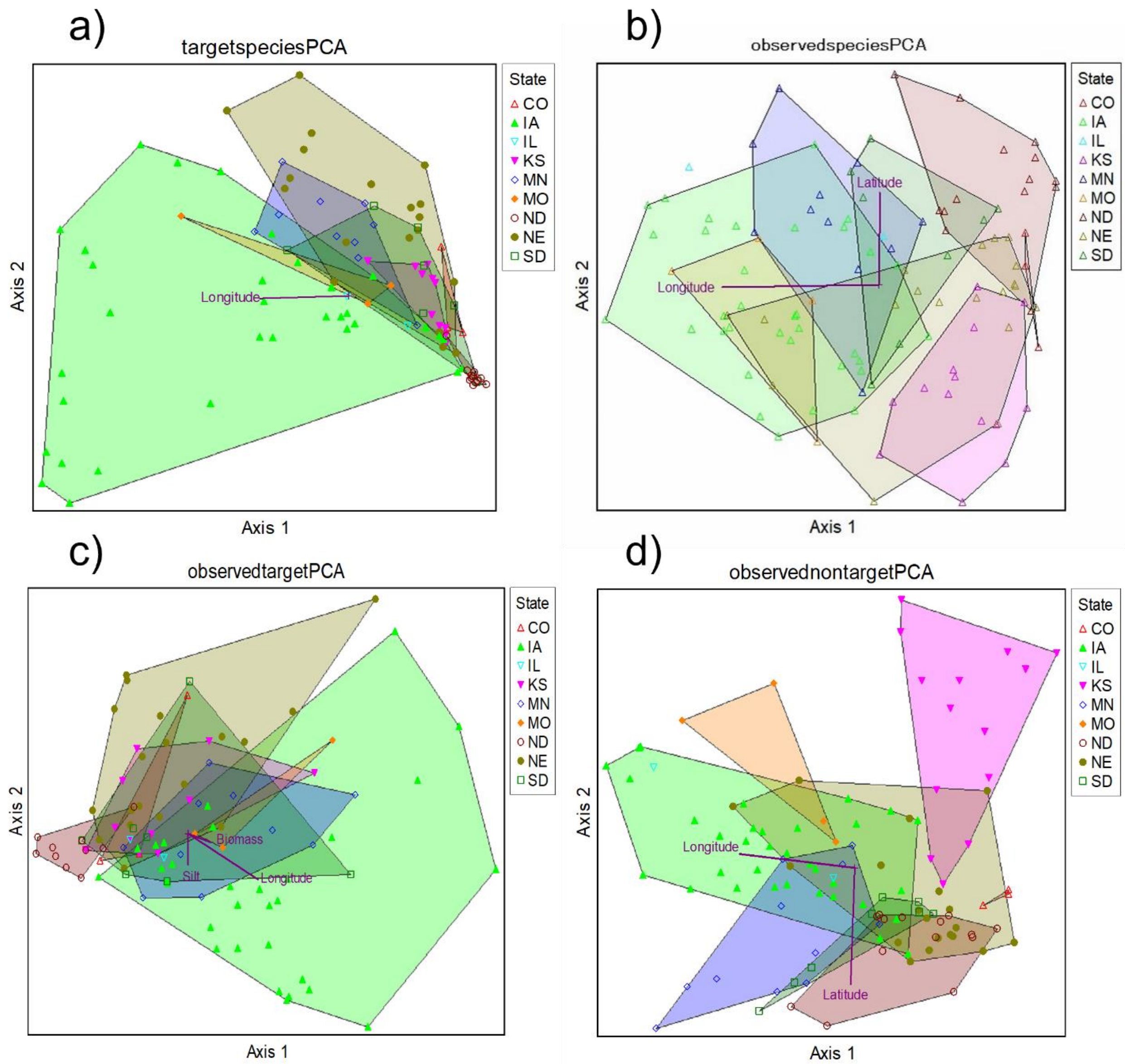

Figure 7: Ordination of (a) target, (b) observed, (c) observed target, and (d) observed nontarget plant species matrices with sites grouped by state. Arrows show loadings with environmental variables correlated with each axis.

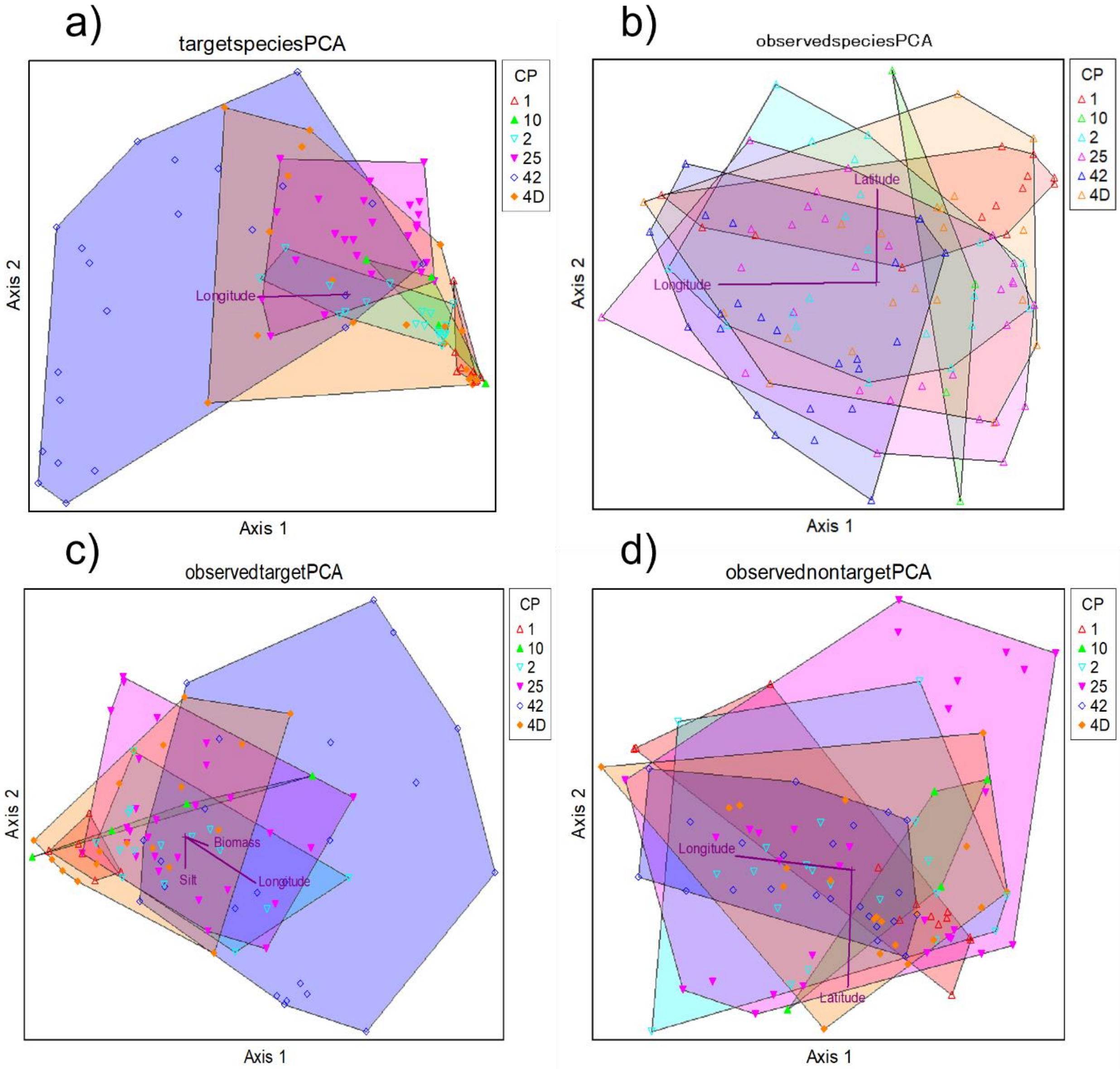

Figure 8: Ordination of (a) target, (b) observed, (c) observed target, and (d) observed nontarget species matrices with sites grouped by Conservation Practice. Arrows show loadings with environmental variables correlated with each axis.

