1

Technical Report

Native Pollinator & Native Plant Demonstration Project

Abstract

The effort to promote biodiversity and restore degraded lands is an important responsibility of the DoD. Increasing biodiversity through the removal of invasive species AND through the re-establishment of native plant and pollinator communities will support the mission by providing a realistic, more stable, and more easily maintained training situation. The management plan developed will serve as a model for other DoD lands with similarly degraded and disturbed systems.

The decline of native pollinator populations is linked to fragmentation of native plant populations and competition with alien invasive species. Restoration efforts that seek to augment and maintain native plant populations must address and incorporate the pollinator ecosystem component.

Dyess Air Force Base provides 4 study areas in which to restore habitat through the removal of invasive species and augmentation of native plant and native bee species. Two of the plots are adjacent to publicly utilized areas and will be used as an instructive setting for the understanding of habitat restoration techniques and goals, the importance of native insect pollinators, and in providing information concerning the destructive role of invasive plant species on ecosystem health. The other two plots will serve as the base natural resource managers training ground.

F-84F Thunderstreak, DAFB

2

Technical Report

I. Pollinators In Restoration

Introduction

Native bee pollinating flower

The restoration of a degraded ecosystem requires more than reintroducing a few plant species or protecting remaining habitat from further degradation. To succeed, a restoration must account for the intricate relationships that make an ecosystem self-sustaining. Perhaps the most critical of these relationships is the pollinator complex. At Dyess Air Force Base (DAFB), our mission was to restore the native prairie ecosystem with specific focus on the symbiosis between the native plants of the restored prairie and their native pollinators. It is the interaction between native pollinators and their native plant hosts that sustain and regenerate native plant communities. Any attempt at restoring an ecosystem that fails to address the health of the pollinator complex cannot succeed. The restoration of this important link is further complicated when the native insect pollinators are not present on the site.

The decline of native pollinator populations is linked to fragmentation of native plant communities and competition with alien invasive species [e.g. European honeybee and Africanized honeybee]. The optimal venue for addressing declines in native pollinator populations is through efforts to restore and conserve native plant communities and through the removal and management of invasive species. Alien invasive plant species have become an integral part of many ecosystems and are especially symptomatic of degraded lands. Research has demonstrated that the presence of invasive plant species changes the ecosystem in many ways, one of which is by creating a less diverse environment.

According to the United States Department of Agriculture, "we are facing an impending pollination crisis in which both wild and managed pollinators are disappearing at alarming rates owing to habitat loss, poisoning, diseases, and pests (USDA-ARS, 1991). The concern that a decline in pollinators may destabilize food production and ecosystem functions has led to the formation of an international working group to advise the United Nations' Food and Agriculture Organization.

We can thank a pollinator for much of the fruit we eat

Why care about native insect pollinators? Ecosystem health, as well as agricultural wealth, depends on native bee communities to deliver pollination services. Pollination is the transfer of pollen from one flower to another and is critical to fruit and seed production. Without pollinators, many plants cannot reproduce sexually. Two-thirds of wild plants depend on animal pollinators, as do ¾ of agriculturally important crop plants. Pollination is an ecosystem service that we take for granted. Reproductive loss in native plant communities could result in the disruption of community function.

European honeybee declines: The loss of one quarter of all managed and feral honeybee colonies since 1990 signals one of the most severe declines U.S. agriculture has ever experienced. Honeybee populations are in decline as the result of an introduced parasitic mite, misuse of pesticides, and threats from the Africanized honeybees. Managed honeybee colonies declined from 2.5 million in 1995 to 1.9 million in 1996 in the U.S. (USDA-NSS, 1997). For agricultural crops, this can result in a significant loss in revenue. As the honeybee populations have declined, many have turned to native bee pollinators in hopes of soliciting their services, only to find their populations are faring worse than the honeybee.

Threats to Native Pollinators

Biologists all agree that most modern extinctions in the world are directly correlated with human activities. The activities that most critically affect native bee populations include habitat degradation, fragmentation and loss; chemical misuse; and the introduction of alien invasive species.


Urban sprawl, anywhere U.S.A.

Habitat destruction & fragmentation: Every day native plant communities and habitat gives way to urban sprawl and development. Urban sprawl not only removes habitat directly but also isolates and fragments the land that is not degraded or assimilated into the sprawl. What pockets of green-space remain, are often small and composed of plant species of which only a few are native. These pockets are not functional ecosystems but ecological fragments trying to find some level of equilibrium in which to exist and regenerate. Habitat fragmentation can accelerate the rate of "genetic erosion" by reducing gene flow to conspecific groups. Fragmentation can also increase the extinction rate of local native plant populations through inbreeding, genetic drift and stochastic processes (Rathcke & Jules, 1993).

