

Final Report – State Wildlife Grant

Grant Title: Enhancing Diversity and At-Risk Species Habitat in Degraded Prairie Landscapes

Grant Number: #T2D6HM01

Project Manager: Chris Helzer

Period of Grant (begin and end dates): May 1, 2010 – November 30, 2012

Summary/Abstract of Project (300 words)

- Eleven units were burned in 2011 and 2012 for a total of 573 acres. All burns were done in conjunction with management plans that incorporated fire and grazing together to target cool-season exotic grasses and increase plant diversity and habitat quality.
- During each of the years between 2010 and 2012, approximately 1,591 acres were included in management that integrated prescribed fire, grazing, and rest. Invasive species control, through chemical and mechanical means, was carried out on all of these prairies.
- We overseeded 62 acres of those burned/grazed areas in 2010, 29 acres in 2011, and 62 acres in 2012. Many of those plots – especially in 2010 - were seeded with a variety of seeding rates to help evaluate the impact of seeding rate on results. Between 2008 and 2012, a total of approximately 500 acres of burned/grazed prairie were overseeded – funded by State Wildlife Grants. We dramatically increased those rates in 2011 and 2012 to see if we could get higher abundances of new forbs. This resulted in fewer acres seeded, but more dramatic results.
- Between 2010 and 2012, we plugged more than 800 prairie plant seedlings into 7 prairies, and another several hundred plants into our nursery for seed production. The very dry weather in 2012 made it very difficult to assess the success of most of our seedling transplants in prairies, so our data on that is thin.
- We conducted butterfly surveys throughout the summers of 2010-2012. In 2010, we conducted transect surveys for all butterfly species, but after finding no at-risk or rare butterfly species other than regal fritillaries, we focused our transect data collection solely on regal fritillaries in 2011 and 2012. During all three years, we did opportunistic sampling for other butterfly species, but still found no new at-risk species.

Federal Aid Requirements

A. Brief summary of the work completed during the grant period compared with the work plan identified in the grant.

All of the fundamentals listed in the grant period were carried out on schedule. The hot dry weather in 2012 affected our ability to evaluate some of the overseeding and seedling plug work, but the actual work was done.

B. Deviations (if any) from original project including the work itself or the cost, reasons for the deviation and how the deviation impacted accomplishing the stated study objectives:

None.

C. Locations of work: Central Platte River BUL—TNC land in Hall, Adams, and Buffalo Co. in Nebraska

D. Cost:

Federal funds requested: \$54,332.00 (reimbursable) 55,001.00 (match) Total =\$109,333.00

Actual Expenses: reimbursed =\$53,377.10 match=\$71,820.38

Total expenses= \$125,197.48

Enhancing Diversity and At-Risk Species Habitat in Degraded Prairie Landscapes

Final Report for State Wildlife Grant # T2D6HM01

Chris Helzer, The Nature Conservancy

This is the final report for a State Wildlife Grant to The Nature Conservancy through the Nebraska Game and Parks Commission. This project started in May 2010 and was completed in November 2012. We had applied for funding to continue our efforts to enhance prairie habitat quality through fire/grazing management and overseeding/seedling plugs – a project that had earlier been funded by a 2007 State Wildlife Grant.

Results of projects done under this grant were also shared with the public through various posts on the Prairie Ecologist blog (<http://prairieecologist.com>). A summary of management recommendations based on activities under this grant can be found on page 11. In addition, several Appendices at the end of this document detail methods and provide more detailed data.

Summary of objectives for this project

1. Evaluate and record the impacts of modified patch-burn grazing management on prairies in which cool-season exotic grasses are dominant and plant diversity is low. Evaluate the response of butterflies, especially Tier I and Tier II species, to that fire/grazing management.
2. Test the efficacy of two methods of enhancing plant diversity; seed addition and seedling plugs.
3. Improve the plant diversity and habitat quality of at least 1000 acres through a combination of factors, including patch-burn grazing, overseeding, and seedling plugs.

Deliverables promised

1. Enhanced plant diversity and at-risk species habitat quality on approximately 1,000 acres
2. Data on the responses of plant communities and at-risk butterflies to various fire/grazing management and restoration strategies
3. Suggested best management practices for enhancing grasslands that are significantly impacted by invasive grasses.

Summary of activities

- In 2011, we burned 5 units under this grant, for a total of 256 acres. In 2012, we burned 6 units, for a total of 317 acres. All of these burns were done in conjunction with management plans

that incorporated fire and grazing together to target cool-season exotic grasses and increase plant diversity and habitat quality.

- During each of the years between 2010 and 2012, approximately 1,591 acres were included in management that integrated prescribed fire, grazing, and rest. Work done to implement fire and grazing in the 2012 season is also covered under another State Wildlife Grant (T76MH1), received in 2011, but is mentioned here because there is so much overlap between that workscope and that of this grant. Invasive species control, through chemical and mechanical means, was carried out on all of these prairies as well. Major species addressed included Siberian elm, eastern red cedar, musk and Canada thistle, smooth brome, reed canarygrass, Kentucky bluegrass, tall wheatgrass, phragmites, and purple loosestrife. Chemical control consisted mainly of spot spraying or application of chemical via a PVC herbicide wand (for small trees).
- We overseeded 62 acres of those burned/grazed areas in 2010, 29 acres in 2011, and 62 acres in 2012. Many of those plots – especially in 2010 - were seeded with a variety of seeding rates to help evaluate the impact of seeding rate on results. Between 2008 and 2012, a total of approximately 500 acres of burned/grazed prairie were overseeded – funded by State Wildlife Grants from 2007 and 2010 (see maps in Appendix A).

Our overseeding within the patch-burn grazing system is designed to take advantage of recently burned areas to get good seed/soil when broadcasting seeds. The subsequent short-term (a single growing season) intensive grazing then reduces competition from dominant grasses and gives new seedlings a chance to establish and survive. During 2008 and 2009, we used seeding rates similar to what we use when establishing new prairie seedings in cropfields (approximately 1-2 lbs PLS of forb seed per acre), but in 2010, 2011, and 2012, we dramatically increased those rates to see if we could get higher abundances of new forbs. This resulted in fewer acres seeded, but (hopefully) more dramatic results.

- Between 2010 and 2012, we plugged more than 800 prairie plant seedlings into 7 prairies, and another several hundred plants into our nursery for seed production. In 2011, we had very poor germination of seedlings in our greenhouse, so we replaced the transparent panels on the front of the greenhouse prior to the 2012 season. Production was better in 2012, but many of the species were not yet mature enough to move into prairies, and are being kept over until the spring of 2013. The very dry weather in 2012 made it very difficult to assess the success of most of our seedling transplants in prairies, so our data on that is thin.
- We conducted butterfly surveys throughout the summers of 2010-2012. In 2010, we conducted transect surveys for all butterfly species, but after finding no at-risk or rare butterfly species other than regal fritillaries, we focused our transect data collection solely on regal fritillaries in 2011 and 2012. During all three years, we did opportunistic sampling for other butterfly species, but still found no new at-risk species.

Results and Discussion (See Appendices for more details, including methods descriptions and data.)

Overseeding success

Overseeding was done by broadcasting seed - primarily forb seeds of species missing from our prairies - soon after a spring prescribed burn. Broadcasting was done either by hand or a drop-spreader (e.g. an EZ-Flow fertilizer spreader) pulled behind an ATV. All seeded sites were under patch-burn grazing management, so cattle focused intensive grazing on the same burned sites for the remainder of that first season following the seeding and then grazed other portions of the prairie in subsequent years. The hope was that the first year grazing would suppress the vigor of the dominant grasses (native and non-native) sufficiently that seeds would have enough light and available moisture to germinate. The vigor of suppressed grasses recovers slowly over the year or two post-fire, giving new seedlings a chance to establish before competition becomes fierce again.

A previous report (Final report for 2007 SWG #T56) presents data from overseeding projects in 2008-2010. Those data showed that with seeding rates similar to what we use when establishing new prairie seedlings in cropfield, establishment of forbs is possible, but densities of new plants are low. Follow-up data collection and observations indicate that established plants in those plots have largely survived, and a few species even seem to be increasing their abundance over time. The severe drought in 2012, combined with intensive grazing where some of those plots were located made it difficult to get useful data this year, but we did collect data from the Miller Tract in 2012, and a graph showing those results can be found in Appendix A.

Between 2010 and 2012, we experimented with much higher seeding rates to see if that would increase densities of newly established forbs. We used seeding rates of up to 8 times those cropfield seeding rates and we continued to see higher establishment rates as we increased seeding rates – we haven't topped out yet (see Appendix A). This may indicate a very limited number of available spaces for new seedlings to establish within existing prairie vegetation, and that increasing our seeding rates allows more of those spaces to receive seeds.

Along those lines, one of the big challenges when attempting to increase the plant diversity of a prairie is determining the best potential locations for successful establishment of each plant species. Soil chemistry, texture, and moisture conditions are among the most important factors – in addition to levels of competition. We can manipulate competition levels to aid in establishment, but the same is not true with soil conditions. Using seedling plugs is particularly challenging because the relatively low number of seedlings being planted provides a limited number of chances to get plants into appropriate micro sites – especially in heterogeneous soils such as the alluvial soils along the Platte River. With overseeding, the challenge is similar, but because of the high number of seeds, there are many more opportunities to hit appropriate locations. We've seen evidence of this as we've increased our seeding rates. In addition to seeing more plants of each species establish as a result of higher seeding rates, we've also seen an increase in the total number of plant species that appear. We assume that those higher seeding rates provide more matches between seeds and the conditions they need to germinate and survive.

Ongoing research by Dr. Jean Knops of the University of Nebraska-Lincoln should help us refine our ability to predict success of both seedling additions and overseeding projects. He and his students are helping us to look at correlations between plant species occurrences and soil conditions (among other things). We hope those results will help us refine our ability to correctly predict where efforts to add missing plant species have the best chance of success.

In 2011, we did a small experiment with shallow tillage (2-3 inches deep) of several small areas within one of our degraded remnant prairies. Seeding on top of those tilled areas resulted in very high establishment rates of new forbs. This contrasted with efforts a few years earlier in which we did some light disking and seeding on several sites and saw no increases in establishment rates between disked and burned areas. Because of the 2011 results, we rented a large tractor-mounted tiller in 2012 and tilled some plots of approximately 20 x 60 foot in size following a burn. Those tilled areas were seeded at the same time, and with the same seeding rate, as the surrounding burned areas, and we left control portions of each type unseeded. Unfortunately, because of the drought conditions in 2012, we saw almost no establishment in either the burned or tilled plots, so the value of tilling is still unknown. Others have reported early success (Carol Grygiel in S Dakota) with this method, but because our results have been inconsistent, we want to experiment more before recommending the practice. Surprisingly, though our seed addition results have been inconsistent, we have seen very good recovery of the pre-existing vegetation with both the shallow tilling and disking we've done. Within a few years, there appears to be no long-lasting impacts of the tillage on the plant species that were there beforehand. However, it's important to point out that we have only quantified that observationally, and have not done explicit pre- and post-surveys of the plant community. If others experiment with this, we would strongly recommend using small plots or strips – as we have done – rather than tilling or disking large areas of prairie.

Based on our overseeding experiences dating back to 1998, the most important factor that determines seeding success is soil moisture – driven by precipitation. Seeding rate, management of the site, and other factors can't override a lack of moisture, and we see almost no establishment from seedings done in drought years. This is frustrating, of course, because it's hard to predict whether or not growing conditions will be favorable until after seed is harvested and planted.

Seedling additions

Between 2010 and 2012, we plugged more than 800 prairie plant seedlings of 10 species into 7 prairies. We typically put the seedlings in groups of 5-7 plants to facilitate their ability to attract pollinators (and to make them easier to find later). In most cases, seedlings were moved out in April and May (sometimes early June) and watered only on the day they were transplanted.

Species added to prairies included:

- Rosinweed
- Butterfly milkweed

- Woolly sedge
- Fox sedge
- Lake sedge
- Crawe's sedge
- Maximilian sunflower
- Purple coneflower
- Foxglove (Agalinus)
- Leadplant
- Woolly locoweed

Wetland sedges were transplanted into wetland swales in restored prairies. We marked plants in order to track survival, but had a very difficult time finding the same plants the following year. Still, we think survival was very good, based on the number of sedge plants we have seen in subsequent years.

Wetland plugs have a great chance of survival, in some ways, relative to those moved into mesic sites, because of the higher soil moisture.