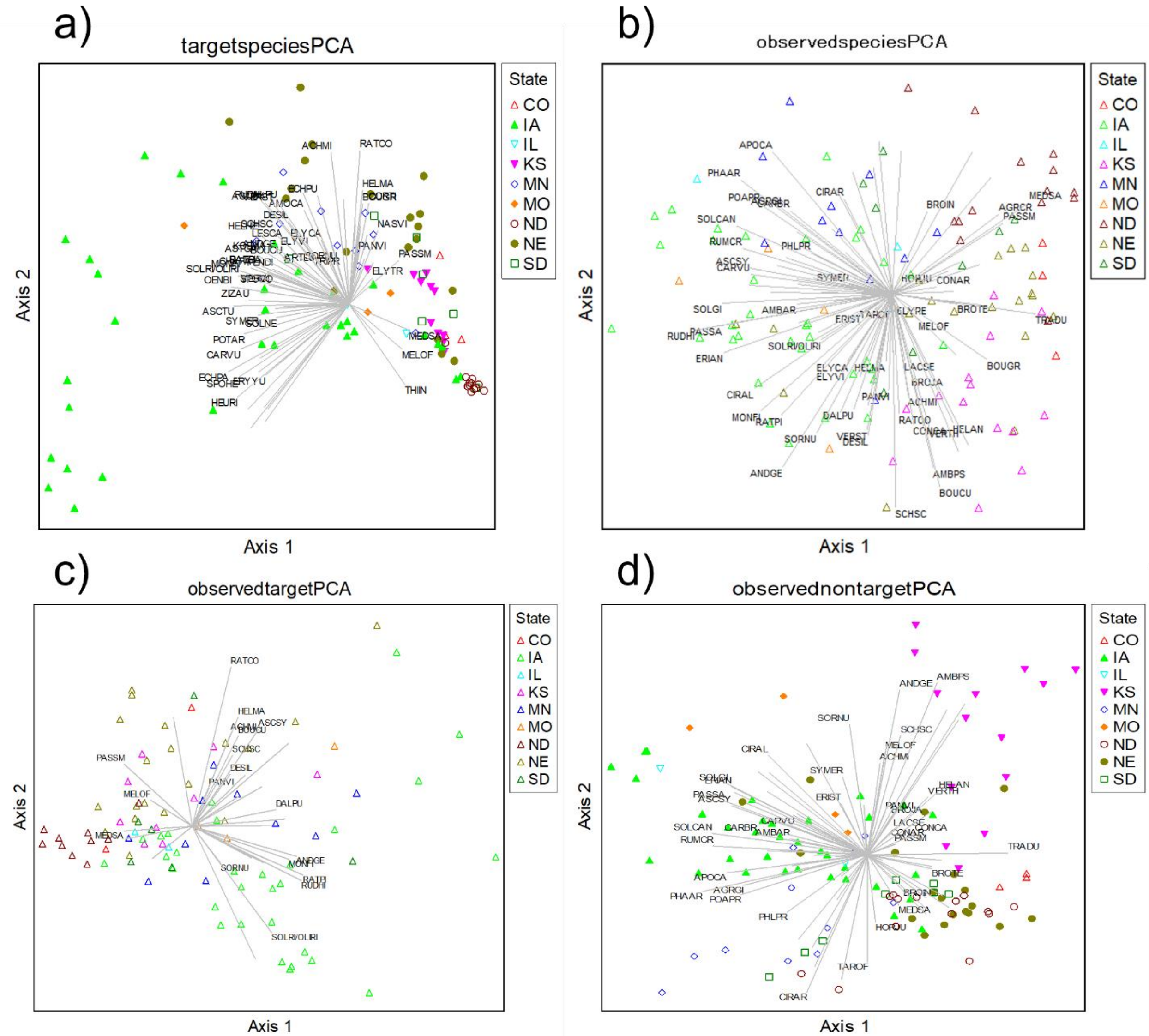

Figure 9: Ordination of (a) target, (b) observed, (c) observed target, and (d) observed nontarget species matrices showing the species most strongly correlated with the first two PCA axes. Sites are grouped by site.

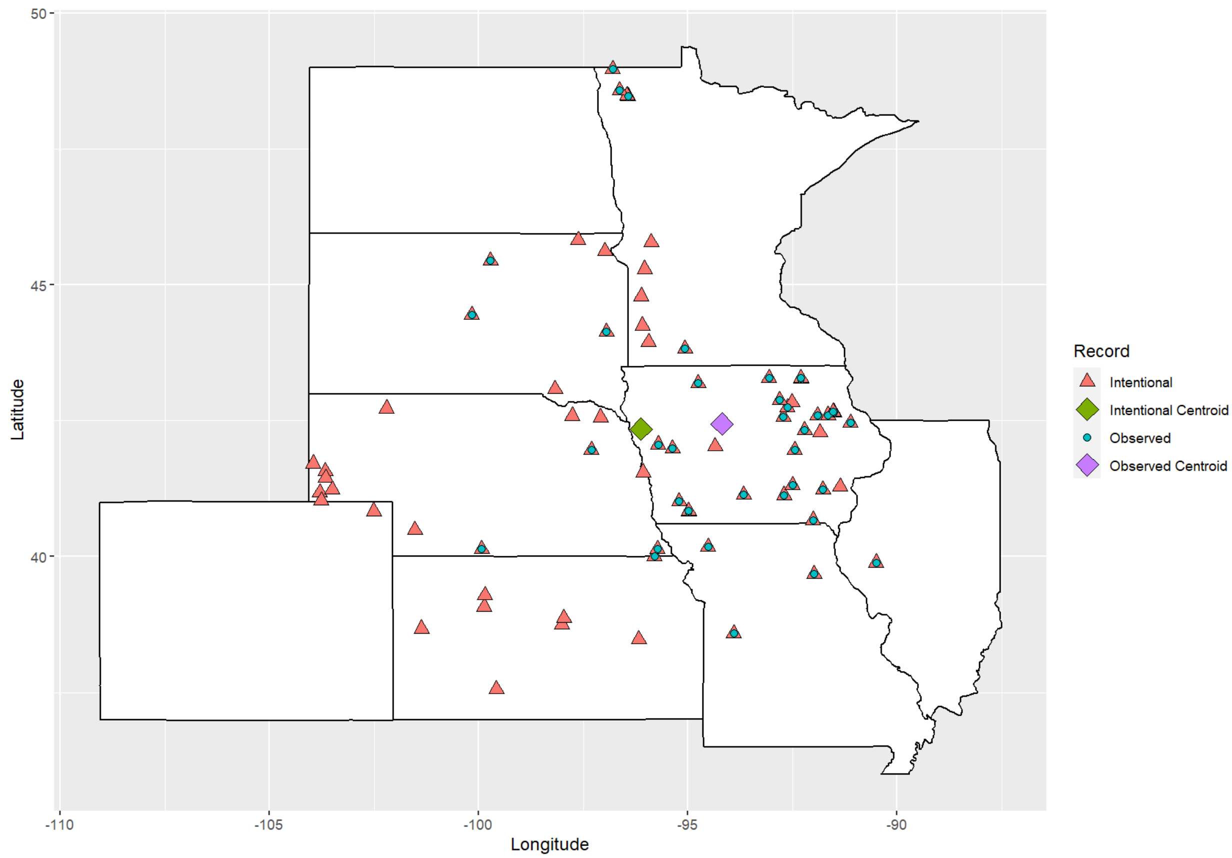

Figure 10: Sites where Black-eyed Susan (*Rudbeckia hirta* L.) was intentionally seeded (red triangles) and observed (blue dots). The average latitude and longitude location for the seeded (green diamond) and observed (purple diamond) datasets are shown.

CHAPTER 3

SUMMARY AND IMPLICATIONS FOR THE CONSERVATION RESERVE PROGRAM

Summary

The Conservation Reserve Program (CRP) aims to improve water quality, wildlife habitat, and soil health. There have been many studies conducted in this program that pertain to wildlife and soil health, specifically, but not many studies emphasize how what is seeded affects site establishment and composition. So, my aim was to understand how what was seeded compares to what was observed on CRP sites. I did this in hopes that our findings would be informative for the continuation of this program.