Chemical fragmentation and toxicity: Excessive exposure to toxins from pesticides and other chemicals can poison or impair pollinator reproduction. These chemicals can eliminate nectar sources and deplete nesting material for bees. Pesticides are not only applied in agricultural fields but also in backyards, rangelands, golf courses, parks, roadsides, forests and mosquito ridden marshes and swamps.

Pesticide and herbicide applications harm native pollinators

Herbicide use also results in chronic plant losses, which could also be a critical factor in the decline of pollinator populations. There are countless examples of pesticide use and the subsequent reduction in pollinator populations. For example, aerial spraying in Canada of coniferous forest pests reduced native bee populations to the point that blueberry yields fell below the norm for four years

(Kevan, 1975). A study demonstrating the economic costs of pesticide use showed that honeybee poisonings resulted in an annual loss of $13.3 million (Pimental et al 1992). Cotton harvests could increase by as much as 20% if the flowers were fully pollinated by bees resulting in an increased farm income by $400 million per year (Pimental et al 1992).


Mesquite thicket at DAFB

Alien invasive species: For native pollinating insects, the threat of invasive plant species is as critical as the threat of other non-native insects like European honeybees and Africanized honeybees. In addition to crowding out native plants, many invasive plant species have a bloom wave that is out of synchrony with that of the native plant community. They often bloom early, which impacts the life cycle and ecology of native bees that have often moved out by the time the native plants come into their bloom cycle. Exotic invasive plant species supply novel resources to native pollinators with unpredictable long-term effects.

The competition from alien pollinators produces more problems that are obvious. European honeybees forage in large numbers—unlike native bees, most of which are solitary—and can decrease the forage success of native pollinators by outcompeting them for resources. Nevertheless, European honeybees are inefficient pollinators. Because they have not coevolved with the native plants, they often cannot get to the nectar easily - so they steal it. The European honeybees' presence disrupts the natural composition of the native bee community and has a detrimental effect on the reproduction of native plants. Research has demonstrated that removing European honeybees will increase food availability for native bees and decreases seed production in alien invasive weedy plant species. The leafcutter bees (*Megachile* sp.), for example, are so efficient that 150 leafcutter bees can do the work of 3000 honeybees (ATTRA, 2000).

DAFB: Demonstration Project

The overall goal of this project is to increase terrestrial biodiversity by restoring a functional prairie *including* the vital ecosystem service of pollination to ensure the long-term biological success of the prairie. In the process, we hope to demonstrate how marginal and degraded DoD landscapes can be put to constructive use for conservation while continuing to meet the needs of military readiness. This demonstration effort will target DoD resource managers to show them how they can better manage their marginal lands to restore ecosystem health and their subsequent critical processes. DoD has the opportunity to take the lead in preserving biodiversity by restoring degraded lands back to functional ecosystems that not only address the floral component of the ecosystem but also the critical pollinator component. A sustainable and regenerative system cannot be fully restored if the floral component has no way to reproduce itself. By taking into consideration the native insect pollinator component, the restoration stands a much better chance of continued success (biologically speaking) than a restored area that does not address the reproductive needs of plants. Long-term persistence of species is more likely to be obtained when restored or reconstructed areas are managed for the needs of both plants and pollinators.

II. DAFB Restoration Strategy: Step-By-Step

Historical Ecology

In order to determine a reference condition to restore, it is essential to have past and current geographic, geologic, and ecological information about the area. A thorough understanding of the floral and faunal histories helps determine which species are suitable in the effort to bring back the appropriate ecosystem for the site. This research is essential to understanding which species belong in the region you will be working, and preventing the introduction of alien species that could cause problems in the future. The best ways to locate this type of information is to search archives for historical documents (e.g. land surveys with descriptions or early settler's accounts of the area); and to visit museum botanical, entomological and other collections to identify the species that have been collected, surveyed and recorded throughout the last 100 – 150 years. Many times, this will be a difficult and time-consuming task. It may seem arbitrary at first, but such a survey will ultimately reveal many details about the historical condition of the site. This makes the restoration effort easier and more effective. If you find that little of this type of information exists, old photographs and paintings can often provide a *sense* of what the flora and fauna consisted of – but be careful, because pictures can often represent an "artists interpretation" of the area.