We had hoped to evaluate the success of the mesic plant transplants in the summer of 2012, but the very dry weather made that difficult because nearly everything was dormant by mid-summer, and we were not able to look at success.

Several hundred plants (11 species) were transplanted into our nursery beds for seed production. These were mainly species for which we either have inconsistent seed harvest years or that we need more seed harvest sites for. Those species included:

- Sensitive briar
- Rosinweed
- Compass plant
- Sideoats grama
- Slender wheatgrass
- Lance-leaved gayfeather
- Prairie larkspur
- Junegrass
- Pale poppy mallow
- Prairie cinquefoil
- Rocky mountain bee plant

We've been able to maintain healthy nursery beds of nearly every species we've tried. Being able to keep the plants watered, of course, makes a big difference. Our seed harvest from nursery species has become very important in terms of filling out our overall annual seed mixtures. Because of the work involved in maintaining nursery beds (watering, weeding, etc.) we have to be judicious in the number of species we put in the nursery. We've eliminated beds that don't provide us with seed we can't easily harvest from wild populations.

We also moved a couple hundred violet (*Viola sororia*) plants from remnant prairies into restored prairies. Survival of those plants was about 50% - much higher and more effective than trying to harvest seeds from wild populations, grow them into seedlings in the greenhouse (takes at least two years) and then transplanting (with low survival). Violets are a particular priority for us because they are the sole larval host plant for regal fritillaries, yet our restored prairies have few violets. Once established, the species spreads readily – we just have to get them started.

However, seedling additions to prairies have met with mixed success. One of the difficulties is that it can be hard to predict where individual plants will survive. Especially in alluvial soils, finding microsites appropriate for each prairie plant species (especially when we know very little about their requirements) is difficult. In most cases, overseeding is a more efficient means for us to introduce new plants because we can broadcast large numbers of seeds and have a better chance of hitting appropriate locations for each species. Of course, one reason overseeding makes sense for us is that we are set up well for harvesting our own seeds, greatly decreasing the cost. If we were buying seed, overseeding would be much more risky, and might not be worth the cost. In that case, seedling plugs might be worth a try, but we would want to provide more care (repeated watering, for example). If enhancing prairie diversity is a real priority for a landowner or land management entity, our strong recommendation would be to invest in the capacity needed to harvest seed from priority species and overseed at high rates. (more on this below under *Management Recommendations*)

Floristic Quality Analysis

Changes in the floristic quality of prairies were assessed with a plotwise method (see Appendix B) that involved data collection from approximately 100 1m² plots per site per year. Floristic quality and plant species richness was calculated within each plot and then averaged across the site. Those averages, and accompanying standard deviations, allowed us to compare sites over time.

To date, plotwise floristic quality assessment does not allow us to effectively measure results of overseeding efforts because the sampling plots are too scattered to pick up the relatively few new plants that have established from seedlings. Results from the most recent overseedings, with higher seeding rates, should be picked up more readily in future years, especially as we continue to seed more acres at those higher seeding rates. However, even without seeing the impacts of overseeding, we have been able to track changes in floristic quality and small-scale plant species richness.

Appendix B shows data from both remnant (unplowed) and restored (converted cropfield) prairies. There is a consistent trend in restored prairies, in which floristic quality increases during the early years of establishment and then levels off at some point. Interestingly, the number of years before floristic quality varies considerably between sites, even when comparing sites seeded in the same year. The pattern fits well with expectations that early weedy vegetation would be replaced over time with a more perennial-dominated plant community. However, the stability of the eventual floristic quality level is encouraging because it shows (so far) that our management is able to maintain the plant species and species diversity achieved through high-diversity seedings.

The longest annual data set we have shows that a 1995 seeding has maintained its high floristic quality through the 18th year of its existence. In that same prairie, two large grazing exclosures have been compared with the rest of the site, which has been managed with patch-burn grazing since 2002. The exclosures (burned only) are significantly lower in both mean floristic quality and plant species richness than the burned/grazed areas. In 2013, we plan to incorporate those exclosures into patch-burn grazing management and see whether or not they increase in floristic quality as a result.

In remnant prairies, there has been a consistent trend of increasing floristic quality over the last several years. There was only one exception to that trend - a sandhills prairie that decreased between sampling periods in 2002 and 2010. We will be sampling that site more frequently in the future to see whether or not there is an actual downward trend. Apart from the sandhills prairie, most remnant prairies are degraded remnants which are missing many conservative wildflower species and dominated by grasses – particularly Kentucky bluegrass. Those degraded sites have been increasing in floristic quality mainly as a result of increased frequency in native grass, sedge, and rush species, along with a few wildflower species. In general, conservative wildflowers have not been increasing in frequency in those sites; probably because there are few populations from which they can spread. These prairies are now being overseeded, and those seeded areas appear to be diversifying nicely. More details on the approach being taken with Kentucky bluegrass control and data on the results can be found here:

<http://prairieecologist.com/2012/11/28/dealing-with-a-pervasive-invasive-kentucky-bluegrass-in-prairies/>

We have put numerous blog posts on the PrairieEcologist.com site that have incorporated results of plotwise floristic quality sampling from our prairies. A few examples include:

<http://prairieecologist.com/2011/11/14/trying-to-figure-out-what-we-did-right/>

<http://prairieecologist.com/2011/10/11/a-measure-of-ecological-resilience-in-a-restored-reconstructed-prairie/>

Despite consistent trends showing increasing floristic quality in remnants and stable floristic quality in restored prairies, we are finding some warning signs that are causing us to tweak our fire/grazing management. In particular, there are several plant species that seem never to survive a season ungrazed, whether they are in the burned or unburned portion of our patch-burn grazed prairies. One of those is sweet clover (*Melilotus* spp), an exotic legume that we are glad to see grazed intensively each year. However, other species that are grazed annually include common and showy milkweeds (*Asclepias syriaca* and *A. speciosa*), entire-leaf rosinweed (*Silphium integrifolium*), and Canada milkvetch (*Astragalus canadensis*). In one quick evaluation, I looked at 150 milkweed plants in a particular restored prairie. Of those plants, 83% of those in the burned portion had their flowers nipped off, and 57% of those in the unburned did. As the season wore on, the percentages rose, and I didn't see any seed pods by the fall. In exclosures and roadsides nearby, milkweed species are common and produce numerous seed pods. Rosinweed and Canada milkvetch are both grazed pretty hard (leaves and stems) for most of the season, though grazing intensity is less in unburned areas and under lighter stocking

rates. However, even under light stocking rates, the plants rarely flower, and when they do, they produce few and small flowers.

During the last two years, we've started building large temporary exclosures within some of our grazed prairies, using electric fence. In other sites, we've incorporated an entire year of no grazing into our patch-burn grazing regime, and plan to rest those prairies every 2-4 years, depending upon the site. So far (this work is being partially funded by another State Wildlife Grant) we are seeing strong blooming by rosinweed, milkvetch, and milkweeds in those exclosures. It will be interesting to see whether or not we can pick up changes in their frequency through our plotwise floristic quality sampling efforts as a result of the exclosures. Regardless, for these three species – and likely others – periodic rest from grazing appears to be important. (see *Management Recommendations* below)

Impacts on Rare Butterflies

Comprehensive butterfly species surveys were conducted along twenty two 200m transects in 2010. All butterfly species observed were recorded, along with their activity type (nectaring, flying, basking, etc.) Any nectaring activity was noted, along with the plant species visited. The transects covered both restored and remnant prairies, as well as the full range of habitat conditions found within patch-burn grazing (e.g. this year's burn, last year's burn, unburned). In addition to the transect surveys, opportunistic sampling was conducted throughout 2010-2012 to search for rare or at-risk butterfly species. No at-risk or rare butterflies were found other than regal fritillaries, so after the 2010 season, we focused solely on regal fritillaries in our transects in order to collect the best data we could on that species. (Opportunistic sampling for other butterflies continued through all three years.)

No rare butterfly species were seen in the Platte River prairies during the summer of 2010 – inside or outside of transects. We found a total of 23 butterfly species through all sampling efforts. Of those 23 species, 19 were found in remnant prairies, and 18 were found in restored prairie. In 2010, the most abundant species seen were orange sulphurs, followed by regal fritillaries, which were apparently having a good year throughout much of the Midwest. Orange sulphurs did not appear to be correlated with habitat structure, but regal fritillary observations were strongly correlated with unburned/ungrazed portions of prairies during late June and early July.

Species richness was not particularly high at any site. The highest number of butterfly species seen within a 200m transect was 7 and there didn't appear to be a particular habitat type (restored or remnant prairie) or management result (burned/unburned, grazed/ungrazed) that correlated with species richness. A few species showed preferences to certain site types, but the majority were not seen often enough to establish patterns. Eastern tailed blue butterflies were much more abundant in restored prairies than remnant prairies – perhaps because of their preference for legumes as larval host plants. Sachems and common checkered found mostly in remnants (11 of 12 sachems, 9 of 13 skippers). Painted ladies were only found in two prairies (one restored and one remnant).

Butterfly nectaring was seen on a wide variety of plant species, but hoary vervain (*Verbena stricta*) was, by far, the most used nectar plant by butterflies in general (see graphs in Appendix C). This is a plant species that is generally considered a pasture weed because it is not palatable to cattle and thrives in heavily grazed areas. However, it is a native prairie wildflower, and appears to be of great value to butterflies.

We focused most of our data collection effort on regal fritillary butterflies because of their status as an at-risk species and their abundance in our prairies. Those surveys were conducted repeatedly during each summer along 300m transects (see Appendix C for maps showing those transect locations and additional descriptions of methods). There were two overwhelming lessons learned from that work.

1. The number of regal fritillaries produced in our Platte River Prairies is primarily tied to two factors: violets and thatch. During the spring, when adults are first emerging from their chrysalises, butterfly abundance is highest in degraded remnant (unplowed) prairies that have few showy native wildflower species, but lots of common blue violets (*Viola sororia*). While they don't have much to excite a prairie botanist, these prairies sure produce a lot of regal fritillaries. We don't find many regals in recently burned portions of these prairies – only in portions that have built up some thatch.

2. After regals emerge and mate in those thatchy violet-rich prairies, they spread out into more flowery sites to feed. In our Platte River Prairies, those feeding sites tend to be restored (reconstructed) prairies located around and between those degraded remnants. Those restored prairies have significantly fewer violets than remnant prairies, but lots of the favorite nectar flowers for regals, including hoary vervain (*Verbena stricta*), milkweeds (*Asclepias spp.*), wild bergamot (*Monarda fistulosa*), and thistles (*Cirsium and Carduus spp.*). Interestingly, while we don't see regals emerging from recently burned prairie, some of the most-used summer nectaring sites are our most recently burned sites.

Providing both degraded remnant prairie habitat with lots of violets (for larval habitat) and restored prairie with lots of nectar flower species appears to be a good mixture for regal fritillaries. Remnant and restored prairies seem to complement each other in terms of the resources they provide. Over time, we hope to improve the nectar flower diversity in remnants and the abundance of violets in restored prairie, but for now having both prairie types near each other seems to be sufficient.

We were hoping to gather data on the oviposition (egg-laying) locations of regal fritillaries, but were unable to do so because of the very low numbers of regal fritillaries found during oviposition (late summer and early fall). One of our concerns is that we may be luring regal females out of flower-poor but violet-rich remnant prairies into flower-rich, violet-poor prairies during oviposition. We were unable

to pick up enough samples along our transects to compare the relative use of the two prairie habitat types.

Methods and additional data, including graphs and tables, can be found in Appendix C. In addition, several blog posts were published in the Prairie Ecologist blog regarding the data we collected on butterflies during this project. Links to those posts are below:

Response of regal fritillaries to Patch-Burn Grazing habitats:

<http://prairieecologist.com/2012/11/13/regal-fritillary-butterflies-in-burned-and-grazed-prairie/>

Summary of 2010-11 data on Regal Fritillaries: <http://prairieecologist.com/2011/12/14/regal-fritillary-butterflies-in-the-platte-river-prairies-2011/>

Nectaring observations for all butterfly species from 2010: <http://prairieecologist.com/2011/01/25/the-importance-of-weedy-flowers-for-butterflies/>

Management Recommendations

In general, we are seeing positive results from our patch-burn grazing management of both restored and remnant prairies. We are careful not to use the same exact burn units repeatedly, and instead burn whichever portion of each prairie is the most thatchy each year. We feel this helps prevent potential negative impacts from using the same boundaries each year, such as changes in plant community because of repeatedly mowing firebreaks in the same places, or encroachment of shrubs or other species along edges. In addition, we want to avoid any kind of predictable repetitive management system that favors some species (plant or animal) over others, so we try to shake up the season of fire, grazing stocking rates, and percentage of the units burned – in addition to location of burn units – as much as possible to avoid that repetition. We set stocking rates annually (in the fall), based mostly on two things: 1) Evaluation of grazing impacts from the previous couple of years, and 2) Precipitation levels during the previous year (we can't predict next year's rainfall, but we can compensate for this year's).