At the start of this project, the initial field survey design for Summer 2021 was inadequate for capturing site species composition. The first year of sampling became a test run to see what was needed to create a better sampling survey structure for the second sample year. We surveyed plant species in two plots (*e.g.*, Plot A, Plot B) and any species that we encountered along a 10 m transect and/or were within the site, but not in the plots. While good for gathering plant biomass and generating a preliminary species list, it did not encompass a substantial area within sites. So, I came to ask if there was a better way to sample the species composition in CRP sites. Was the species composition identified in the first-year representative of the entire field? Yes, there are sites that were filled with smooth brome (*Bromus inermis* Leyss.), reed canarygrass (*Phalaris arundinacea* L.) or alfalfa (*Medicago sativa* L.), but for those sites that visibly had higher abundance of species, was I capturing those species? And did my survey represent those sites? With that, I expanded the sampling so that instead of covering the small area that was surveyed the first year, I tested out (at University of North Dakota Oakville Prairie, Grand Forks, ND) a new survey idea that increased the area that was covered and identified more species within the site. The idea is that as you increase sample area, you will encounter more species until you have encountered all of the potential species on a site (*e.g.*, species area curve). So, this change included a 50 m × 50 m square walk-through that started from the initial plot A position and ended at that same position. This change improved my assessment of species composition for each site, from 13 max species observed in 2021 to 42 max species observed in 2022, and in my opinion did improve on understanding the species composition of sites visited.

With the species identification done, I separated the data into different datasets. But finding the best way to do this did come with its difficulties. We first entertained the idea of separating the species by native and nonnative based on plants.USDA.gov, but this proved difficult because not all species are considered just native or nonnative throughout the United States. Some species are considered both, since they are commonly native to only a few states and have over time been introduced to areas/states that they are not native to. Along with that, CRP does not seed just native species, the program does include species that are considered nonnative/introduced, so distinguishing between the two scenarios in the analyses would be challenging. So, we shifted gears and thought of separating the species as seeded and observed. The logic for this was that seeded would mean species that are seeded in CRP sites based on contract documents and it would address the issue of nonnative/introduced species seeded among native species. Observed species would be any other species that we did not have seeding information on and would include both native and nonnative/introduced species. This worked in part, but there was still something that was missing because the idea of defining something as seeded means that it was seeded on the site. But that is not always true. As we learned from a meeting with the Grand Forks NRCS office, not all seed for a particular contract is seeded. There are cases where producers inadvertently divert from a seeding plan presumably from a lack of experience with these types of plants. Additionally, since the equipment used is specifically made for farming, adjusting it to native grassland seeding does give some drawbacks (*e.g.*, drilling depth). Eventually, I ended up reviewing the literature and came across the use of target species and nontarget species to define seeding information. Target species are species that are seeded in the landscape, while nontarget species are not. There were some species that we put in both target and nontarget species pools because these were species that can establish on their own without the need to seed (*e.g.*, smooth brome (*Bromus inermis* Leyss.), alfalfa (*Medicago sativa* L.), yellow sweetclover (*Melilotus officinalis* (L.) Lam.)). So, when we analyzed our results for the final time we had four datasets – target, observed, observed target, and observed nontarget species pools.

To analyze our datasets, we initially were going use both the Pacific Northwest and Great Plains. But with time restraints and other issues, we removed the Pacific Northwest. Seeding documents for that region were not made available to us. Plus, the vegetation in that region is entirely different from the Great Plains, so there would be a slight difference in species composition when compared to one another. Now with just the Great Plains, we initially wanted to visualize the difference between regions, states, and ages, and eventually added in practice type. After some deliberations and preliminary data analysis, we decided that region would be taken out because it did not explain how species composition and diversity varied among sites, as well as how the states, age, and practice type did. The one drawback though with our 109-site dataset was that we were unable to do a balanced state by state or practice by practice analysis because states and practice type were confounded, but by using multi-response permutation procedure (MRPP) analysis did give an analysis of that difference. Though in the future, an analysis looking state by state and practice by practice would be very informative on how plant community composition differs within states and within practices. This could also bring light to whether certain practices are establishing how they were intended to.

Another struggle that was encountered was the idea of SDR simplex models to understand species similarity, richness difference, and species replacement among sites. Explaining an SDR was and is still a struggle from trying to understand how it pertains to my thesis objectives to explaining what it is. To me they are very informative, giving different insights on beta diversity among my sites.

Implications for the Conservation Reserve Program

What needs to change to improve how the Conservation Reserve Program is implemented? First off, I found that CRP sites in the Great Plains are seeded along a longitudinal gradient. But should that be how they seed CRP sites? Sites in North Dakota are not the same as sites in Colorado or Iowa. There is a reason that sites are usually seeded at a latitudinal gradient because as you get further North, the climate changes. Northerly regions are subject to shorter growing seasons and colder temperatures, so you would assume that species seeded in North Dakota should be different to what is seeded in Kansas or Colorado. Also, they should consider different types of grasslands from tall to short to mixed grasslands, not all species that are seeded are necessarily fit for all three types. As I saw with blackeyed Susan (*Rudbeckia hirta* L.), that was intentionally seeded in western part of Nebraska, but was never observed. So, for the future, CRP should change how it structures its seed mixes and/or practices, so that they consider change in latitude, not just longitude, and that every state has relatively different biomes.

Along the lines of seeding, local NRCS managers/offices could improve their collection of documentation from landowners, specifically in seeding information. Most of the contracts that we received had more information on emergency haying, status updates, and mid-contract management than they did of species information from what was seeded to when it was seeded. There should be a guideline set by the program that states that they should obtain/collect and keep specific information, so that it can be used in future research that helps understand the importance and effect that CRP has on the landscape. This information can address how CRP sites are established and if what is seeded establishes. With that in mind, they could also be encouraged to follow standardized species naming systems, so when others (like me) are reviewing Status documents, it is clear what species were observed. Instead of just stating they saw a sunflower, which could mean a sawtooth sunflower (*Helianthus grosseserratus* M. Martens), Maximilian sunflower (*Helianthus maximiliani* Schrad.), annual sunflower (*Helianthus annuus* L.), false sunflower (*Heliopsis helianthoides* (L.) Sweet), and so forth. Along those lines, the seeding companies that are used should use conventionally accepted species names (*e.g.,* plants.USDA.gov), so that what they state on their receipts is what was seeded. Lastly, the use of nonnative/native species that are still seeded on the landscape as either in the initial seed mix or as interseeding mid-contract management, should in my opinion be minimized. I know that they would be the seed that is easily available, but if they are trying to create successful grassland habitats, the introduction of those species could lead to them outcompeting native species.

To continue with the management of these sites, management is very important when starting or implementing a grassland reconstruction. Management practices that are commonly used are haying, mowing and interseeding. Interseeding for this program, though, is not the greatest because they usually interseed alfalfa and clover. In my mind, if you interseed it should be species that are able to increase species diversity in the sites and/or decrease the competition of invasive, weedy species, not just using species that are usually used for agriculture. Common interseeded species in CRP is alfalfa (*Medicago sativa* L.), which has been linked to increase in water use efficiency and decreased weed biomass, but if the goal is to increase plant diversity the use of native, diverse seed mixes are the key (Dhakal et al. 2020). Now interseeding with native species has been seen to increase plant diversity and richness, which improves plant community composition and has the ability to alter functional diversity of grasslands (Bailey and Martin 2007, Rossiter et al. 2016, Link et al. 2017). Another management opportunity that landowners have is fire but is not commonly used since it is harder to do and requires more labor. I think in the future this should be used more often because I came across fields that were in much need of it, based on low species diversity and litter depth, and the use of haying/mowing/interseeding would not be helpful or be of any use at that point. And then, should these mid-contract managements be issued more than once? Are they able to do it more than once during the contract period? I know after meeting with local NRCS practitioners/managers, they really don't have that much time on their hands to be issuing more than one management period. But if it is possible, I think that there should be at least two times in which the CRP site is put through different management regimes, such as having the first be something as simple as mowing, then the second being more intensive (*e.g.,* fire, interseeding with more than just alfalfa). For example, altering the microsite conditions of a site through tilling/disking, alongside managing established vegetation with mowing/haying increased the establishment of interseeded species (Rossiter et al. 2016). Same goes with the use of glyphosate application with interseeded native species increased species richness and vegetation biomass (Link et al. 2017). I recommend that the USDA talk to local NRCS offices to understand the issues/setbacks that they encounter when establishing and managing CRP, so that in the future those issues/concerns can be fixed/addressed.

Future Implications

There are many questions that went unanswered throughout this project, and many questions that that have yet to be asked. Some of those questions are as follows: Are we ending up with grasslands that have lost their function over time? Are we creating habitats that are homogeneous? Are we considering variation of species and sites? We can see that there is a difference in plant composition, but what is its role in these environments? Some of these questions will require more time to pass or more data to be collected. The real challenge is that with all these differences in CP practices and differences seen between states, can we really answer those for the entirety of the CRP program?