DAFB Geographic Background

This demonstration project was located on the Dyess Air Force Base [DAFB], in Abilene, Texas. Abilene is in the northeast corner of Taylor County, which ranges in elevation between 800 - 3000 feet above sea level. Taylor County, named for Edward, James and George Taylor who fell in the Alamo, is about 913 square miles and was organized in 1878. Before the Texas and Pacific railroad arrived, Taylor County was inhabited primarily by nomadic Indians, buffalo hunters and a few ranchers. In 1881, the railroad arrived and the county seat moved from Buffalo Gap to Abilene in 1883 (Zachry, 1999). Over the last 100 years, Abilene has gone from being predominately agricultural to a more diversified economy including oil, agriculture, commerce, light manufacturing and service. Camp Barkeley was established in 1940 as a U.S. Army Post during World War II and Dyess Air Force Base was created in 1952 (Duff, 1980).

Geologic and Ecological Information

The underlying geology of a region significantly influences the species composition of the ecosystem. For restoration to be successful, one must consider the geological information of the region as a way to understand the current ecological conditions found at the site.

__DAFB Geology:__ At DAFB, the underlying geology consists of the "Permian red beds" which occupy the southern and northern parts of Taylor County. This is most evident when looking at the soil structure on the base, which is a coarse red sand. The USGS soil survey for Taylor county states that "soils can vary, from coarse red sands, to tight red clays or red-bed clays and shales". There are Cretaceous remnants forming the limestone hills through the central part of Taylor County but this is not the situation found on the base. Generally, DAFB is flat to gently rolling with some moderately rough topography on the extended outlying areas.

__DAFB Ecology__: The ecozone of DAFB is often referred to as the "Rolling Red Plains" or the "Reddish Prairies". The original prairie vegetation (pre-settlement) included tall and mid-grass species such as: *Schizachyrium scoparium* var. *frequens* (little bluestem)*; Andropogon gerardii* var. *gerardii* (big bluestem); *A. gerardii* var. *paucipilus* (sand bluestem); *Bouteloua curtipendula* (sideoats grama)*; B. gracilis* (blue grama)*; B. hirsute* (hairy grama)*; Sorgastrum nutans* (yellow Indiangrass)*; Panicum virgatum* (switchgrass)*; Elymus canadensis* (Canada wildrye*;* and *Agropyron smithii* (western wheat grass). Historically the "Rolling {red} Plains" was mainly grassland with mesquite as the dominant upland tree or shrub. Mesquite is now a weed species that overwhelms the grassland when left unmanaged.

The reddish prairies of Taylor County completely disappeared about 20 years after the American Civil War when Abilene became the center for west Texas cattle shipping.

From 1898 to 1901 the first field station in the United States was formed, about five miles south of Abilene, to restore native prairie species. This field station was part of the United States Department of Agriculture's Division of Agrostology. The surrounding area was described as ". . . a denuded rangeland with most of the grass roots destroyed." In general, the early reports demonstrate that seeds from native grass species had the highest degree of success and that by restoring the native prairie the number of cattle grazing a specific area could be doubled "from 40 to 100 head".

The average annual rainfall at DAFB is 22 inches a year with May and September being the months with highest rainfall amounts. When the project began, late 1999, the area was in the middle of a significant 4-year drought where water was being tightly rationed and the area was incredibly dry.

Restoration Process

The strategy for restoration can best be explained as a four-part process. After initial inspection of the potential project locations on base, historical information on the floral and invertebrate communities for Taylor County was researched and collected. The goal was to establish a reference condition for the area prior to disturbances to the environment by invasive species including man. The historical research phase of the restoration process is more than developing a list of plant and invertebrate taxa, it is the foundation from which all other decisions will be based.

The next step was to establish a plan for inventories of the current floral and faunal conditions on the base project sites and at the off-base control locations. For the third part, we compared the current and historical surveys and used this information to develop and implement a restoration plan. Finally, after the restoration plan had been implemented, follow-up inventories and monitoring were used to assess both biological and project success and a management plan developed.

The preliminary historical research for this demonstration project offered both information and obstacles. William Mahler spent six years in Taylor County and established the Herbarium at Hardin-Simmons University (Diggs et al., 1999). The information he gathered was indispensable in providing a historical basis for evaluating the floral components of the project. Unfortunately, despite the vast amounts of data on the floral community, no invertebrate surveys had ever been conducted that could identify the historical insect pollinators within Taylor County. In addition, there were no pollinator association records with any of the plant specimens at the herbaria or in any of the taxonomic monographs.