Invasive grasses

Most of our remnant prairies have degraded plant communities that are dominated by grasses, especially Kentucky bluegrass and smooth brome. We are able to manage against bluegrass and brome, through early intensive grazing and late spring burns, and shift the vegetative community to one more dominated by native warm-season grasses. However, while that gives us some gains in plant diversity, in some ways it is just exchanging one set of dominant grasses for another. By keeping cattle in the pasture through the summer – albeit at sometimes lower stocking rates – we can suppress warm-season grasses as well, allowing wildflowers (including those we overseed into the site) a chance to grow without strong competition from grasses of any species. We are careful not to repeat treatments that specifically target spring grasses for very many seasons in a row because we have a number of native sedges, cool-season grasses, and spring wildflowers that are important components of prairies, and we don't want to manage too intensively against them. For more information on the approach we take with Kentucky bluegrass control, and data showing the results, you can look at this blog post:

<http://prairieecologist.com/2012/11/28/dealing-with-a-pervasive-invasive-kentucky-bluegrass-in-prairies/>

Pollinators

In the last several years, we have focused more on pollinators, their importance to prairie ecosystems, and their responses to management. Through this grant-funded project, we looked closely at butterflies – especially regal fritillaries – but we have also been collecting data on bees, and thinking about impacts of management on them. Both butterflies and bees, of course, rely on nectar sources for much of the season. A major difference between them, though, is that bees are tied to a nest site, while butterflies can roam widely in search of food. Most bee species can not forage further than ¼ mile from their nest (much less for some species), which means that management can have significant impacts on bees if large blocks of habitat are denuded of flowers all at once, through haying, burning, or intensive grazing. Determining how to use this information to design management treatments for such regimes as patch-

burn grazing is something we're still working on, but it seems likely that several smaller burn patches may be better than a single large one, when that is a possibility.

Fortunately, the most commonly used flower species for butterflies in our prairies is hoary vervain (*Verbena stricta*), which can be very abundant even in intensively grazed sites. It is the most visited nectar plant species for regal fritillary butterflies, but also for the larger community of butterflies. Commonly dismissed (and sometimes sprayed) by many private landowners as a pasture weed, this plant provides extremely important resources for butterflies. It is most abundant in prairies that are disturbed through grazing because it is non-palatable to cattle and can spread quickly by seed in weakened grasslands. It subsequently declines quickly as grass vigor increases. Other important nectar plants for butterflies include milkweeds, thistles (native and non-native), and wild bergamot. Butterflies tend to be fairly generalist in habitat in terms of which kinds of flowers they nectar from, but many bee species are more specialized. Plant species such as purple prairie clover are particularly attractive numerous bee species, but bee diversity also relies on having the plant species that each specialist bee relies on for food.

Encouraging plant diversity, as well as abundant flowering of each species, is an important management goal for both bees and butterflies. When designing management strategies, it's important to consider not only long-term opportunities for plant species to flower (incorporating periodic intensive grazing for hoary vervain, as an example), but also spreading those management treatments across the landscape so that there are multiple management units available for pollinators to choose from at any one time. As mentioned earlier, the scale of those management treatments is important as well. For example, intensive grazing can be beneficial in terms of favoring hoary vervain, but a bee species that relies on prairie clovers may not be able to find sufficient nectaring opportunities in a large block of intensively grazed prairie. Ensuring that management blocks containing abundant prairie clover (and other plant species) within a reasonable distance of each other is an important consideration.

Grazing Enclosures

On the subject of encouraging plant diversity, we're beginning to find that complete rest from grazing is important for some plant species. Milkweeds, for example, are rarely allowed to bloom and produce seed in prairies where we have even light grazing stocking rates. Rosinweed and Canada milkvetch are also prone to repeated grazing, even in unburned portions of patch-burn grazed pastures. We are beginning to incorporate large "moving window" temporary enclosures (with electric fence) into some patch-burn grazed prairies, and years of complete rest for other prairies. The temporary enclosures are moved each year, so that every part of the prairie will get a year of rest over time. It is easy to see differences between grazed areas and adjacent enclosures in terms of the vigor and blooming abundance of the above plant species, even after just a single year of grazing exclusion. Without that grazing exclusion, these plants would gradually disappear from many of our prairies because they would cumulatively lose vigor year after year, without being able to complete their growth cycle periodically. We assume that there are other plant species, as well as animal species, that also benefit from this kind of periodic complete rest.

Overseeding and Seedling Plugs

During the period of this grant, we overseeded both restored and remnant prairies, but focused largely on degraded restored prairies that are missing many wildflower (forb) species. We have had good luck broadcast seeding immediately after both early and late spring burns in patch-burn grazed prairies. We have not seen any patterns that indicate that earlier seedings are more successful. However, seeding rate is very important. So far, the more seed we broadcast, the more plants establish, even with seeding rates up to 8 gallons of rough-cleaned forb seed/acre – which is 8 times what we use in cropland seedings. Focusing on smaller areas with more seed appears to be the best option for increasing the plant diversity of these degraded sites.

Seedling plugs have been successful in some situations – particularly in terms of getting wetland sedge species established in restored wetlands. We have found that most prairie plants are easily grown in greenhouse situations (with some exceptions) but that some take more than a year to germinate, and then perhaps a full year or more to grow large enough to transplant. When growing native plants in a greenhouse, it pays to be patient and not discard pots that haven't germinated after the first several months. Holding them, and continuing to water them periodically, as long as a full year (allowing them to freeze in the winter), often leads to eventual germination.

The downsides of seedlings are that they can take a lot of time and infrastructure to grow, and success in mesic prairie transplants is mixed at best. We only watered plants at the time of initial transplant, so success could be improved with repeated waterings, but that becomes even more time intensive. In addition, finding appropriate sites for seedlings of various species can be more challenging than it might seem. At least in our alluvial soils, it seems that some plants – especially those that are rare enough that we're trying to increase populations – are pretty picky about microsite habitats. It might make sense to focus seedling transplants around small existing populations because it's likely that the microhabitat is appropriate nearby. On the other hand, it seems beneficial to create new populations as well as expand current ones. In that vein, we tried to plant groups of plants (5-8 or more in any location) to establish populations that would attract pollinators and facilitate cross-pollination more effectively than a single plant.

In general, our experience is showing us that overseeding is a cheaper and more efficient way for us to increase the abundance of most plant species. Even though most seeds don't turn into new plants, high seedings rates mean that there is a good chance of getting at least some of each species planted into locations where they can establish. Exceptions to the generalization that seeding is better than seedlings include violets and wetland sedges. We have found that harvesting seed from violets is very time consuming and they are slow to grow to mature seedlings. Because we have very abundant populations of violets in our remnant prairies, we have had good luck digging and transplanting bare-root plants of violets from remnants to restored prairies where violets are rare. We are attempting the same technique with an upland sedge (*Carex heliophila*) as well, because it makes few seeds, and we have not been able to get it to germinate in the greenhouse. The tiny size of the plants, however, has made it difficult to see whether or not our transplants have survived so far. We hope to see populations

developing over time in transplant areas so we can see if our work has paid off. Wetland sedges certainly transplant well, and high survival rates can make that strategy worthwhile.

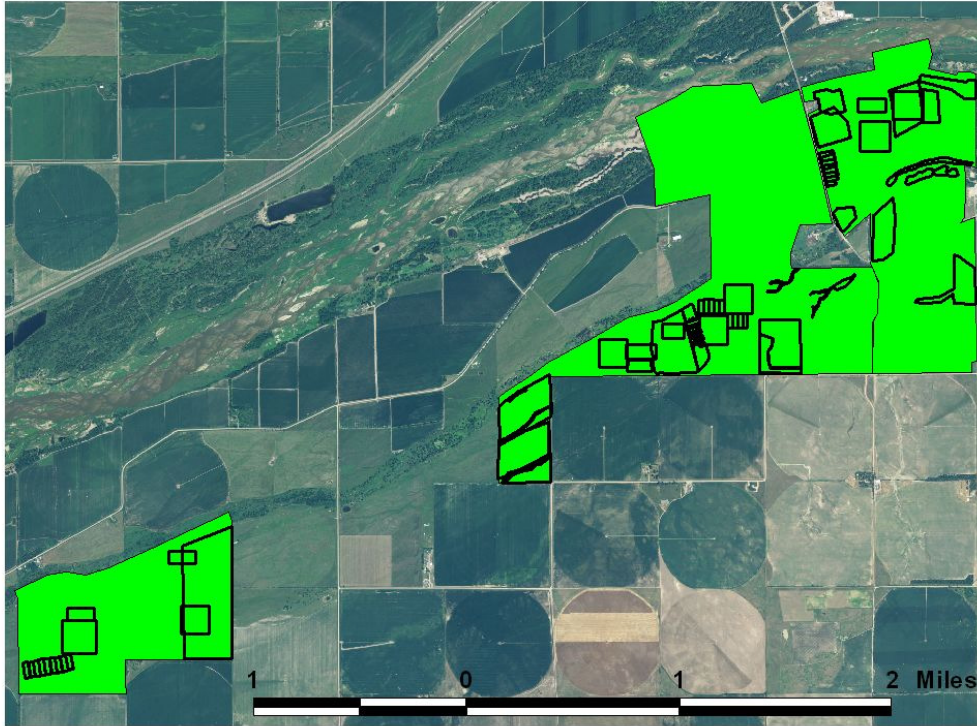
Of course, one big reason it's cheaper in our case is that we have existing capacity for large-scale seed harvest. We would recommend that if enhancement of degraded prairies is a high priority for a landowner or land management entity, they should invest in building seed harvest capacity. That doesn't necessarily mean large investments in equipment or people, though a pull-behind seed stripper, for example, can be a nice way to harvest large amounts of seed quickly. More information on seed harvest techniques and equipment needs can be found here:

<http://prairienebraska.files.wordpress.com/2011/01/restoration-manual.pdf>

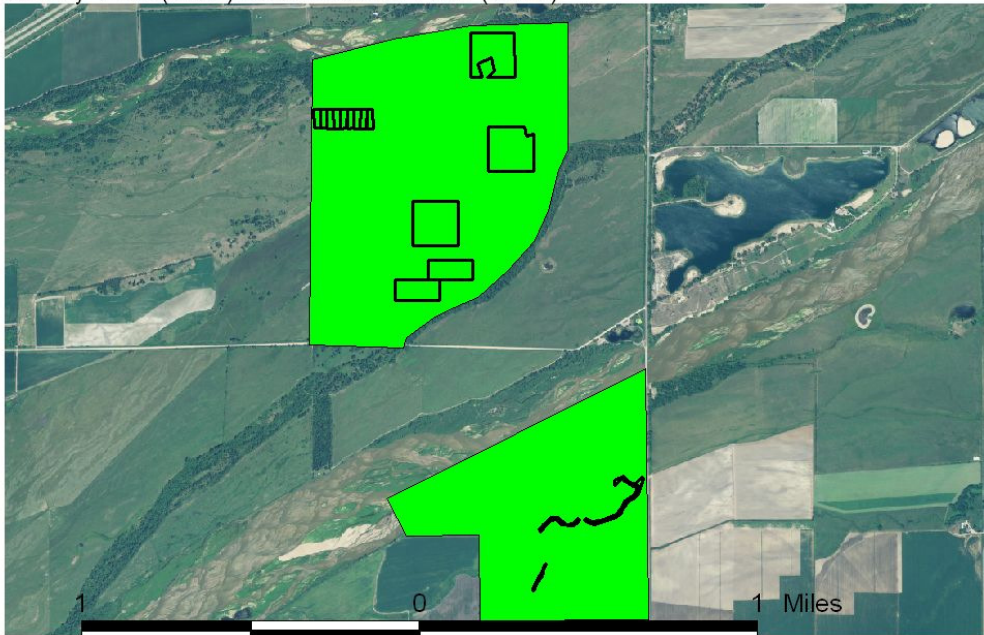
APPENDIX A: Overseeding Results

Below – a map of the overseeding work done on TNC land between 2008 and 2012. The total area seeded is approximately 500 acres. Seeding rate varied from light (early years) to heavy (later years).