So, from here I want to continue to understand how seed source affects establishment through whether if it is local or nonlocal (*e.g.,* assisted gene flow, shift in climate change envelope, gene flow) affects the reconstruction outcome and how seed sourcing could change with climate change. Though local adaptation can enhance the success of grassland plants addressing the effects of climate change through assisted gene flow (*e.g.,* use of species within local or regional scale), assisted migration of species northward, and/or matching seed source with projected climate are the future of seed sourcing (McLachlan et al. 2007, Broadhurst et al. 2008, Galatowitsch et al. 2009, Aitken and Whitlock 2013, Breed et al. 2013, Broadhurst et al. 2015, Breed et al. 2018, Ahlering and Binggeli 2022). This study just addressed the basics of seed sourcing by analyzing how what is seeded compares to what is observed, but it doesn't go into depth on where the seed came from. Along the lines of what seed to use, I want to understand more on what should be used in seed mixes (*e.g.*, ratio of forbs to grass and legumes, diversity of seed mixture, quantity of seed). The choice between using low diversity or high diversity seed mixes can come down to cost and field size. Török et al. (2011) suggest that when selecting a seed mixture, you should consider a low diversity mix for large fields and high diversity mix for smaller fields to offset seed cost. With that, I want to go more in depth on what makes a successful seed mixture, one that can compete with weedy, invasive species. I also want to dive into how management affects grassland restoration and how that might change with climate change. I know that I mentioned management a few times in this study as just an introduction to what it was, but was not able to go into it much, since CRP is not the ideal program to study it, since most of it is mowing and haying. Now specifically with CRP, since I did not get into analyzing the Pacific Northwest, I would like to understand whether what I saw with the Great Plains is like what is happening in the Pacific Northwest, even though they don't have seeding information and species found there are very different than what is seen in the Great Plains.

To conclude, CRP has great intentions, but there are still aspects that can be improved upon. Some of that includes the use of common and rare species, local and nonlocal, change in management practices, and change in seed documentation. As I saw from my analysis, they are spending lots of money on these rare species that are just not being seen. And this money, if used on more common species, that would still increase diversity can save money to use elsewhere in the program. So, though the future of CRP is uncertain in how it will accomplish its aims. With climate change effects, these aims might need to shift or the way they are implemented should be considered as the environment changes.

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APPENDIX

Appendix A

Species List

List of all species seeded and/or observed in this study. The code is the reference ID for 2022 field season, generally used the first three letters of genus and first two letters of the specific epithet. There are some cases where more or different letters were used because species had same five-letter code or had scientific name changes. Scientific name, common name, family, functional group, and N/I (*e.g.,* native or introduced) were all gathered from plants.USDA.gov. Species were marked as either target, observed, observed target, and/or observed nontarget species.

Code	*Scientific name*	Common name	Family	Functional Group	N/I	Target Species	Observed Species	Observed Target Species	Observed Nontarget Species
ACESA	*Acer saccharum*	sugar maple	Aceraceae	Shrub/Tree	N		X		X
ACHHY	*Achnatherum hymenoides*	Indian ricegrass	Poaceae	Grass	N	X	X	X	
ACHMI	*Achillea millefolium*	common yarrow	Asteraceae	Forb	N/I	X	X	X	
AGAFO	*Agastache foeniculum*	blue giant hyssop	Lamiaceae	Forb	N	X	X	X	
AGRCR	*Agropyron cristatum*	crested wheatgrass	Poaceae	Grass	I	X	X	X	
AGRGI	*Agrostis gigantea*	redtop	Poaceae	Grass	I	X	X	X	
AGRGR	*Agrimonia gryposepala*	tall hairy agrimony	Rosaceae	Forb	N		X		X
AGRHY	*Agrostis hyemalis*	winter bentgrass	Poaceae	Grass	N		X		X
AGRPA	*Agrimonia parviflora*	harvestlice	Rosaceae	Forb	N		X		X
ALLCA	*Allium canadense*	Canadian meadow garlic	Liliaceae	Forb	N	X	X	X	
ALLST	*Allium stellatum*	autumn onion	Liliaceae	Forb	N	X			
ALLVI	*Allium vineale*	wild garlic	Liliaceae	Forb	I		X		X
AMASP	*Amaranthus spp.*	amaranthus	Amaranthaceae	Forb	N/I		X		X
AMBAR	*Ambrosia artemisiifolia*	annual ragweed	Asteraceae	Forb	N/I		X		X

AMBPS	*Ambrosia psilostachya*	Cuman ragweed	Asteraceae	Forb	N		X		X
AMBTR	*Ambrosia trifida*	great ragweed	Asteraceae	Forb	N		X		X
AMOCA	*Amorpha canescens*	leadplant	Fabaceae	Legume	N	X	X	X	
ANDGE	*Andropogon gerardii*	big bluestem	Poaceae	Grass	N	X	X	X	
ANDHA	*Andropogon hallii*	sand bluestem	Poaceae	Grass	N	X	X	X	
ANDVI	*Andropogon virginicus*	broomsedge bluestem	Poaceae	Grass	N	X			
ANECA	*Anemone canadensis*	Canadian anemone	Ranunculaceae	Forb	N	X	X	X	
ANECY	*Anemone cylindrica*	candle anemone	Ranunculaceae	Forb	N	X	X	X	
ANEVI	*Anemone virginiana*	tall thimbleweed	Ranunculaceae	Forb	N	X			
APOCA	*Apocynum cannabinum*	Indianhemp	Apocynaceae	Forb	N		X		X
AQUCA	*Aquilegia canadensis*	red columbine	Ranunculaceae	Forb	N	X	X	X	
ARCLA	*Arctium lappa*	greater burdock	Asteraceae	Forb	I		X		X
ARCMI	*Arctium minus*	lesser burdock	Asteraceae	Forb	I		X		X
ARGAN	*Argentina anserina*	silverleaf cinquefoil	Rosaceae	Forb	N		X		X
ARIOL	*Aristida oligantha*	prairie threeawn	Poaceae	Grass	N		X		X
ARTAB	*Artemisia absinthium*	absinthium	Asteraceae	Forb	I		X		X
ARTDR	*Artemisia dracunculus*	tarragon	Asteraceae	Forb	N		X		X
ARTFR	*Artemisia frigida*	prairie sagewort	Asteraceae	Forb	N	X	X	X	
ARTFU	*Artemisia furcata*	forked wormwood	Asteraceae	Forb	N		X		X
ARTLU	*Artemisia ludoviciana*	white sagebrush	Asteraceae	Forb	N	X	X	X	
ASCAS	*Asclepias asperula*	spider milkweed	Asclepiadaceae	Forb	N		X		X
ASCHI	*Asclepias hirtella*	green milkweed	Asclepiadaceae	Forb	N		X		X
ASCIN	*Asclepias incarnata*	swamp milkweed	Asclepiadaceae	Forb	N	X	X	X	

ASCLA	*Asclepias latifolia*	broadleaf milkweed	Asclepiadaceae	Forb	N		X		X
ASCSPE	*Asclepias speciosa*	showy milkweed	Asclepiadaceae	Forb	N	X	X	X	
ASCSU	*Asclepias sullivantii*	prairie milkweed	Asclepiadaceae	Forb	N		X		X
ASCSY	*Asclepias syriaca*	common milkweed	Asclepiadaceae	Forb	N	X	X	X	
ASCTU	*Asclepias tuberosa*	butterfly milkweed	Asclepiadaceae	Forb	N	X	X	X	
ASCVE	*Asclepias verticillata*	whorled milkweed	Asclepiadaceae	Forb	N		X		X
ASCVIRIDIFLORA	*Asclepias viridiflora*	green comet milkweek	Asteraceae	Forb	N		X		X
ASCVIRIDIS	*Asclepias viridis*	green antelopehorn	Asclepiadaceae	Forb	N		X		X
ASTCA	*Astragalus canadensis*	Canadian milkvetch	Fabaceae	Legume	N	X	X	X	
ATRCA	*Atriplex canescens*	fourwing saltbrush	Chenopodiaceae	Forb	N		X		X
AVESA	*Avena sativa*	common oat	Poaceae	Grass	I	X	X	X	
BAPAL	*Baptisia alba*	white wild indigo	Fabaceae	Legume	N	X	X	X	
BAPAU	*Baptisia australis*	blue wild indigo	Fabaceae	Legume	N	X			
BASSC	*Bassia scoparia*	burningbush	Chenopodiaceae	Forb	I		X		X
BERIN	*Berteroa incana*	hoary alyssum	Brassicaceae	Forb	I		X		X
BIDFR	*Bidens frondosa*	devil's beggartick	Asteraceae	Forb	N	X	X	X	
BOUCU	*Bouteloua curtipendula*	sideoats grama	Poaceae	Grass	N	X	X	X	
BOUDA	*Bouteloua dactyloides*	buffalograss	Poaceae	Grass	N	X	X	X	
BOUGR	*Bouteloua gracilis*	blue grama	Poaceae	Grass	N	X	X	X	
BRIEU	*Brickellia eupatorioides*	false boneset	Asteraceae	Forb	N	X	X	X	
BROIN	*Bromus inermis*	smooth brome	Poaceae	Grass	N/I	X	X	X	
BROJA	*Bromus arvensis*	field brome	Poaceae	Grass	I		X		X
BROKA	*Bromus kalmii*	arctic brome	Poaceae	Grass	N	X	X	X	