Historical Floral Surveys

The earliest recorded floral studies of Taylor County were carried out in conjunction with land surveys done in 1878. We were remarkably fortunate to have our demonstration project in Taylor County, as it is the only county in Texas to have its flora completely documented. The historical floral surveys were conducted by William F. Mahler and Lloyd Herbert Shinner, who compiled the works of others and incorporated them into their own surveys. Mahler and Shinner's works synthesized information from early collections, and written references dating back into the early 1800's: from accounts by early settlers, land surveys, and herbarium collections of Reverchon (mid 1800's), Tolstead and Cory (1940's), and Mahler's personal collecting in the 1960's. This work culminated in the publication of the "Flora of Taylor County" (Mahler, 1973). Since Mahler's initial publication there have been two updated versions published: Shinners' Manual of the North Central Texas flora (Mahler, 1988); and Shinner's & Mahler's illustrated flora of North Central Texas (Diggs et al., 1999). These references proved invaluable in helping us establish which plant species would be appropriate for the restoration of a prairie system at Dyess.

In addition to the extensive written material on the historical floral ecology of the region, we had several very good herbarium collections to which we could refer. Both Hardin-Simmons University in Abilene and the Botanical Research Institute of Texas, Fort Worth, supplied us with an extensive reference collection of the vascular plants of Taylor County. This not only simplified the identification of plant specimens, it gave us a complete picture of what to expect in the region.

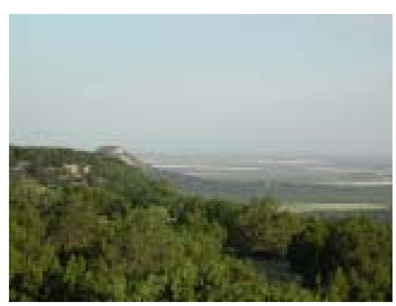
For this demonstration project, the historical floral information helped us determine that our reference condition for restoration was a tall to mid-grass prairie, which is the type of ecosystem that occurred in the area prior to settlement.

Historical Pollinator Surveys

Normally, the best way to find out what insect communities were present between 100 ~ 150 years ago would be to go through entomological collections at major museums.

Texas A&M has the largest entomological collection in the state and that is where we began our research. Unfortunately, there were no insects (Hymenoptera or Diptera – the two largest orders of insect pollinators) collected from Taylor County [or within a 6-county region surrounding Taylor County] in the collection. We spoke to regional entomologists who stated that Abilene was a "black hole" because it was not considered a region of ecological significance and would therefore not yield any insect specimens of interest. We then went to several other Texas entomological collections (Abilene Christian University, Hardin Simmons University, and the University of Texas) and again found nothing. We scoured the collection at the University of Kansas, where some of the top insect pollination biologists work, and again, found nothing from Taylor County. The Smithsonian Institution's National Museum of Natural History also had very few specimens from Texas and nothing from Taylor County. Major museums and University entomological collections were devoid of any samples representing the insect pollinator community that could be conclusively linked to the plants of Taylor County or even the Rolling Plains and Edwards Plateau regions. Without representative samples of the historic invertebrate community or historical literature about the pollinator community within this eco-region there was no basis with which to evaluate the current pollinator community structure. In order to approximate the entomological component of the project, we were obliged to devise an alternative plan.

Off-base Control Sites



The lack of historical information of the invertebrate communities in Taylor

County meant that representative invertebrate data had to either be collected or inferred. Without the data from historic collections, the closest estimate of past pollinator communities would be found on undisturbed sites with a floral community equal or approximate to that found in the historical data of floral surveys. In order to determine what the historical insect pollinator component would be of a tall to mid-grass prairie system, we had to rely on adequate off-base control sites to provide us with information. The off-base control sites would serve multiple purposes: first, to help determine the health of the base insect community; but we also needed a glimpse of what the historical insect community assemblage might have looked like. The overriding concern was that we did not want to introduce insect pollinators onto the base site if they would not have historically occurred there. We also augmented our research with historical papers on insect communities in prairie systems outside the eco-region in which we were working. This gave us an idea about the potential taxonomic diversity we might have encountered.

The region surrounding DAFB is mostly agricultural and/or urban. This fact made it very difficult to find a suitable off-base control site. We worked collaboratively with several of the local universities one of which (Abilene Christian University - ACU) permitted us access to a site that is slightly degraded but that had a few intact native plant communities. An off-site control plot that was minimally degraded was necessary to help us find native bee species that do not currently occur on base but that we knew were once part of the pollinator guild for the prairie.