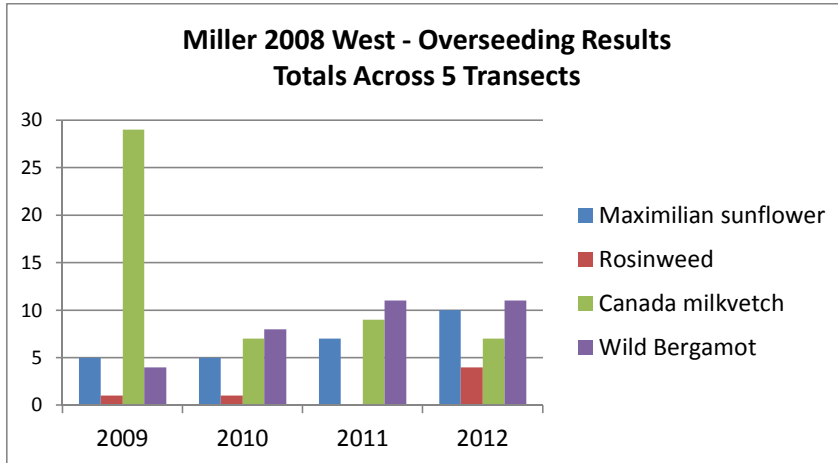
Miller Tract (west) and Dahms/Derr Tracts (east)



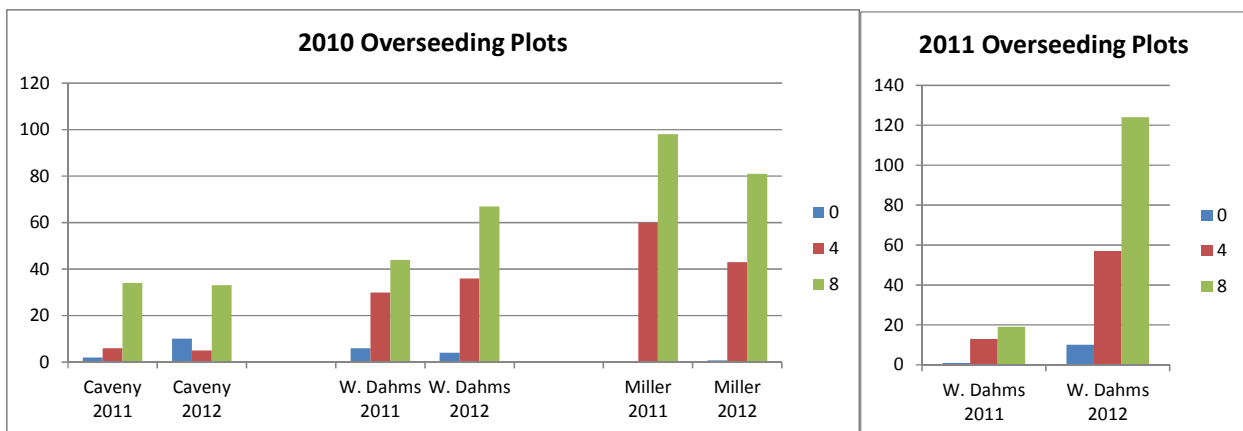
Caveny Tract (north) and Studnicka Tract (south)



This graph shows the total number of plants found each year across five 50m x 2m transects within a 10 acre plot overseeded in 2008. The transects were marked with GPS, sampling areas were not exactly identical from year to year.



The graphs below show results from 100m x 30m overseeding trial plots at three sites, in which seeding rates of 0, 4, and 8 gallons per acre of rough-cleaned seed were broadcast. The graphs show the total number of plants found (across all seeded species) in a total of three 100m x 2m sampling transects – one transect in each of three replicate plots at each site. In both 2010 and 2011, higher seeding rates generally resulted in more plants establishing.



In the above graph, one patch of wild bergamot found at the Caveny tract in 2012 made the 0 gals/acre treatment higher than the 4 gals/acre treatment.

In the W. Dahms 2010 plots, the increase plants seen between 2011 and 2012 was driven mostly by wild bergamot, black-eyed susan, rosinweed, and some by purple prairie clover. It's difficult to say whether that increase was due to visibility of those plants as they matured, or an actual increase in abundance.

At the Miller tract, the number of plants in the 2010 plots decreased between 2011 and 2012, but that was driven largely by two species; Illinois bundleflower and foxtail dalea. The foxtail dalea drop off was likely because it is an annual plant that germinated less well in 2012 because of lower light conditions as vegetation recovered.

The data from the W. Dahms 2011 seeding show a dramatic increase between 2011 and 2012, but that is most likely due to sampling in 2011 being the first growing season, at which time it is difficult to see many of the new plants – and because some likely didn’t germinate until late in the 2011 season.

The four tables below show detailed establishment data from the sites overseeded in 2010 and 2011. In each table, the total number of plants found within each of the treatments is a total from three 100m x 2m transects (one sampling transect from each of three 100m x 30m seeding plots per treatment). It is interesting to note the differences in the plant species that established well between the various sites. For example, Illinois bundleflower established strongly at West Dahms and Miller in 2010, but hardly at all at Caveny in the same year, and minimally at West Dahms in 2011. While there was variation between sites and years, however, establishment of all species was generally higher at higher seeding rates, and the number of established species also increased with seeding rate.

Caveny N 2010 Plots						
	2011 Data			2012 Data		
	0 gals	4 gals	8 gals	0 gals	4 gals	8 gals
Illinois Bundleflower			4		2	
Black-eyed Susan		13	28	1	3	15
Bergamot	1	3	47	23	10	139
Maximilian Sunflower			1			
Purple Prairie Clover		1	1	1		4
White Prairie Clover	3		7	4		
Rosinweed	1		2	1	1	5
Stiff Sunflower						2
Canada Milkvetch			5			
Illinois Tickclover		2	4			6
Stiff Goldenrod			1			
False Sunflower			2			

West Dahms 2010 Plots						
	2011 Data			2012 Data		
	0 gals	4 gals	8 gals	0 gals	4 gals	8 gals
Illinois Bundleflower	7	14	48	0	21	37
Black-eyed Susan	3	36	18		21	34
Bergamot		8	14		27	61
Maximilian Sunflower	1	11	24		21	27
Purple Prairie Clover	1	3	6	1	7	15
White Prairie Clover	7	13	3		1	7
Foxtail Dalea			2			
Rosinweed		1	5		8	28
Stiff Sunflower		3	2		3	1
Canada Milkvetch		1	1			5
Illinois Tickclover			1			1
Stiff Goldenrod			6	6		10
False Sunflower						2
New England Aster		1				

Miller 2010 Plots						
	2011 Data			2012 Data		
	0 gals	4 gals	8 gals	0 gals	4 gals	8 gals
Illinois Bundleflower	1	34	102	2	31	51
Black-eyed Susan		27	35		16	36
Bergamot		19	20		17	47
Maximilian Sunflower		24	33		19	30
Purple Prairie Clover		22	46		17	34
White Prairie Clover		7	5		3	1
Foxtail Dalea		30	13			
Rosinweed		7	21		19	19
Stiff Sunflower					3	6
Canada Milkvetch			3		2	2
Illinois Tickclover			2			
False Sunflower			4			5
New England Aster		4	1			
Pitcher Sage			1		1	1
Sawtooth Sunflower						1

West Dahms 2011 Plots						
	2011 Data			2012 Data		
	0 gals	4 gals	8 gals	0 gals	4 gals	8 gals
Illinois Bundleflower		10	24	1	7	17
Black-eyed Susan		2	7	8	76	177
Bergamot	1			12	57	114
Maximilian Sunflower		6	5		1	6
Purple Prairie Clover		1				2
White Prairie Clover			2			3
Rosinweed		2	1	2	23	23
Stiff Sunflower		1	2			4
Canada Milkvetch		1	1	1	3	6
Illinois Tickclover		2	4			5
Stiff Goldenrod	1	8	3	4	2	1
Sawtooth Sunflower		4	7	1	4	14
Deer Vetch		2				

APPENDIX B: Impacts of Management on Prairie Communities

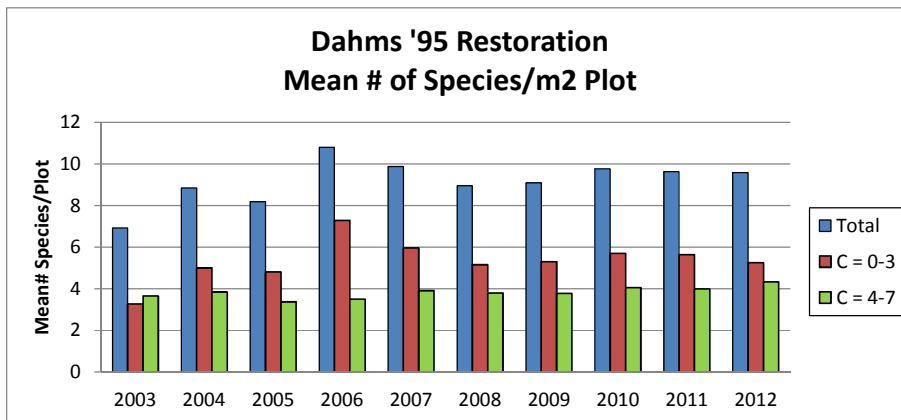
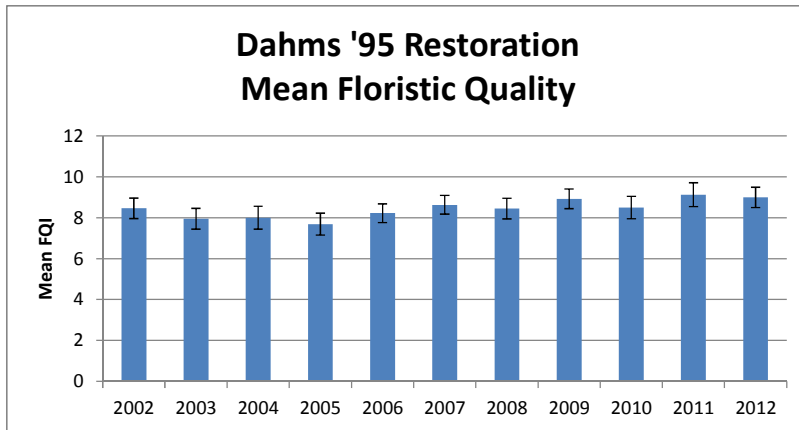
To assess changes in the floristic quality of the natural communities (grasslands) on our sites, we use a plotwise floristic quality assessment technique that we've been developing along with Gerry Steinauer with Nebraska Game and Parks Commission and two other scientists (Bob Unnasch and David Maddox). The method used employs 100 1m² plots stratified across the site being evaluated. Within each plot, all plant species present are listed and the floristic quality (calculation developed by Swink and Wilhelm from the Chicago region - see a description here: <http://www.botany.wisc.edu/WFQA.asp>) is calculated for each plot and averaged across the site. This gives us an average floristic quality that can be tracked over time – with confidence intervals – to assess how it's doing through changes in climate, management, etc. We can also look at the frequency of occurrence of individual plant species over time to assess patterns. This use of floristic quality analysis differs from the more commonly employed method of simply listing the species across an entire site and calculating a single floristic quality number for the site.

The plotwise floristic quality (pFQI) assessments can help us see whether or not our management appears to be helping limit impacts by invasive species to our plant communities. While it's not reasonable to expect fire and grazing (and even herbicides) to effectively eliminate species like smooth brome and Kentucky bluegrass from prairies, the hope is to suppress their vigor enough to allow the surrounding diverse plant community to flourish – and that result can be seen in the pFQI data. Unfortunately, the scattered nature of the plots makes it difficult to pick up any early results of our overseeding and seedling plug work, so that assessment has to be done more directly.