BROTE	*Bromus tectorum*	cheatgrass	Poaceae	Grass	I		X		X
CALCA	*Calamagrostis canadensis*	bluejoint	Poaceae	Grass	N	X			
CALLO	*Calamovilfa longifolia*	prairie sandreed	Poaceae	Grass	N	X			
CAMAM	*Campanulastrum americanum*	American bellflower	Campanulaceae	Forb	N	X			
CAMAP	*Campanula aparinoides*	marsh bellflower	Campanulaceae	Forb	N		X		X
CAMSA	*Camelina sativa*	littlepod false flax	Brassicaceae	Forb	I		X		X
CANSA	*Cannabis sativa*	marijuana	Cannabaceae	Forb	I		X		X
CARBR	*Carex brevior*	shortbeak sedge	Cyperaceae	Sedge	N	X	X	X	
CAREX	*Carex spp.*	sedge	Cyperaceae	Sedge	N		X		X
CARLU	*Carex lupulina*	hop sedge	Cyperaceae	Sedge	N	X	X	X	
CARMO	*Carex molesta*	troublesome sedge	Cyperaceae	Sedge	N		X		X
CARNU	*Carduus nutans*	nodding plumeless thistle	Asteraceae	Forb	I		X		X
CARVU	*Carex vulpinoidea*	fox sedge	Cyperaceae	Sedge	N	X	X	X	
CASSE	*Castilleja sessiliflora*	downy paintedcup	Scrophulariaceae	Forb	N		X		X
CEAAM	*Ceanothus americanus*	New Jersey tea	Rhamnaceae	Shrub	N	X	X	X	
CHAFA	*Chamaecrista fasciculata*	partridge pea	Fabaceae	Legume	N	X	X	X	
CHEAL	*Chenopodium album*	lambsquarters	Chenopodiaceae	Forb	N/I		X		X
CHOJU	*Chondrilla juncea*	rush skeletonweed	Asteraceae	Forb	I		X		X
CICIN	*Cichorium intybus*	chicory	Asteraceae	Forb	I		X		X
CIRAL	*Cirsium altissimum*	tall thistle	Asteraceae	Forb	N		X		X
CIRAR	*Cirsium arvense*	Canada thistle	Asteraceae	Forb	I		X		X
CIRDI	*Cirsium discolor*	field thistle	Asteraceae	Forb	N		X		X
CIRFL	*Cirsium flodmanii*	Flodman's thistle	Asteraceae	Forb	N		X		X

CIROC	*Cirsium ochrocentrum*	yellowspine thistle	Asteraceae	Forb	N		X		X
CIRUN	*Cirsium undulatum*	wavyleaf thistle	Asteraceae	Forb	N		X		X
CIRVU	*Cirsium vulgare*	bull thistle	Asteraceae	Forb	I		X		X
CLESE	*Cleome serrulata*	Rocky Mountain beeplant	Capparaceae	Forb	N	X			
CONAR	*Convolvulus arvensis*	field bindweed	Convolvulaceae	Forb	I		X		X
CONCA	*Conyza canadensis*	Canadian horseweed	Asteraceae	Forb	N		X		X
CONMA	*Conium maculatum*	poison hemlock	Apiaceae	Forb	I		X		X
CORDR	*Cornus drummondii*	roughleaf dogwood	Cornaceae	Shrub/Tree	N		X		X
CORLA	*Coreopsis lanceolata*	lanceleaf tickseed	Asteraceae	Forb	N	X	X	X	
CORSE	*Cornus sericea*	redosier dogwood	Cornaceae	Shrub/Tree	N		X		X
CORTI	*Coreopsis tinctoria*	golden tickseed	Asteraceae	Forb	N	X	X	X	
CORTR	*Coreopsis tripteris*	tall tickseed	Asteraceae	Forb	N	X	X	X	
CRETE	*Crepis tectorum*	narrowleaved hawksbeard	Asteraceae	Forb	I		X		X
CROSA	*Crotalaria sagittalis*	arrowhead rattlebox	Fabaceae	Legume	N	X			
CUCFO	*Cucurbita foetidissima*	Missouri gourd	Cucurbitaceae	Vine/Forb	N		X		X
CYNLA	*Cynanchum laeve*	honeyvine	Asclepiadaceae	Forb	N		X		X
DACGL	*Dactylis glomerata*	orchardgrass	Poaceae	Grass	I	X	X	X	
DALCA	*Dalea candida*	white prairie clover	Fabaceae	Legume	N	X	X	X	
DALPU	*Dalea purpurea*	purple prairie clover	Fabaceae	Legume	N	X	X	X	
DAUCA	*Daucus carota*	Queen Anne's lace	Apiaceae	Forb	I		X		X

DELCA	*Delphinium carolinianum*	Carolina larkspur	Ranunculaceae	Forb	N	X	X	X	
DESCA	*Desmodium canadense*	showy ticktrefoil	Fabaceae	Legume	N	X	X	X	
DESIL	*Desmanthus illinoensis*	Illinois bundleflower	Fabaceae	Legume	N	X	X	X	
DESILLINOENSE	*Desmodium illinoense*	Illinois ticktrefoil	Fabaceae	Legume	N	X			
DESPI	*Descurainia pinnata*	western tansymustard	Brassicaceae	Forb	N		X		X
DESSO	*Descurainia sophia*	herb sophia	Brassicaceae	Forb	I		X		X
DIAAR	*Dianthus armeria*	Deptford pink	Caryophyllaceae	Forb	I		X		X
DICOL	*Dichanthelium oligosanthes*	Heller's rosette grass	Poaceae	Grass	N		X		X
DRAAM	*Dracopis amplexicaulis*	clasping coneflower	Asteraceae	Forb	N	X			
ECHAN	*Echinacea angustifolia*	narrowleaf purple coneflower	Asteraceae	Forb	N	X			
ECHMU	*Echinochloa muricata*	rough barnyardgrass	Poaceae	Grass	N		X		X
ECHPA	*Echinacea pallida*	pale purple coneflower	Asteraceae	Forb	N	X	X	X	
ECHPU	*Echinacea purpurea*	eastern purple coneflower	Asteraceae	Forb	N	X	X	X	
ECHVI	*Echinocereus viridiflorus*	nylon hedgehog cactus	Cactaceae	Shrub	N		X		X
ELAAN	*Elaeagnus angustifolia*	Russian olive	Elaeagnaceae	Tree	I		X		X
ELEPA	*Eleocharis palustris*	common spikerush	Cyperaceae	Sedge	N		X		X
ELYCA	*Elymus canadensis*	Canada wildrye	Poaceae	Grass	N	X	X	X	
ELYGL	*Elymus glaucus*	blue wildrye	Poaceae	Grass	N		X		X
ELYHO	*Elymus hoffmannii*	RS wheatgrass	Poaceae	Grass	I	X			
ELYRE	*Elymus repens*	quackgrass	Poaceae	Grass	I	X	X	X	