Our goal was to use the site to trap-nest bees for relocation on to the restored prairie at DAFB.

All public and private lands within a 50-mile radius of the demonstration site were given a quick visual inspection to determine the possibility for their use as a suitable control site for pollinator evaluation. Once a possible site was identified, the landowner had to be contacted. In addition to asking for permission to conduct preliminary floral surveys and later invertebrate surveys, information on the historical use of the land and the short term plans for the property had to be gathered from the owner. The goal was to find sites that would allow the pollinator community to be monitored throughout the duration of the project without external disturbances [e.g. plowing, mowing, grazing, or in extreme cases - building]. Landowner information alone generally helped to rule out any site that had had development (agricultural or otherwise) in the last 50 years. This was just the initial step in documenting the closest estimate of the past pollinator communities within systems similar to the historic floral data for Taylor County.

Once the land for suitable control sites was identified and permission acquired, it had to be evaluated. The evaluation process consisted of a simple floral survey of 10 100-meter transects and the survey results compared to the historical floral information. Sites that were similar to the historic accounts of the floral community of a prairie enabled representative pollinator sampling.

The next step, after researching the historical ecology, was to summarize the existing historical information and compare that with any floral and faunal surveys that the base natural resource manager might have available. Before we could utilize any of the historical or current information and make comparisons with present day conditions of the site we needed to choose our project locations on base.

DAFB Demonstration Site Selection

Dyess Air Force base is an installation of about 5000 acres. Within the installation, the demonstration project consists of four plots: two that are highly visible public plots, one control plot, and one experimental. To achieve our goals of restoration and to educate and instill stewardship we decided that having four smaller plots was more appropriate rather than one large 10-acre plot. We reasoned that our efforts would have a much broader reach from an education standpoint and enhance the overall aesthetic on the installations' housing and family areas. Having four plots in different places on the base allowed us to work in several different types of environments, which challenged us to use multiple management strategies increasing the overall educational value of the project. Each plot ranged between 1.5 ~ 5 acres in size and two of the four plots have trails with interpretive signage.

As discussed earlier, we chose to use four plots for the demonstration project rather than one large one. The choice in plot locations was dictated by our goals of restoring habitat and providing an educational venue. Two of our plots were situated in areas that were highly visible to the base population – one behind a portion of base housing and the other adjacent to the picnic and playground area.

Both of these plots would serve to educate the base community about the critical decline in native insect pollinators and the importance of the prairie ecosystem to the health of the surrounding environment. The other two plots were chosen based on the level of disturbance by mesquite and the opportunity to incorporate more intensive management strategies that could later be incorporated by the base resource manager to other problem areas. As it turned out, one of the four plots was used as an on-base control to demonstrate the effect of mesquite on the levels of floral and faunal diversity.

The plot behind base housing will be referred to as the BH plot. This plot, about 2.5 acres in size, was completely denuded. The topsoil had been exposed for several years and the only living things able to thrive in the area were rattlesnakes and yucca. This plot was unsightly and not a welcoming place for the residents or children in the base-housing complex. A small restored prairie would not only enhance the aesthetics of the area, it would also restore an area almost completely devoid of life. The second plot, behind the picnic and playground area, will be referred to as the Picnic plot. The entire area is about 50-acres in size and we utilized about 5 acres of this space. The plot was largely overrun by mesquite, catclaw, and cactus—an area once grassland was being quickly overtaken by woody invasives. There were large grassy areas but most of it was inhabited by non-native invasive grass species and weeds.

The third plot was on the golf course outside the area of play and will be referred to as the Golf plot. We chose an area of about 3 acres that could be easily viewed by the golfers but that also had some interesting topographical features that would make restoration a challenge. This plot was chosen more for the opportunity to demonstrate restoration techniques to both the base natural resource manager and to the golf course superintendent. The Golf plot had no native plant species and was covered with escaped turf grass species and mesquite. The last plot was behind the aircraft exhibit and will be referred to as the Arc plot. This plot, an area of about 5-acres, was covered by mesquite and could be classified as a mesquite thicket. This plot provided an exceptional opportunity to demonstrate how mesquite can drastically change the environment and completely reduce plant and animal diversity.

Sampling & Monitoring

Once the site selection process was completed and the plots were identified and marked, both a plant and insect pollinator survey were needed. There are many different kinds of insect sampling protocols and we used both active and passive methods to minimize the amount of bias in the samples.