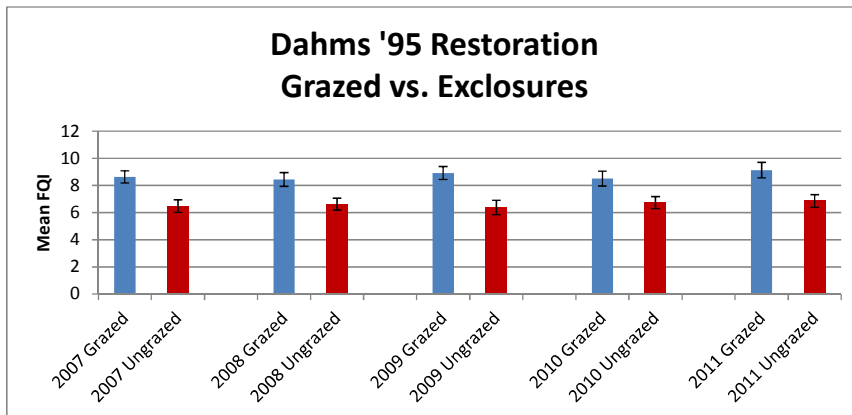
Below are a series of graphs showing changes in mean floristic quality and mean species richness across a variety of prairies. Both the floristic quality and plant species richness were calculated in each of approximately 100 1m² plots per site and averaged to obtain the means shown in the graphs. Error bars on the graphs indicated 95% confidence intervals.

Floristic Quality Trends in Restored Prairies

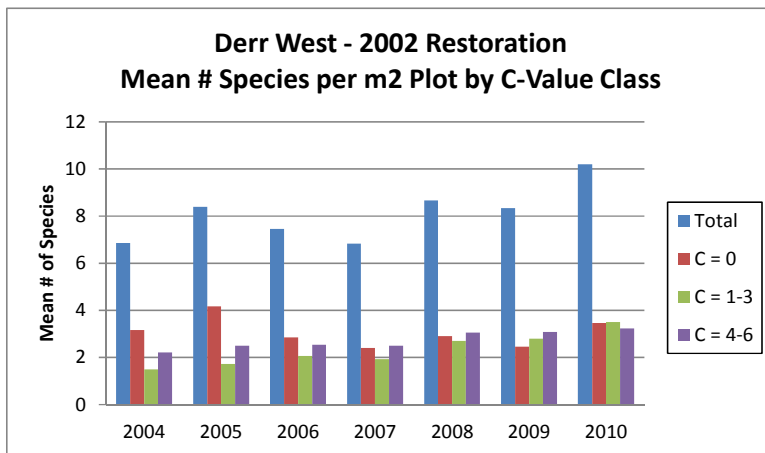
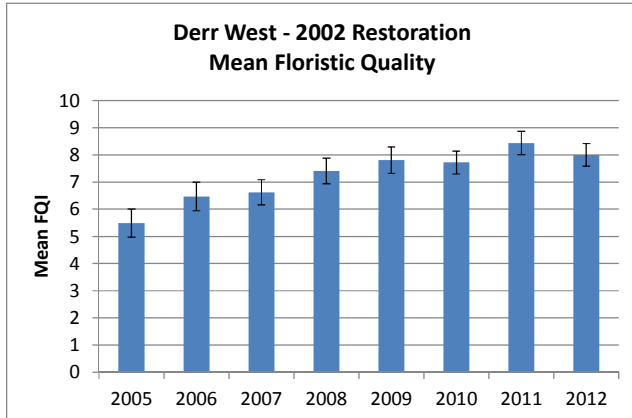
The first three graphs below show data from a prairie that was seeded in 1995 on a mesic site. This is the site for which we have our longest annual data set, and it is very nice to see consistent floristic quality throughout that entire period. The first graph shows that mean floristic quality has not changed significantly since 2002, even though the seeding is now 18 years old. The second graph shows mean plant species richness (per square meter), which has also stayed fairly constant, though there has been some fluctuation in the lower c-value species – especially during the drought years of 2002-2006.



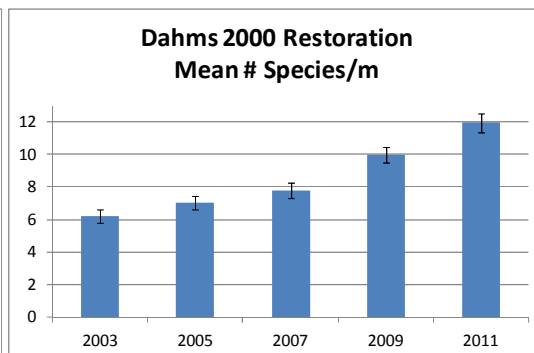
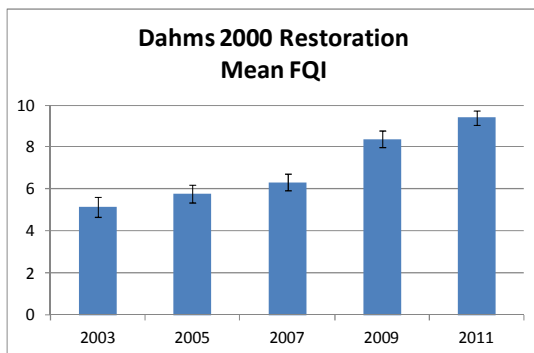
The graph below shows the difference between the mean floristic quality of the grazed portions of the 1995 restoration and two large exclosures that have had prescribed fire, but no grazing. There is a consistent and stark difference between the two. The ungrazed areas have fewer species of all categories (c-value, grasses, forbs, etc.).



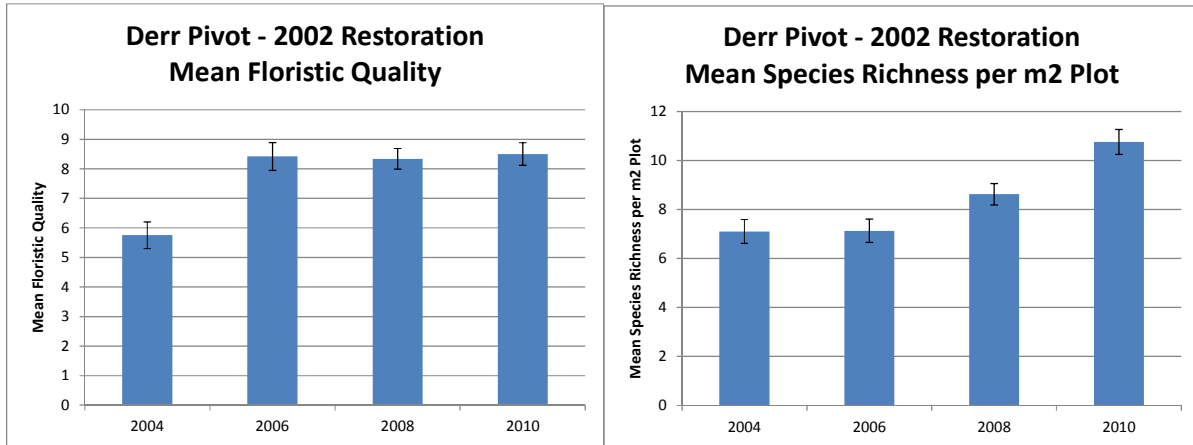
These two graphs show the mean floristic quality and mean species richness for a prairie that was seeded in 2002. Mean floristic quality rose between 2005 and 2008, and then has leveled off since then. There has been some fluctuation in the mean plant species richness at the site, but higher c-value species have generally increased slightly over the years and most of the fluctuation is among “weedier” species, as would be expected for a site managed by periodic fire and intensive grazing.



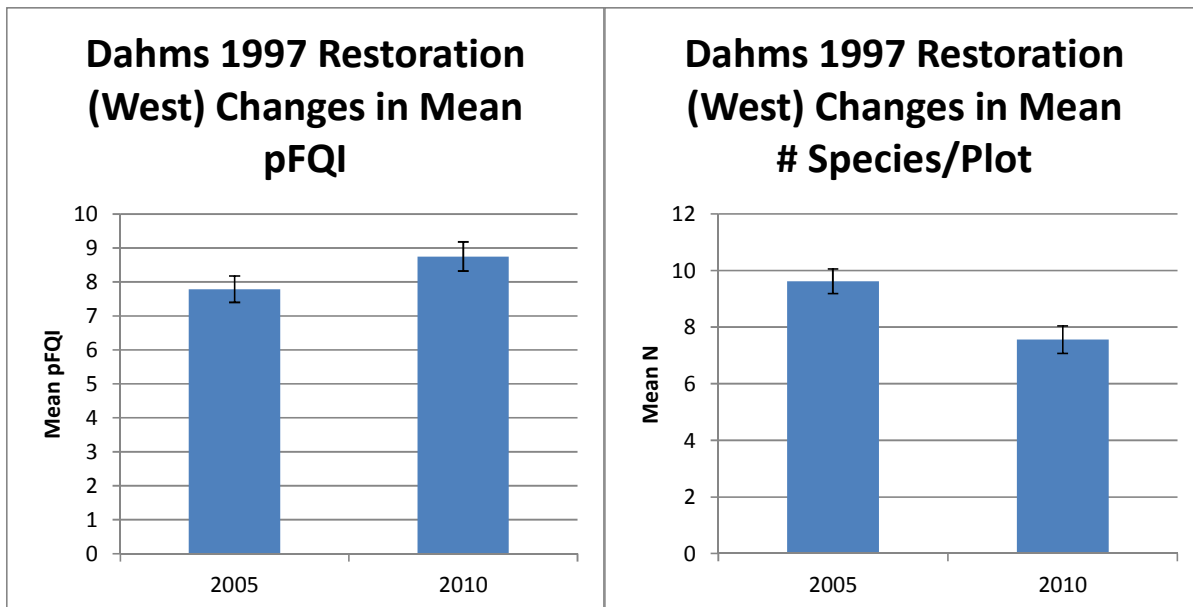
The graphs below show steadily increasing mean floristic quality and mean plant species richness over time for a prairie seeded in 2000. This site is unusual in that it has continued to show increases in both mean floristic quality and mean species richness over time. We’re not sure why.



The Derr Pivot was seeded in 2002 on cropland within the sandhills just east of the Derr House. Mean floristic quality has leveled off since 2006, but mean species richness has continued to rise since patch-burn grazing has been implemented more consistently since about 2008.

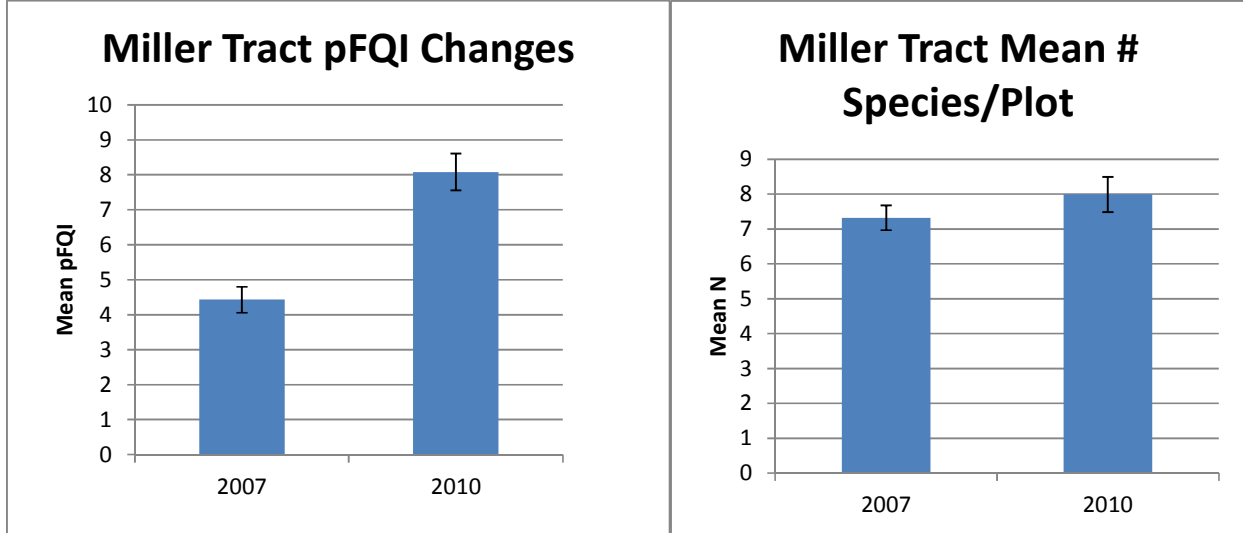


The west 1997 prairie restoration at the Dahms tract increased in mean floristic quality but decreased in mean species richness between 2005 (toward the end of the multi-year drought) and 2010. Lots of short-lived forb species decreased (because the drought ended?), along with heath aster, showy milkweed, and Canada goldenrod. Several species increased, but indiagrass increased the most (21% to 60%).