ELYTR	*Elymus trachycaulus*	slender wheatgrass	Poaceae	Grass	N	X	X	X	
ELYVI	*Elymus virginicus*	Virginia wildrye	Poaceae	Grass	N/I	X	X	X	
ENGPE	*Engelmannia peristenia*	Engelmann's daisy	Asteraceae	Forb	N	X			
EQUAR	*Equisetum arvense*	field horsetail	Equisetaceae	Forb	N		X		X
EQUFL	*Equisetum fluviatile*	water horsetail	Equisetaceae	Forb	N		X		X
EQUSPP	*Equisetum spp.*	horsetails	Equisetaceae	Forb	N		X		X
ERATR	*Eragrostis trichodes*	sand lovegrass	Poaceae	Grass	N	X			
ERIAN	*Erigeron annuus*	eastern daisy fleabane	Asteraceae	Forb	N		X		X
ERIDI	*Erigeron divergens*	spreading fleabane	Asteraceae	Forb	N		X		X
ERIMO	*Erigeron modestu*	plains fleabane	Asteraceae	Forb	N		X		X
ERIST	*Erigeron strigosus*	prairie fleabane	Asteraceae	Forb	N		X		X
EROCI	*Erodium cicutarium*	redstem stork's bill	Geraniaceae	Forb	I		X		X
ERYCA	*Erysimum capitatum*	sanddune wallflower	Brassicaceae	Forb	N/I		X		X
ERYYU	*Eryngium yuccifolium*	button eryngo	Apiaceae	Forb	N	X	X	X	
EUPAL	*Eupatorium album*	white thoroughwort	Asteraceae	Forb	N	X			
EUPCO	*Euphorbia corollata*	flowering spurge	Euphorbiaceae	Forb	N	X			
EUPES	*Euphorbia esula*	leafy spurge	Euphorbiaceae	Forb	I		X		X
EUPPE	*Eupatorium perfoliatum*	common boneset	Asteraceae	Forb	N	X			
EUPSE	*Eupatorium serotinum*	lateflowering thoroughwort	Asteraceae	Forb	N		X		X
EUTPU	*Eutrochium purpureum*	sweetscented joe pye weed	Asteraceae	Forb	N	X	X	X	
FESSPP	*Festuca spp.*	fescue spp.	Poaceae	Grass	N/I		X		X
FRANI	*Fraxinus nigra*	black ash	Oleaceae	Tree	N		X		X

FRAPE	*Fraxinus pennsylvanica*	green ash	Oleaceae	Tree	N		X		X
FRAVI	*Fragaria virginiana*	Virginia strawberry	Rosaceae	Forb	N		X		X
GAIAR	*Gaillardia aristata*	blanketflower	Asteraceae	Forb	N	X	X	X	
GAIPU	*Gaillardia pulchella*	Indian blanket	Asteraceae	Forb	N	X	X	X	
GALAP	*Galium aparine*	stickywilly	Rubiaceae	Vine/Forb	N		X		X
GALBO	*Galium boreale*	northern bedstraw	Rubiaceae	Vine/Forb	N		X		X
GENAL	*Gentiana alba*	plain gentian	Gentianaceae	Forb	N	X	X	X	
GEUCA	*Geum canadense*	white avens	Rosaceae	Forb	N		X		X
GEULAE	*Geum aleppicum*	yellow avens	Rosaceae	Forb	N		X		X
GLETR	*Gleditsia triacanthos*	honeylocust	Fabaceae	Legume	N		X		X
GLYLE	*Glycyrrhiza lepidota*	American licorice	Fabaceae	Legume	N		X		X
GLYST	*Glyceria striata*	fowl managrass	Poaceae	Grass	N	X			
GRISQ	*Grindelia squarrosa*	curlycup gumweed	Asteraceae	Forb	N		X		X
GUTSA	*Gutierrezia sarothrae*	broom snakeweed	Asteraceae	Forb	N		X		X
GYPPA	*Gypsophila paniculata*	baby's breath	Caryophyllaceae	Forb	I		X		X
HELAN	*Helianthus annuus*	common sunflower	Asteraceae	Forb	N/I	X	X	X	
HELAU	*Helenium autumnale*	common sneezeweed	Asteraceae	Forb	N	X			
HELGR	*Helianthus grosseserratus*	sawtooth sunflower	Asteraceae	Forb	N	X	X	X	
HELHE	*Heliopsis helianthoides*	smooth oxeye	Asteraceae	Forb	N	X	X	X	
HELMA	*Helianthus maximiliani*	Maximilian sunflower	Asteraceae	Forb	N	X	X	X	
HELPA	*Helianthus pauciflorus*	stiff sunflower	Asteraceae	Forb	N	X	X	X	

HESCO	*Hesperostipa comata*	needle and thread	Poaceae	Grass	N	X	X	X	
HETVI	*Heterotheca villosa*	hairy false goldenaster	Asteraceae	Forb	N	X	X	X	
HEURI	*Heuchera richardsonii*	Richardson's alumroot	Saxifragaceae	Forb	N	X			
HORJU	*Hordeum jubatum*	foxtail barley	Poaceae	Grass	N		X		X
HYPAS	*Hypericum ascyron*	great St. Johnswort	Clusiaceae	Forb	N	X			
HYPPE	*Hypericum perforatum*	common St. Johnswort	Clusiaceae	Forb	I		X		X
HYPPU	*Hypericum punctatum*	spotted St. Johnswort	Clusiaceae	Forb	N		X		X
IRIVE	*Iris versicolor*	harlequin blueflag	Iridaceae	Forb	N	X			
JUNBA	*Juncus arcticus*	mountain rush	Juncaceae	Rush	N		X		X
JUNDU	*Juncus dudleyi*	Dudley's rush	Juncaceae	Rush	N		X		X
JUNTO	*Juncus torreyi*	Torrey's rush	Juncaceae	Rush	N		X		X
JUNVI	*Juniperus virginiana*	eastern redcedar	Cupressaceae	Tree	N		X		X
KOEMA	*Koeleria macrantha*	prairie Junegrass	Poaceae	Grass	N	X	X	X	
KRALA	*Krascheninnikovia lanata*	winterfat	Chenopodiaceae	Shrub	N	X	X	X	
LACSE	*Lactuca serriola*	prickly lettuce	Asteraceae	Forb	I		X		X
LACTA	*Lactuca tatarica*	blue lettuce	Asteraceae	Forb	N		X		X
LAPSQ	*Lappula squarrosa*	European tickseed	Boraginaceae	Forb	I		X		X
LEOCA	*Leonurus cardiaca*	common motherwort	Lamiaceae	Forb	I		X		X
LEPDE	*Lepidium densiflorum*	common pepperweed	Brassicaceae	Forb	N/I		X		X
LESCA	*Lespedeza capitata*	roundhead lespedeza	Fabaceae	Legume	N	X	X	X	
LESCU	*Lespedeza cuneata*	sericea lespedeza	Fabaceae	Legume	I		X		X

LEUVU	*Leucanthemum vulgare*	oxeye daisy	Asteraceae	Forb	I		X		X
LIAAS	*Liatris aspera*	tall blazing star	Asteraceae	Forb	N	X	X	X	
LIAPU	*Liatris punctata*	dotted blazingstar	Asteraceae	Forb	N	X	X	X	
LIAPY	*Liatris pycnostachya*	prairie blazing star	Asteraceae	Forb	N	X	X	X	
LINLE	*Linum lewisii*	Lewis flax	Linaceae	Forb	N	X	X	X	
LINPE	*Linum perenne*	blue flax	Linaceae	Forb	I	X	X	X	
LOBCA	*Lobelia cardinalis*	cardinalflower	Campanulaceae	Forb	N	X			
LOBSI	*Lobelia siphilitica*	great blue lobelia	Campanulaceae	Forb	N	X			
LOBSP	*Lobelia spicata*	palespike lobelia	Campanulaceae	Forb	N		X		X
LOLPE	*Lolium perenne*	perennial ryegrass	Poaceae	Grass	I	X			
LOTCO	*Lotus corniculatus*	bird's-foot trefoil	Fabaceae	Legume	I	X	X	X	
LUDAL	*Ludwigia alternifolia*	seedbox	Onagraceae	Forb	N	X			
MACTA	*Machaeranthera tanacetifolia*	tanseyleaf tansyaster	Asteraceae	Forb	N	X			
MALSPP	*Malus spp.*	crab apple	Rosaceae	Tree	N/I		X		X
MEDLU	*Medicago lupulina*	black medick	Fabaceae	Legume	I		X		X
MEDSA	*Medicago sativa*	alfalfa	Fabaceae	Legume	I	X	X	X	
MELOF	*Melilotus officinalis*	sweetclover	Fabaceae	Legume	I	X	X	X	
MENCA	*Mentha arvensis*	wild mint	Lamiaceae	Forb	N		X		X
MIMRI	*Mimulus ringens*	Allegheny monkeyflower	Scrophulariaceae	Forb	N	X			
MIRNY	*Mirabilis nyctaginea*	heartleaf four o'clock	Nyctaginaceae	Forb	N		X		X
MONCI	*Monarda citriodora*	lemon beebalm	Lamiaceae	Forb	N	X			
MONFI	*Monarda fistulosa*	wild bergamot	Lamiaceae	Forb	N	X	X	X	
MORAL	*Morus alba*	white mulberry	Moraceae	Tree	I		X		X
NASVI	*Nassella viridula*	green needlegrass	Poaceae	Grass	N	X	X	X	
NEPCA	*Nepeta cataria*	catnip	Lamiaceae	Forb	I		X		X
OENBI	*Oenothera biennis*	common evening primrose	Onagraceae	Forb	N	X	X	X	