The two passive sampling protocols we used were yellow pan trapping, and malaise trapping. Yellow pan traps are what most pollinator biologist's use in the field to get a quick handle on the insect pollinator community. The malaise trap is more suitable for high flying insect pollinators, especially those that pollinate trees and tall shrubs.

Yellow Pan Trap Protocol On each plot 10 bright yellow opaque bowls were put out randomly. Each bowl held approximately 1 gallon of fluid. Bowls were filled with ¾ gallon of water. One drop of dishwashing fluid was added after bowl was filled to avoid excessive foaming on the surface. The dishwashing fluid acted as a surfactant (breaking the surface tension of the water) in order to allow the bowls to act like a trap. The bowls were set out a half hour before sunrise for periods of 24 hours and then picked up. The high daytime temperature was a minimum 80 degrees. Also, to keep the sampling consistent the collections were always conducted on sunny or primarily cloudless days and nights. After the 24-hour period, specimens were removed from the water and put in 90% ethanol for 24 hours. Then they were either pinned or transferred into 70% ETOH. This protocol was repeated on each plot every month for the duration of the project.

Malaise Trap Protocol A 6-meter migratory malaise trap was set out on each plot a half hour before sunrise for a period of 24 hours. There was a baffle in the middle of the trap that kept the insects that flew in from a specific direction separate. This allowed us to determine which side of the plot the different insect pollinators were utilizing.

Vegetative Sampling Protocol Transects were deemed to be too biased for the size of the plots so a 2' X 2' vegetation square/grid was used to survey the plant species on each plot. The grid was placed in close proximity (usually within 5 feet) to each of the 10 yellow pan traps. All plants in the grid were identified, counted, and recorded. Only one of each species was collected. In each of the four plots floral surveys were taken on a monthly basis not only to get information about the occurrence of species but also to track the bloom wave and seeding time as a means to help determine how much nectar and pollen support there would be for pollinating insects and to help write the management plan. Our floral sampling data was augmented with two prior vascular plant surveys done on the base. The prior surveys did not have a location associated with them so it was impossible to repeat the sampling protocol at the previous locations. We did notice that those samples did not represent the taxonomic diversity or abundances found on our plots so we only used those surveys as a reference.

Historical versus Current Conditions

These protocols were carried out both on the DAFB plots and at the off-site control plots. The initial samples were compared to the historical information and we found that the DAFB plots contained only 3 species of plants that were historically recorded in Taylor County. As mentioned before, there was no historical information to evaluate the current insect pollinator community so we relied on the results of the off-base control plot to determine how different the species assemblages were on the base plots.These comparisons helped reveal how much the landscape had changed – focusing on the disturbance due mainly to the presence of non-native flora, but also to changes in the environmental regime [drought, human disturbance, chemical disturbance, habitat fragmentation and the absence of fire]. It was clear that the components of a prairie system no longer existed in any of the plots at DAFB.

Habitat Restoration

Selecting a Plant Palette For the prairie restoration component of this project, we looked at the species matrix of plants that occurred in the historical tall-mid grass prairie system and compared that with the plant community *in situ* at DAFB. The main focus was on which plants would be best introduced to mimic the early successional processes of a prairie ecosystem.

An important element to examine was which plants currently on the DAFB plots were invasive and to determine the most appropriate methods of removal. There were many factors to consider regarding the removal of invasive plant species. First, we wanted to minimize the amount of disturbance to the wildlife community and increase the overall taxonomic diversity at the site. We were limited in our ability to use chemicals to remove invasive species because we did not want to damage the insect community. Invasive plant species can often provide food and shelter for wildlife, especially if they are the predominant component of the environment, so it is important not to go in and remove everything at one time. Besides, certain invasive plant species are only effectively removed at particular times of year. Controlled burns are an effective strategy to help minimize encroachment by woody plants and are an important part of controlling and removing mesquite. However, because the project was on an Air Force base where there is an abundance of jet fuel, fire was not a method we had at our disposal. The final determination was that all invasive native and non-native plant species would have to be removed by hand or specialized equipment.

Once all of the different factors were considered, we devised a plant list of species we would introduce to help restore the prairie system. Native seeds that are specific for an eco-region can be difficult to purchase. The importance of using straight native species that are eco-type specific cannot be stressed enough. At DAFB the drought was so severe that the use of water was very restricted. Our project was not exempt from this restriction and we were informed that once we seeded there would not be water available for us to use on the plots. We found a seed producer who had been collecting seed in the Taylor County region the previous two years so we knew the seed was not only specific for our eco-region, but the species available

were all on our list. The seed was purchased and the plots were cleared and seeded in late fall. No water was brought to the sites after seeding and we had to rely on nature to water our plots.