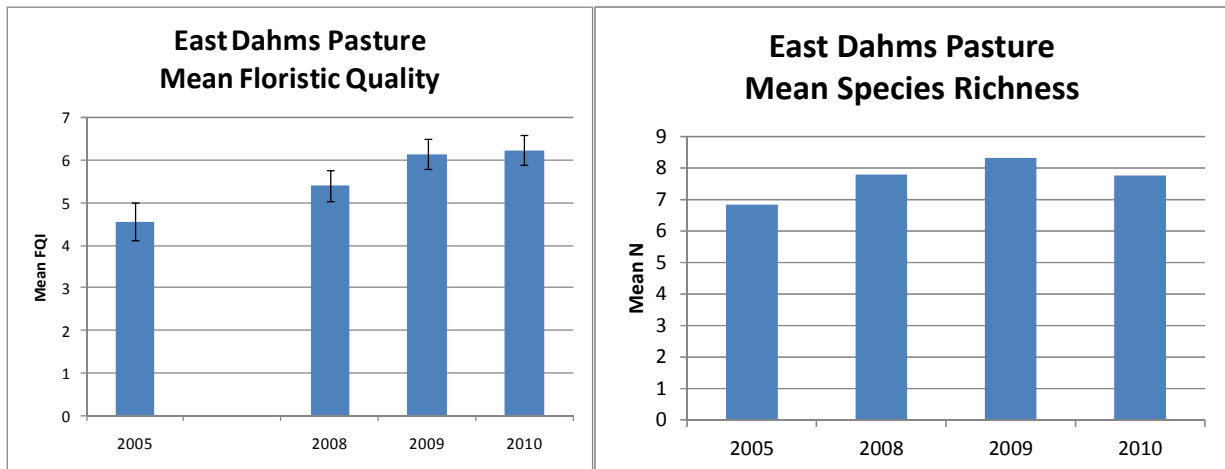


Floristic Quality Trends in Remnant (Unplowed) Prairies

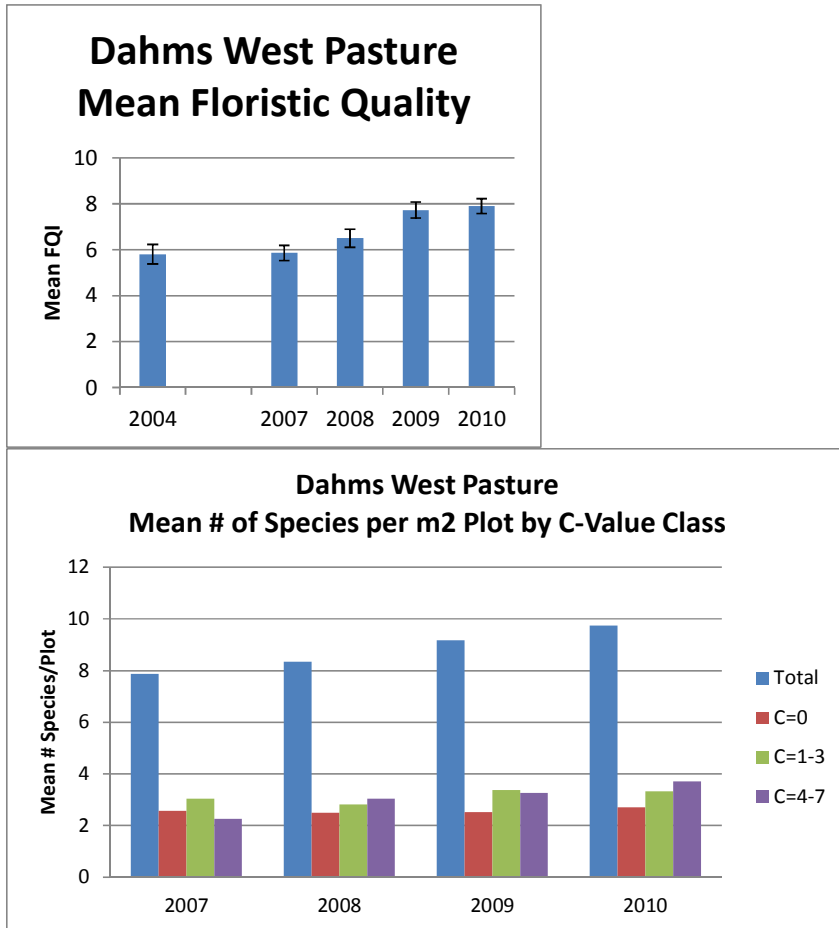
The Miller tract is a degraded native prairie that was purchased by TNC in 2007. Mean floristic quality increased dramatically following a year of rest and implementation of patch-burn grazing. .



The East Dahms pasture has also increased in mean floristic quality over time, though mean species richness has not changed much.

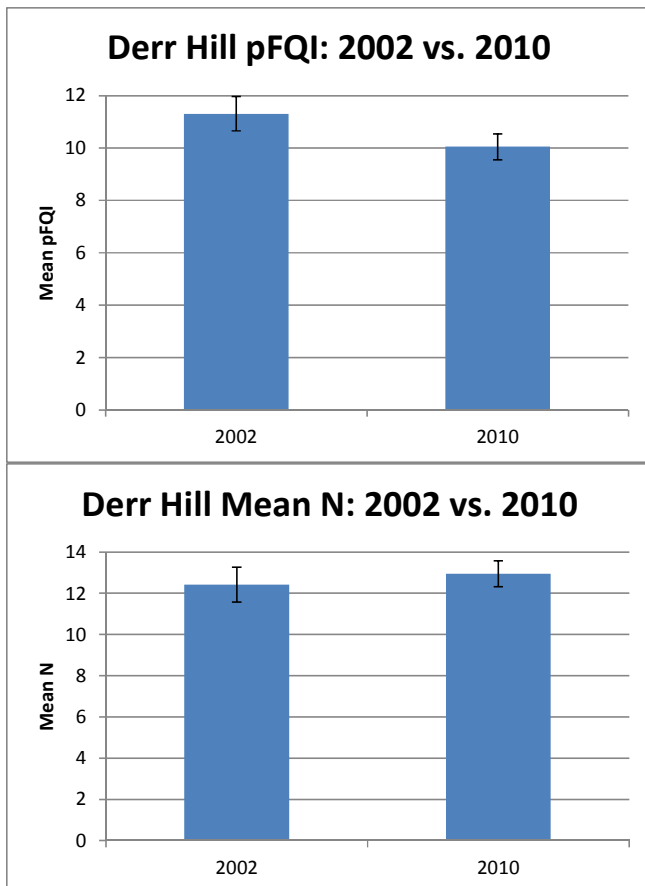


The Dahms West pasture is a long triangular pasture of approximately 175 acres west of the Derr House. Both mean floristic quality and species richness has been increasing over the years.

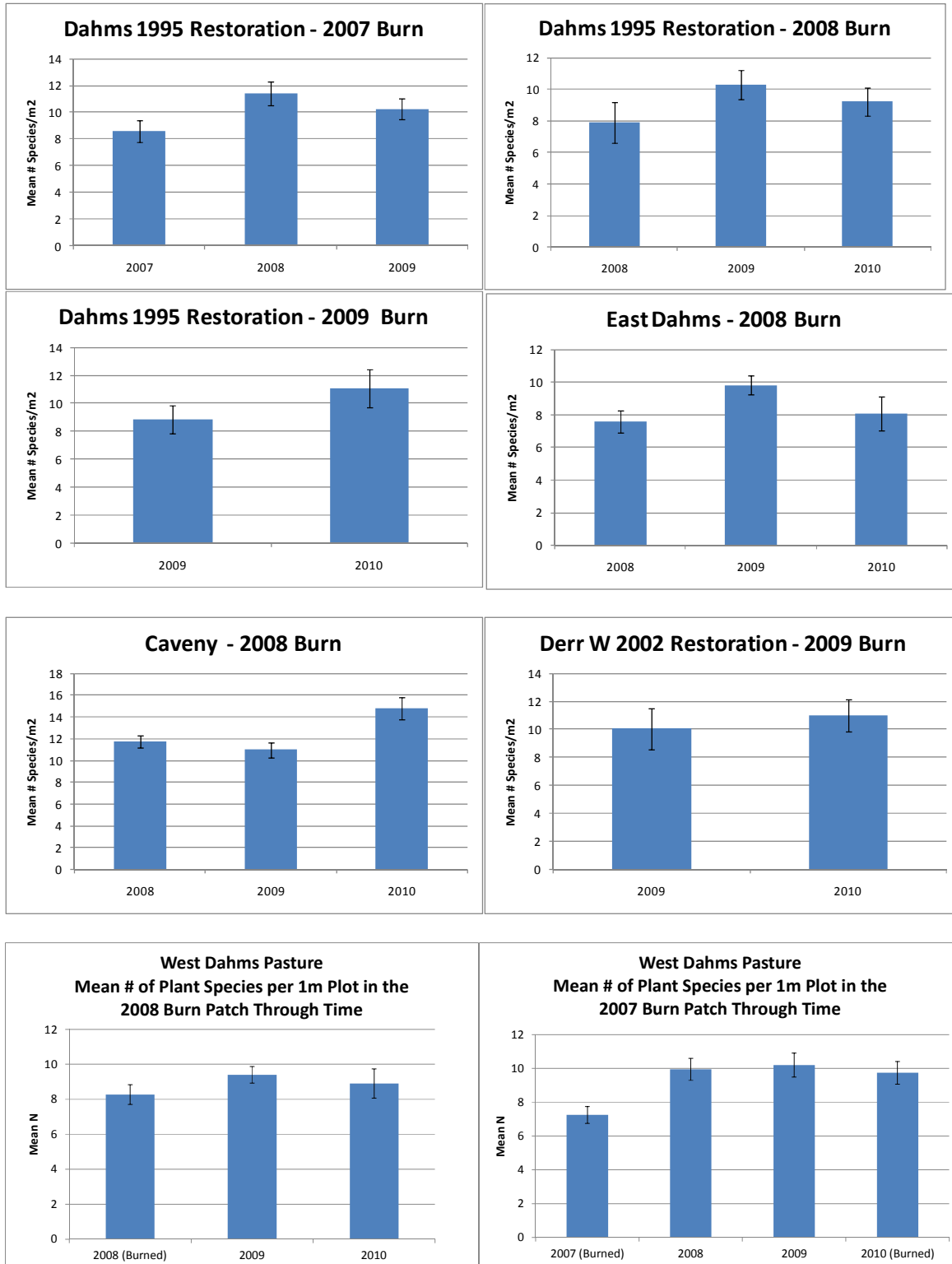


The only remnant prairie that has shown a decrease in mean floristic quality over time is the Derr sandhills prairie (southeast of the Derr House). It's difficult to extrapolate too much from only two years of sampling, but it is troubling that the floristic quality was lower in 2010 than in 2002. Mean species richness was not different between years. We will be sampling from this site more frequently to see if we can get a better feel for any trend in floristic quality and/or individual species frequency.

The only major changes in the frequency of individual species were increases in Kentucky bluegrass (*Poa pratensis*) from 49 to 83% and deer vetch (*Lotus unifoliatus*) from 16 to 43%. Decreases were seen in three species, including needle-and-thread (*Hesperostipa comata*) from 37% to 17%, brittle prickly pear (*Opuntia fragilis*) from 51% to 16%, and fringed puccoon (*Lithospermum incisum*) from 41% to 9%. Prior to 2002, the prairie had been hayed annually for about 20 years until 2000, when TNC took ownership, and then it was rested and portions were burned. The year 2002 was still early in the drought that extended from about 2000 until about 2006. The site has been managed with patch-burn grazing since about 2007. Kentucky bluegrass increased in other sites during the drought, so it's hard to know whether the higher frequency of that species seen in 2010 was because of the drought, weather conditions in 2010, or a response to our management.



Below is a series of graphs from multiple sites that show a general trend of increasing mean plant species richness in patch-burn grazed burn patches in the year after the initial year of fire/grazing. Some sites then bounce back down, while others seem to maintain that higher richness.