OENCA	*Oenothera canescens*	spotted evening primrose	Onagraceae	Forb	N		X		X
OENLA	*Oenothera laciniata*	cutleaf evening primrose	Onagraceae	Forb	N		X		X
OENRH	*Oenothera rhombipetala*	fourpoint evening primrose	Onagraceae	Forb	N	X			
ONOVI	*Onobrychis viciifolia*	sainfoin	Fabaceae	Legume	I	X	X	X	
OPUPO	*Opuntia polyacantha*	plains pricklypear	Cactaceae	Shrub	N		X		X
OXADI	*Oxalis dillenii*	slender yellow woodsorrel	Oxalidaceae	Forb	N		X		X
OXAST	*Oxalis stricta*	common yellow woodsorrel	Oxalidaceae	Forb	N		X		X
PACAU	*Packera aurea*	golden ragwort	Asteraceae	Forb	N		X		X
PACTR	*Packera tridenticulata*	threetooth ragwort	Asteraceae	Forb	N		X		X
PANCA	*Panicum capillare*	witchgrass	Poaceae	Grass	N		X		X
PANVI	*Panicum virgatum*	switchgrass	Poaceae	Grass	N	X	X	X	
PARIN	*Parthenium integrifolium*	wild quinine	Asteraceae	Forb	N	X	X	X	
PASSA	*Pastinaca sativa*	wild parsnip	Apiaceae	Forb	I		X		X
PASSM	*Pascopyrum smithii*	western wheatgrass	Poaceae	Grass	N	X	X	X	
PEDAR	*Pediomelum argophyllum*	silverleaf Indian breadroot	Fabaceae	Legume	N		X		X
PEDTE	*Psoralidium tenuiflorum*	slimflower scurfpea	Fabaceae	Legume	N		X		X
PENDI	*Penstemon digitalis*	foxglove beardtongue	Scrophulariaceae	Forb	N	X	X	X	
PENGL	*Penstemon glaber*	sawsepal beardtongue	Scrophulariaceae	Forb	N		X		X
PENGR	*Penstemon grandiflorus*	large beardtongue	Scrophulariaceae	Forb	N	X	X	X	

PHAAR	*Phalaris arundinacea*	reed canarygrass	Poaceae	Grass	N		X		X
PHAVU	*Phaseolus vulgaris*	kidney beans	Fabaceae	Legume	I		X		X
PHLPI	*Phlox pilosa*	downy phlox	Polemoniaceae	Forb	N	X	X	X	
PHLPR	*Phleum pratense*	timothy	Poaceae	Grass	I	X	X	X	
PHRAU	*Phragmites australis*	common reed	Poaceae	Grass	N/I		X		X
PHYCU	*Phyla cuneifolia*	wedgeleaf	Verbenaceae	Forb	N		X		X
PHYHE	*Physalis heterophylla*	clammy groundcherry	Solanaceae	Forb	N		X		X
PHYVI	*Physostegia virginiana*	obedient plant	Lamiaceae	Forb	N	X	X	X	
PLAMA	*Plantago major*	common plantain	Plantaginaceae	Forb	I		X		X
PLAPA	*Plantago patagonica*	woolly plantain	Plantaginaceae	Forb	N		X		X
POACO	*Poa compressa*	Canada bluegrass	Poaceae	Grass	I	X	X	X	
POAPA	*Poa palustris*	fowl bluegrass	Poaceae	Grass	N	X			
POAPR	*Poa pratensis*	Kentucky bluegrass	Poaceae	Grass	N/I	X	X	X	
POLAM	*Polygonum amphibium*	water knotweed	Polygonaceae	Forb	N		X		X
POLSPP	*Polygonum spp.*	smartweed	Polygonaceae	Forb	N/I		X		X
POPDE	*Populus deltoides*	eastern cottonwood	Salicaceae	Tree	N		X		X
POPSPP	*Populus spp.*	poplar	Salicaceae	Tree	N/I		X		X
POTAR	*Potentilla argentea*	silver cinqufoil	Rosaceae	Forb	I	X	X	X	
POTARGU/DRYAR	*Potentilla arguta*	tall cinquefoil	Rosaceae	Forb	N		X		X
POTNO	*Potentilla norvegica*	Norwegian cinquefoil	Rosaceae	Forb	N		X		X
POTRE	*Potentilla recta*	sulphur cinquefoil	Rosaceae	Forb	I		X		X
PRUAM	*Prunus americana*	American plum	Rosaceae	Shrub/Tree	N		X		X
PRUVU	*Prunella vulgaris*	common selfheal	Lamiaceae	Forb	N		X		X
PYCTE	*Pycnanthemum tenuifolium*	narrowleaf mountainmint	Lamiaceae	Forb	N	X	X	X	

PYCVI	*Pycnanthemum virginianum*	Virginia mountainmint	Lamiaceae	Forb	N	X	X	X	
PYRSP	*Pyrus spp.*	pear	Rosaceae	Tree	I		X		X
RATCO	*Ratibida columnifera*	upright prairie coneflower	Asteraceae	Forb	N	X	X	X	
RATPI	*Ratibida pinnata*	pinnate prairie coneflower	Asteraceae	Forb	N	X	X	X	
REDFI	*Redfieldia flexuosa*	blowout grass	Poaceae	Grass	N		X		X
RHUGL	*Rhus glabra*	smooth sumac	Anacardiaceae	Shrub	N		X		X
ROBPS	*Robinia pseudoacacia*	black locust	Fabaceae	Tree/Legume	N		X		X
RORPA	*Rorippa palustris*	bog yellowcress	Brassicaceae	Forb	N		X		X
ROSAR	*Rosa arkansana*	prairie rose	Rosaceae	Subshrub	N	X	X	X	
RUBID	*Rubus idaeus*	American red raspberry	Rosaceae	Subshrub	N/I		X		X
RUBOC	*Rubus occidentalis*	black raspberry	Rosaceae	Subshrub	N		X		X
RUBSPP	*Rubus spp.*	blackberry	Rosaceae	Shrub	N/I		X		X
RUDHI	*Rudbeckia hirta*	blackeyed susan	Asteraceae	Forb	N	X	X	X	
RUDSU	*Rudbeckia subtomentosa*	sweet coneflower	Asteraceae	Forb	N	X	X	X	
RUDTR	*Rudbeckia triloba*	browneyed susan	Asteraceae	Forb	N	X			
RUEHU	*Ruellia humilis*	fringleleaf wild petunia	Acanthaceae	Forb	N	X	X	X	
RUMAC	*Rumex acetosella*	common sheep sorrel	Polygonaceae	Forb	I		X		X
RUMCR	*Rumex crispus*	curly dock	Polygonaceae	Forb	I		X		X
SALHU	*Salix humilis*	prairie willow	Salicaceae	Tree	N		X		X
SALSP	*Salvia spathacea*	hummingbird sage	Lamiaceae	Forb	N	X			
SALSPP	*Salix spp.*	willow	Salicaceae	Tree	N/I		X		X
SALTR	*Salsola tragus*	prickly Russian thistle	Chenopodiaceae	Forb	I		X		X
SAMCA	*Sambucus nigra*	black elderberry	Caprifoliaceae	Shrub	N		X		X
SANMI	*Sanguisorba minor*	small burnet	Rosaceae	Forb	I	X	X	X	