Preparing and Seeding the Plots The plots were cleared of mesquite and smaller woody vegetation using a tractor with a front-loading bucket and a bush-hog. The most important element in the restoration was to remove as much of the woody vegetation as possible to keep the area open for prairie establishment. The mesquite was removed using the front-loader bucket on the tractor and the stumps were painted with Remedy®. Once the mesquite was cleared, the bush-hog was brought in and set on different settings – starting high and moving to the lowest by the end to help clear the yucca and other small woody plants on the site. The seeding of the site was done using a no-till seeding drill (Truax®) and was very time consuming. Seeding can be done by hand, but a more thorough job is accomplished using a no-till seeding drill and a seeding rate can be quickly calculated. We were seeding at about 14lbs per acre of each species of grass, and 1lb per acre for each species of forb (flowering plant). The ratio of grass to wildflower in a prairie system is approximately 7:1 and we tried to standardize the ratio during our seeding of the plots. The clearing and seeding of the plots was accomplished over a three-day period.

To maximize the educational outreach component, the land clearing and seeding of the plots was done in conjunction with

National Public Lands Day. We used volunteers and Boy Scouts to help with the effort – especially in putting in the trails. There were posters explaining what we were doing and why, we had set-up a microscope for them to view native insect pollinators and we made it a whole day affair with food and drinks and lots of educational material available. Our effort to educate the base resource manager and local base population paid off as we ended up having a number of volunteers who remained interested in participating in the project for its duration.

Pollinator Restoration

Our initial sampling, before the prairie restoration, indicated that the native pollinator community at DAFB was made up of a few generalist species, one species of which was found in great abundance, but the overall taxonomic diversity was quite low. There were no bee species collected that nested in wood; they were all ground nesting bees. When compared to our off-base site, the DAFB plots were found to be greatly lacking in overall taxonomic diversity and abundance. The immediate conclusion was that the community assemblage was not healthy and not as taxonomically diverse as it could be even for the habitat that was there.

Native insect pollinators, mainly bees, nest either in the ground or in wood. In any pollinator restoration project, the two most important considerations are nesting sites and food resources. We developed a strategy that encompassed the food and nesting components into the restoration process as well as a plan that would help introduce native bees from the off-site control plot onto the base.

In addition, we chose to augment nesting habitat using both artificial and natural methods.

Diversity of Food Resources: The restoration plan for the native prairie incorporated a diversity of flower morphologies that would accommodate a wide range of bee species. In addition, the plant palette for the native prairie was designed to provide a bloom wave from April through October in order to insure an adequate food supply over the entire season that bees are active.

Nesting Augmentation: Many pollination biologists believe that nesting sites are the limiting factor to healthy native bee populations. Nesting sites can be augmented both naturally and artificially. Simple steps such as clearing ground, creating limestone trails, and putting in sand mounds can help augment nesting sites for native ground nesting bees. For those native bees that nest in wood, leaving woodpiles (such as the mesquite that was cleared from the plot), or putting in wood trap-nesting boxes are two sure ways to increase nesting habitat.

Pollinator Re-Introduction: Artificial bee nesting boxes (or bee nest-trap boxes) are commercially available for a specific species of bee (the blue orchard bee). We modified the design to attract more than a single species of bee, and allowed for easy portability. We call these nest-traps "mobile pollination units" or MPU's. These nesting traps can satisfy two complementary objectives in the restoration process, both of which ensure greater diversity and abundance.

The first instance that these traps were used was to re-introduce species of bees that were absent on the DAFB plots but that would have been present in the historical prairies of Taylor County. The second function was to increase the amount of nesting sites available both on the off-site control plot and on the DAFB plots. The principle goal of the MPU was to attract females to lay eggs in the nest-trap boxes and then bring them on to our site once we were sure we had all the ecological requirements for that species (nesting and food sources).

The re-introduction efforts, for the aboveground nesting bees, focused on Megachile and Osmia genera, which include dozens of native bee species. For these particular genera, holes of two different sizes were drilled 5 to 6 inches into wood – preferably pine or fir. For the larger Megachile the average hole size was about ¼ inch. The smaller Osmia genus requires a hole that is best kept around 1/8 inch. Of special note – it is always best not to make all the holes either 1/8 or ¼ inch although these many be your target genera. There is variation of size between species, between ecotypes, as well as seasonal variation. If adult bees are found trapped in smaller holes, it is most likely the case that they have filled all the larger ones up and refused to move to a new block. The following year, or even during that trapping season, new MPU's can be made and the filled ones moved immediately to the site of re-introduction. The key is to drill as many holes about an inch apart in as many blocks of wood as possible. When using a 'roof' or cover for the nest-traps these should be painted a dark color so that it serves to attract the bees as well.