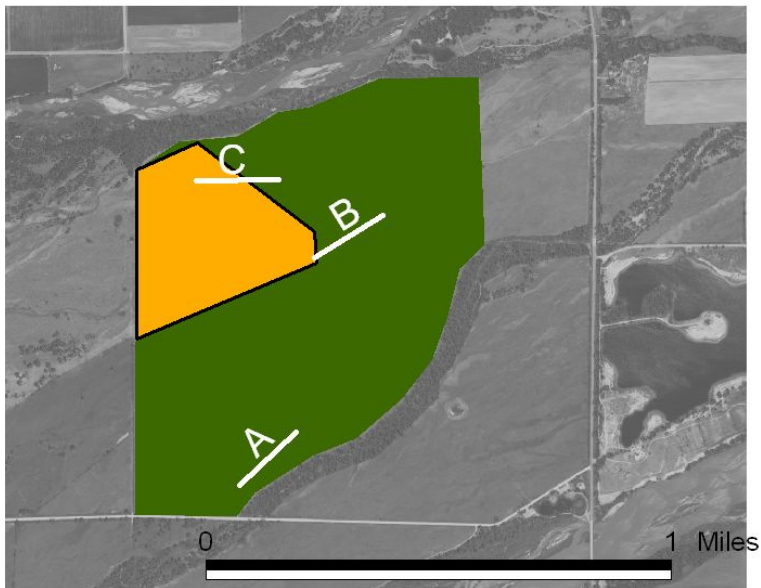
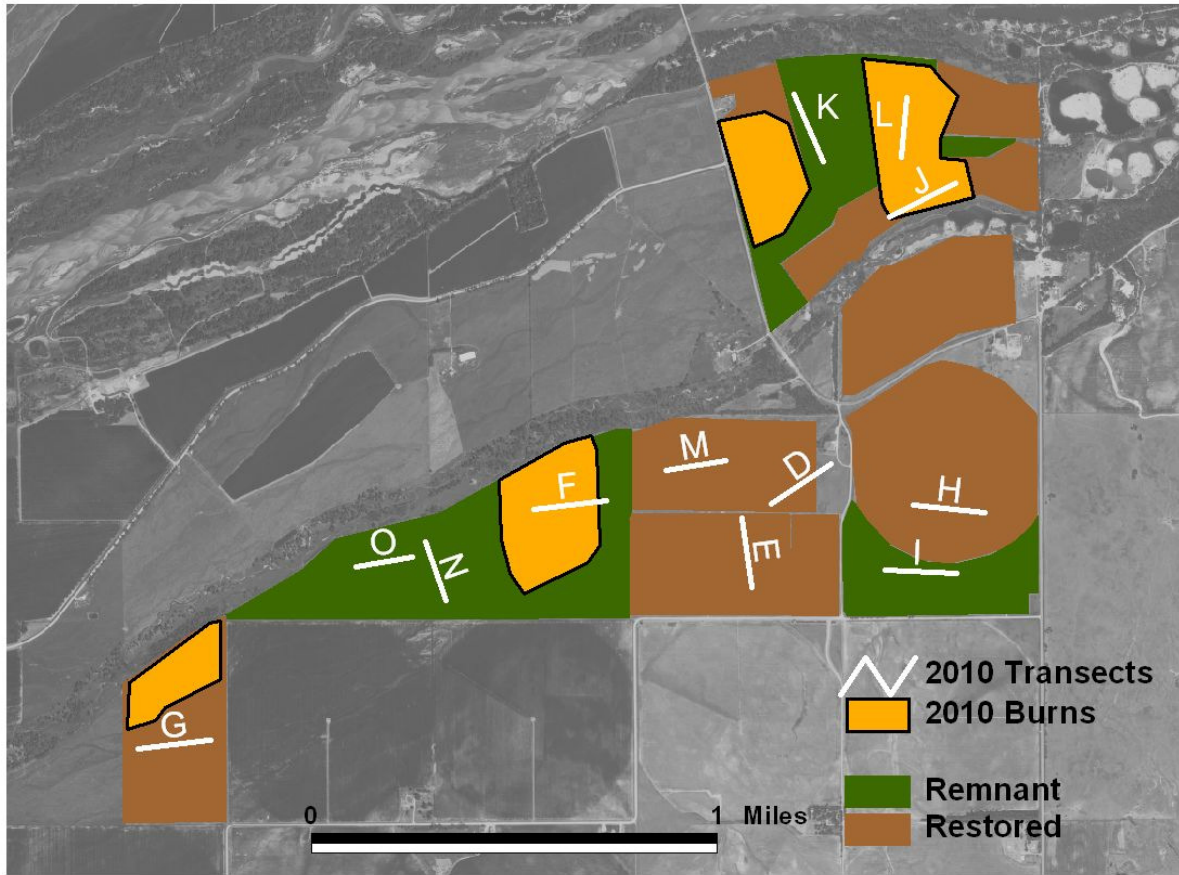
APPENDIX C: Impacts of Prairie Restoration and Management on At-Risk Butterfly Species

Methods

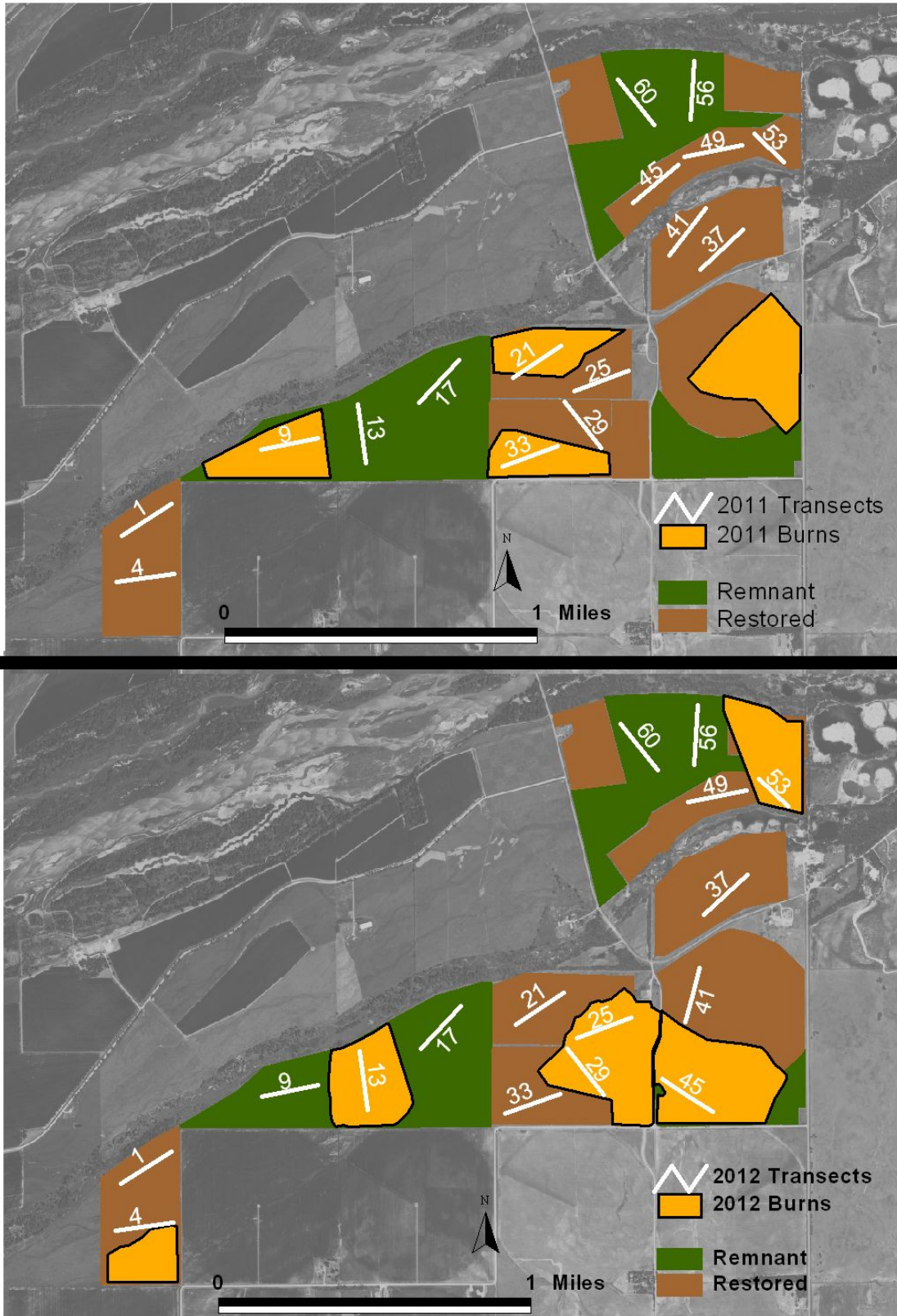
Butterfly survey methods were adapted from those used by Dr. Ray Moranz of Iowa State (and Oklahoma State) University. Observers walked permanently marked (by GPS) transects of 300 meters in length. Any butterflies observed were noted, along with their perpendicular distance from the transect (though we have not used those measures in our analysis). In addition, any information about behavior (flying, basking, nectaring, etc) were noted, and if nectaring, the flower species was recorded. Nectar flower abundance was also recorded along the same transects, following each butterfly survey conducted. The number of blossoms of each flower species within 1 meter of the transect line (on each side) was recorded for each 100m segment of the transect.

Butterfly surveys were conducted between 10am and 4pm, when weather was above 70 degrees Fahrenheit and wind speeds were 15-20mph or less. During 2010, we had some transects and observers focused only on regal fritillaries, to ensure that we collected sufficient data on that species, and a separate set of transects laid out for surveying all butterfly species. In 2011 and 2012, we added more transects to the regal fritillary effort and abandoned the all butterfly transects because we were not observing any rare or at-risk species apart from regals. Transect locations shifted some from year to year as we tried to ensure that we were collecting data that represented a variety of burned/unburned areas and restored/remnant locations. In all three years, Chris Helzer conducted frequent observational surveys of butterflies throughout the season to look for other rare or at-risk species, but none were found. All survey data will be shared with Ray Moranz for incorporation into his larger data set on butterflies and regal fritillaries (and patch-burn grazing) from Oklahoma, Iowa, and Missouri – and for possible publication.

Map of Regal Fritillary Survey Transects in 2010



Map of 2011 (top) and 2012 (bottom) Regal Fritillary Survey Transects



Butterfly Species Seen During 2010-2012

23 species seen in all Sites

Black Swallowtail
Bronze Copper
Buckeye
Checkered White
Common Checkered Skipper
Eastern Tailed Blue
Gorgone's Checkerspot
Gray Copper
Gray Hairstreak
Least Skipper
Little Yellow
Melissa Blue
Monarch
Orange Sulphur
Painted Lady
Pearly Crescent
Peck's Skipper
Red Admiral
Regal Fritillary
Sachem
Tawny-edged Skipper
Variegated Fritillary
Viceroy

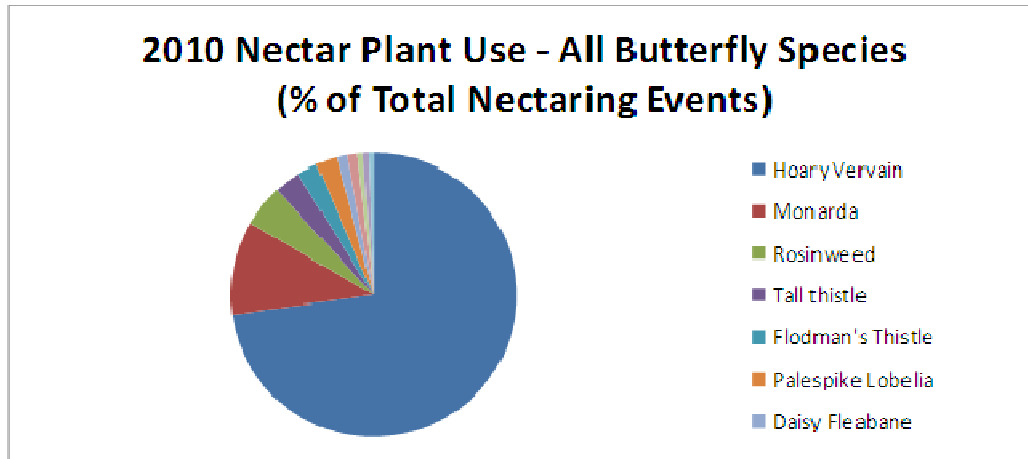
18 Species in Restorations

Black Swallowtail
Bronze Copper
Buckeye
Common Checkered Skipper
Eastern Tailed Blue
Gray Copper
Gray Hairstreak
Little Yellow
Melissa Blue
Monarch
Orange Sulphur
Painted Lady
Pearly Crescent
Red Admiral
Regal Fritillary
Sachem
Variegated Fritillary
Viceroy