SCHAR/FESAR	*Schedonorus arundinaceus*	tall fescue	Poaceae	Grass	I		X		X
SCHPA	*Schedonnardus paniculatus*	tumblegrass	Poaceae	Grass	N		X		X
SCHSC	*Schizachyrium scoparium*	little bluestem	Poaceae	Grass	N	X	X	X	
SCIAT	*Scirpus atrovirens*	green bulrush	Cyperaceae	Sedge	N		X		X
SCIPU	*Schoenoplectus pungens*	common threesquare	Cyperaceae	Sedge	N		X		X
SCUGA	*Scutellaria galericulata*	marsh skullcap	Lamiaceae	Forb	N		X		X
SECVA	*Securigera varia*	crownvetch	Fabaceae	Legume	I		X		X
SENMA	*Senna marilandica*	Maryland senna	Fabaceae	Legume	N	X			
SETPU	*Setaria pumila*	yellow foxtail	Poaceae	Grass	I		X		X
SETVI	*Setaria viridis*	green bristlegrass	Poaceae	Grass	I		X		X
SILAN	*Silene antirrhina*	sleepy silene	Caryophyllaceae	Forb	N		X		X
SILIN	*Silphium integrifolium*	wholeleaf rosinweed	Asteraceae	Forb	N	X	X	X	
SILLAC	*Silphium laciniatum*	compassplant	Asteraceae	Forb	N	X	X	X	
SILLAT	*Silene latifolia*	bladder campion	Caryophyllaceae	Forb	I		X		X
SILPE	*Silphium perfoliatum*	cup plant	Asteraceae	Forb	N	X	X	X	
SILTE	*Silphium terebinthinaceum*	prairie rosinweed	Asteraceae	Forb	N	X	X	X	
SISAL	*Sisymbrium altissimum*	tall tumblemustard	Brassicaceae	Forb	I		X		X
SOLCAN	*Solidago canadensis*	Canada goldenrod	Asteraceae	Forb	N	X	X	X	
SOLCAR	*Solanum carolinense*	Carolina horsenettle	Solanaceae	Forb	N		X		X
SOLGI	*Solidago gigantea*	giant goldenrod	Asteraceae	Forb	N		X		X
SOLMI	*Solidago missouriensis*	Missouri goldenrod	Asteraceae	Forb	N		X		X
SOLNE	*Solidago nemoralis*	gray goldenrod	Asteraceae	Forb	N	X	X	X	

SOLRI/OLIRI	*Oligoneuron rigidum*	stiff goldenrod	Asteraceae	Forb	N	X	X	X	
SOLRID/OLIRID	*Oligoneuron riddellii*	Riddell's goldenrod	Asteraceae	Forb	N	X			
SOLRO	*Solanum rostratum*	buffalobur nightshade	Solanaceae	Forb	N		X		X
SOLSPE	*Solidago speciosa*	showy goldenrod	Asteraceae	Forb	N	X			
SOLSPP	*Solidago spp.*	goldenrod	Asteraceae	Forb	N/I		X		X
SONAR	*Sonchus arvensis*	field sowthistle	Asteraceae	Forb	I		X		X
SONOL	*Sonchus oleraceus*	common sowthistle	Asteraceae	Forb	I		X		X
SORBI	*Sorghum bicolor*	sorghum	Poaceae	Grass	I	X	X	X	
SORNU	*Sorghastrum nutans*	Indiangrass	Poaceae	Grass	N	X	X	X	
SPAGR	*Spartina gracilis*	alkali cordgrass	Poaceae	Grass	N		X		X
SPAPE	*Spartina pectinata*	prairie cordgrass	Poaceae	Grass	N		X		X
SPHCO	*Sphaeralcea coccinea*	scarlet globemallow	Malvaceae	Forb	N	X	X	X	
SPIAL	*Spiraea alba*	white meadowsweet	Rosaceae	Shrub	N		X		X
SPOCO	*Sporobolus compositus*	composite dropseed	Poaceae	Grass	N	X	X	X	
SPOCR	*Sporobolus cryptandrus*	sand dropseed	Poaceae	Grass	N	X	X	X	
SPOHE	*Sporobolus heterolepis*	prairie dropseed	Poaceae	Grass	N	X	X	X	
STAOF/BETOF	*Stachys officinalis*	common hedgenettle	Lamiaceae	Forb	I	X			
STAPA	*Stachys palustris*	marsh hedgenettle	Lamiaceae	Forb	N		X		X
SYMER	*Symphyotrichum ericoides*	white heath aster	Asteraceae	Forb	N	X	X	X	
SYMLAE	*Symphyotrichum laeve*	smooth blue aster	Asteraceae	Forb	N		X		X

SYMLAN	*Symphyotrichum lanceolatum*	white panicle aster	Asteraceae	Forb	N		X		X
SYMNO	*Symphyotrichum novae-angliae*	New England aster	Asteraceae	Forb	N	X	X	X	
SYMOC	*Symphoricarpos occidentalis*	western snowberry	Caprifoliaceae	Shrub	N		X		X
SYMOO/ASTAZ	*Symphyotrichum oolentangiense*	skyblue aster	Asteraceae	Forb	N	X			
SYMPI	*Symphyotrichum pilosum*	hairy white oldfield aster	Asteraceae	Forb	N	X	X	X	
TAROF	*Taraxacum officinale*	common dandelion	Asteraceae	Forb	N/I		X		X
THEFI	*Thelesperma filifolium*	stiff greenthread	Asteraceae	Forb	N		X		X
THEME	*Thelesperma megapotamicum*	Hopi tea greenthread	Asteraceae	Forb	N		X		X
THIIN	*Thinopyrum intermedium*	intermediate wheatgrass	Poaceae	Grass	I	X	X	X	
THIPO	*Thinopyrum ponticum*	tall wheatgrass	Poaceae	Grass	I	X	X	X	
THLAR	*Thlaspi arvense*	field pennycress	Brassicaceae	Forb	I		X		X
TOXRY	*Toxicodendron rydbergii*	western poison ivy	Anacardiaceae	Shrub	N		X		X
TRADU	*Tragopogon dubius*	yellow salsify	Asteraceae	Forb	I		X		X
TRAOH	*Tradescantia ohiensis*	bluejacket	Commelinaceae	Forb	N	X	X	X	
TRIAE	*Triticum aestivum*	common wheat	Poaceae	Grass	I		X		X
TRIDA	*Tripsacum dactyloides*	eastern gamagrass	Poaceae	Grass	N		X		X
TRIHY	*Trifolium hybridum*	alsike clover	Fabaceae	Legume	I	X	X	X	
TRIPER	*Triodanis perfoliata*	clasping Venus' looking-glass	Campanulaceae	Forb	N		X		X
TRIPR	*Trifolium pratense*	red clover	Fabaceae	Legume	I	X	X	X	
TRIRE	*Trifolium repens*	white clover	Fabaceae	Legume	I	X	X	X	

TYPSPP/TYPLA	*Typha spp.*	cattails	Typhaceae	Forb	N/I		X		X
ULMAM	*Ulmus americana*	American elm	Ulmaceae	Tree	N		X		X
ULMPU	*Ulmus pumila*	Siberian elm	Ulmaceae	Tree	I		X		X
ULMRU	*Ulmus rubra*	slippery elm	Ulmaceae	Tree	N		X		X
URTDI	*Urtica dioica*	stinging nettle	Urticaceae	Tree	N/I		X		X
VACHI	*Vaccaria hispanica*	cow soapwort	Caryophyllaceae	Forb	I		X		X
VERAVI	*Veratrum virginicum*	Virginia buchflower	Liliaceae	Forb	N		X		X
VERBA	*Vernonia baldwinii*	Baldwin's ironweed	Asteraceae	Forb	N	X	X	X	
VERFA	*Vernonia fasciculata*	prairie ironweed	Asteraceae	Forb	N	X	X	X	
VERHA	*Verbena hastata*	swamp verbena	Verbenaceae	Forb	N	X	X	X	
VEROVI	*Veronicastrum virginicum*	Culver's root	Scrophulariaceae	Forb	N		X		X
VERSP	*Vernonia spp.*	ironweed species	Asteraceae	Forb	N/I	X			
VERST	*Verbena stricta*	hoary verbena	Verbenaceae	Forb	N	X	X	X	
VERTH	*Verbascum thapsus*	common mullein	Scrophulariaceae	Forb	I	X	X	X	
VICCR	*Vicia cracca*	bird vetch	Fabaceae	Legume	I		X		X
VICLU	*Vicia ludoviciana*	Louisiana vetch	Fabaceae	Legume	N		X		X
VITRI	*Vitis riparia*	riverbank grape	Vitaceae	Vine	N		X		X
YUCGL	*Yucca glauca*	soapweed yucca	Agavaceae	Forb	N		X		X
ZEAMA	*Zea mays*	corn	Poaceae	Grass	I		X		X
ZIZAP	*Zizia aptera*	meadow zizia	Apiaceae	Forb	N	X	X	X	
ZIZAU	*Zizia aurea*	golden zizia	Apiaceae	Forb	N	X	X	X	