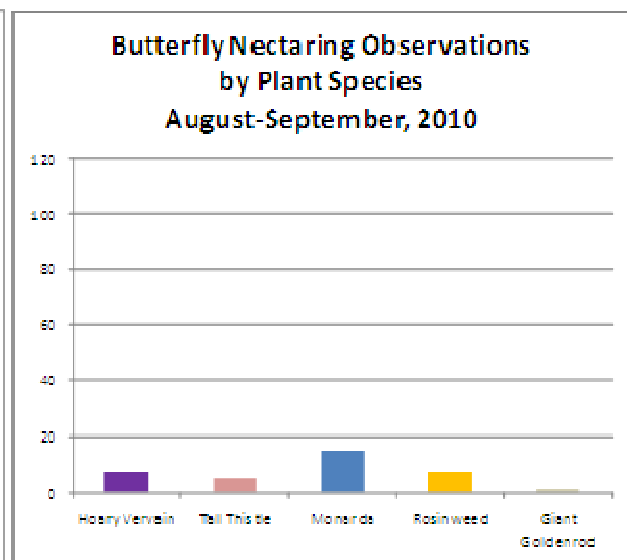
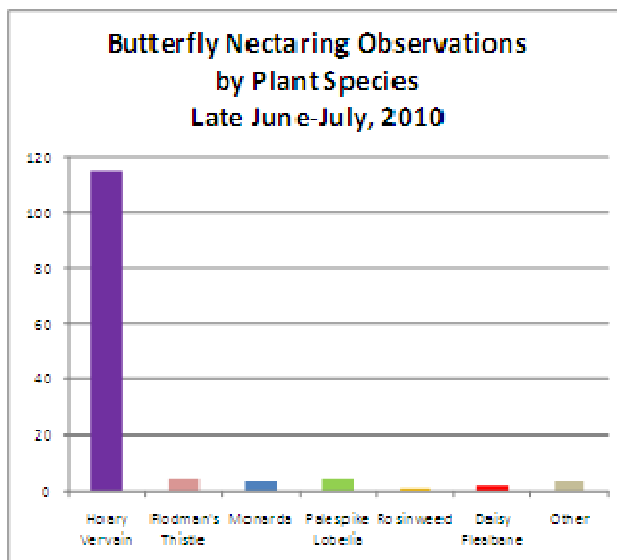
19 Species in Remnants

Bronze Copper
Buckeye
Checkered White
Common Checkered Skipper
Common Sootywing Skipper
Eastern Tailed Blue
Gorgone's Checkerspot
Gray Hairstreak
Least Skipper
Monarch
Orange Sulphur
Painted Lady
Pearly Crescent
Peck's Skipper
Red Admiral
Regal Fritillary
Sachem
Tawny-edged Skipper
Variegated Fritillary

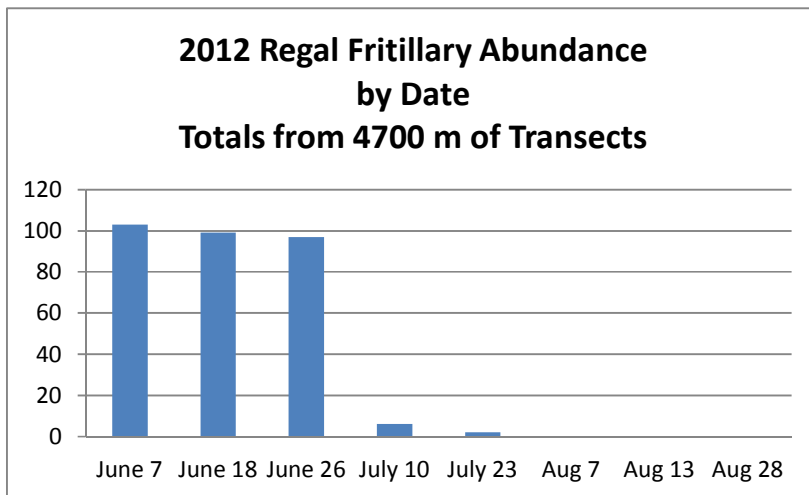
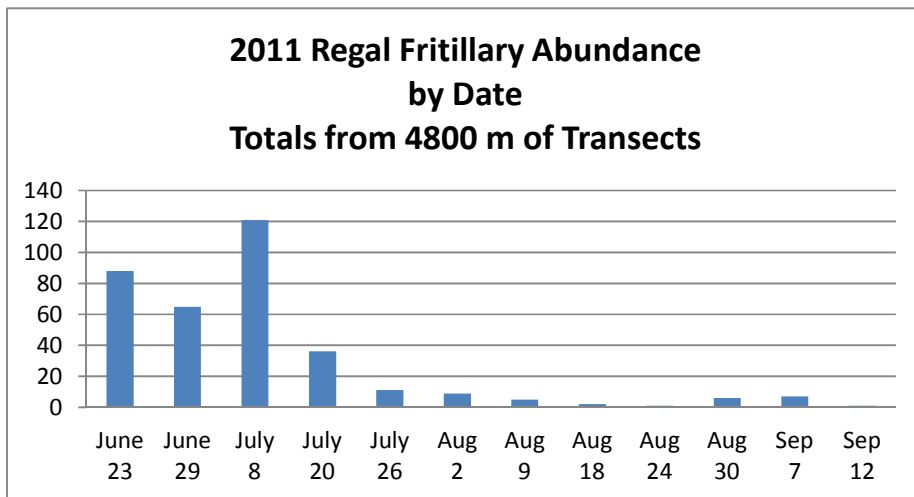
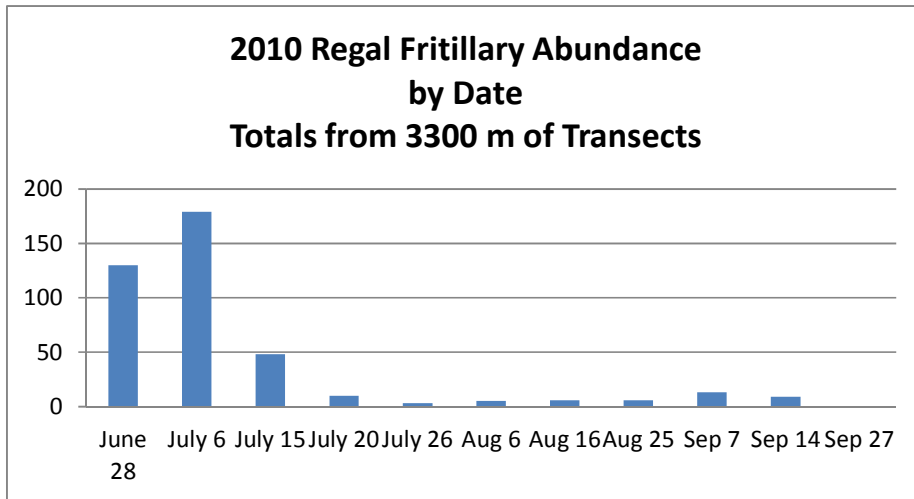
Hoary vervain (*Verbena stricta*) was by far the most used flower for nectaring by butterflies. Over 70% of all butterflies observed nectaring on plants were feeding on hoary vervain. In part, that preference is driven by the lack of many other appropriate flowering species, especially in remnant prairies, which are largely degraded. However, even when other plant species normally thought to be attractive to butterflies were present, vervain appeared to be the flower of choice for most butterflies.



The use of hoary vervain was particularly important during late June and July, when it was blooming most strongly. As vervain became less available in August, other plants started to receive more feeding – although butterfly numbers were much lower in those months due to significant drops in the numbers of regal fritillaries and orange sulphurs by that time in the season.



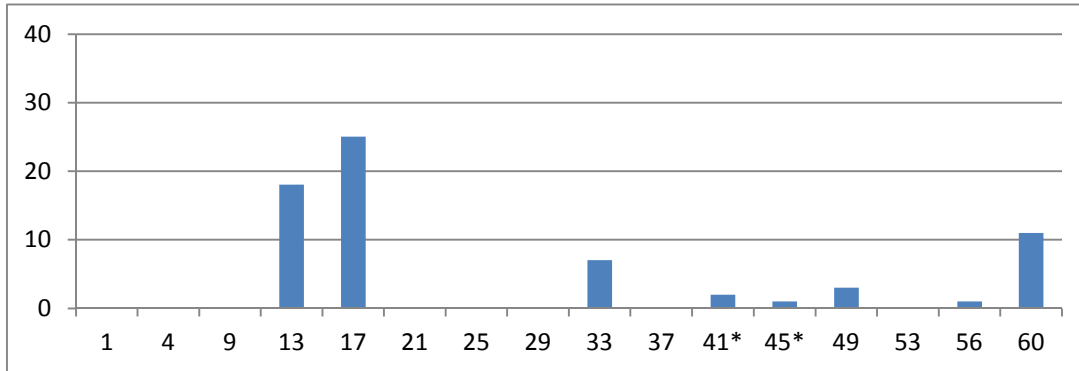
Regal Fritillary Abundance in 2010-2012. Peak numbers were similar in all three years. The biggest difference was that the peak was much earlier in 2012, and no regals were seen along transects after the peak time period in that year – likely because of the drought and heat.



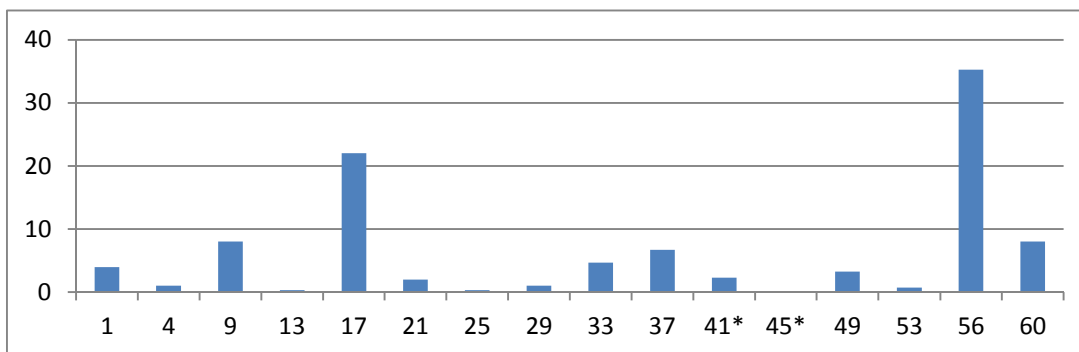
Average abundance during the three peak sampling periods in 2011 and 2012 – by transect.

(Transects #41 and 45 were in different locations between years)

2011



2012



While overall abundance of regal fritillaries was similar between all three years of the study, abundance at each transect location changed from year to year with management. In the above two graphs, the average abundance during the peak three sampling periods changes dramatically within some transects. We assume that adult butterflies seen this time of year are primarily in the location they emerged from.

Particularly interesting observations include:

- Transects 9, 13, and 17 are all in the West Dahms Pasture. The area around #9 was burned in 2011, and no regals were present during the peak time in that year, but a moderate number were seen in 2012. The opposite was true for #13 which was unburned in 2011 but burned 2012. Number 17 was burned in 2010 and had high numbers in both 2011 and 2012.
- Transect #33 had similar numbers in both years, even though it was burned 2011. This is a restored site right next to Transect #17, so while it's unlikely there were many adults emerging (few violets present) along this transect, we might have been seeing spillover adults from the West Dahms Pasture.

- Transect # 37 is a restored site that was not burned during the study, but was grazed only in 2011 (pretty hard). There were no adults seen during the peak periods of 2011 but a moderate number in 2012 when it was idled. It's hard to say if intensive grazing influenced regal numbers, but it's worth noting and trying to watch when we have future opportunities.
- The most dramatic difference between years was in Transect #56, which had very few regals in 2011 but the highest number of any transect in 2012. This remnant prairie area was burned in 2010, and grazed pretty hard that year. Other sites have shown pretty good numbers of adults during the peak of the year following a burn (see above comments about the West Dahms Pasture) but at this site it took two years for the numbers to come back up. No explanation is apparent at this point.

As listed in the Results Section more data and discussion can be found in the following blog post links:

Response of regal fritillaries to Patch-Burn Grazing habitats:

<http://prairieecologist.com/2012/11/13/regal-fritillary-butterflies-in-burned-and-grazed-prairie/>

Summary of 2010-11 data on Regal Fritillaries: <http://prairieecologist.com/2011/12/14/regal-fritillary-butterflies-in-the-platte-river-prairies-2011/>

Nectaring observations for all butterfly species from 2010: <http://prairieecologist.com/2011/01/25/the-importance-of-weedy-flowers-for-butterflies/>