When timing restoration work for the Abilene area the nesting-traps needed to be set out by February and moved on to the restoration sites after late summer and before mid winter. This window had been extended greatly around the maximum activity for both of these genera [March/April to early July]. It is best that the traps are in place before any bloom wave is established. New traps can always be set out in areas with an abundance of activity in April or June. Although time and consideration for the design and construction of the traps is crucial to their success the ultimate limiting factor is the correct choice of environments for the traps to be set.

In both cases, (on-site and off base) the traps needed to be placed in areas that had an established bloom wave and contained the needed nectar and pollen resources. When trapping for re-introduction this can simply be determined by the presence of the bees themselves but knowledge of the habitat and the plants that they forage upon will greatly enhance the possibility for success. In addition, when trapping for re-introduction on another site it is best to leave 25% of the traps behind so as not to harm the population from which you are trapping. The traps themselves should be placed facing to the east. The face of the traps (the side with the open holes) should not have direct sun for more that 3 to 4 hours. In general, the bees seem to seek the shaded areas over full sun. Thus the larger the shaded area the better the chances are for attracting bees.

Successful trap placement does not depend as much on shielding the trap bodies from afternoon sun as long as the face of the trap does not receive any of the late day sunlight. It is best that the shaded areas always contain holes or that the traps are butted up against a wall or tree and that the traps are always positioned so that the bees are drawn to the side on which they will nest.

Measures of Success

The intent of the restoration was not only to increase terrestrial biodiversity but also to educate both the base natural resource personnel and the base residents. Measures of success are important in evaluating a project. There are two measures of success; one is project success, and the other is biological success. Biological success can easily be quantified by seed set, number of species and overall ecosystem health in terms of sustainability and regeneration. Project success is a qualitative measure and is best measured by how much intrinsic value the project has to the surrounding constituents. The notion of buy-in is often overlooked, and project success is critical to the long-term viability of a prairie restoration.

In an area that is predominately mesquite, like that found on DAFB, if a prairie system is going to survive it will need a constituency that not only enjoys its presence, but who will also realize the negative impact of mesquite encroachment.

If the constituents are educated and understand the importance and the value of the ecological services provided by the restoration, the long-term viability of the restoration effort will be ensured and project success will be achieved.

Success of habitat restoration

Overall, the initial seeding for the prairie was a success. A visit in February 2001, (4 months after seeding) found about a 90% germination rate. The winter was wetter than normal, and after the 4-year drought, this was a welcome change. The total rainfall in 1998 and 1999 was 13.88 and 16.67 respectively (the average rainfall is recorded to be 23 inches annually). When we seeded in October of 2000, we had less than 0.4 inches of rain since July and only 10.59 inches for the year. From the time of planting in October to May of 2001, there had been 21.38 inches of rain – a significant departure from the prior four years. This played an important part in the successful germination rate, but the fact that we planted drought tolerant, eco-type seed that were adapted to local conditions no doubt contributed also.

Restoring native plants would appear to have had a measurable effect upon the insect community. The pollinator diversity increased by 27% (overall species diversity) and abundance increased by 41%. Nevertheless, the climatic change poses something of a wildcard. We cannot determine if the changes in pollinator community resulted from the prairie restoration and the pollinator re-introduction; or, whether the increase in moisture played a part in this. A careful examination of the new taxa on base suggests that the increase in diversity of plant morphology and the prolonged availability of pollen and nectar played a significant part in the successful increase in overall native pollinator diversity.

The project achieved biological success because we were able to reintroduce native pollinators to the site and restore the native prairie. Long-term monitoring will be necessary to determine whether these populations are viable and sustainable. Project success was not as notable as biological success, in large part because it was difficult to get the base community involved. Our efforts to reach out to the community were not enough to increase overall awareness about pollinator declines and the importance of habitat restoration. Perhaps with more time and a more focused campaign our effort to include the base community would have been more successful.

Lessons Learned

Our biggest problem was controlling invasive plant species. Because the project began in a drought year, most of the typical base plants were not present on the plots when we did our sampling. However, seed remained dormant in the soil. After the wet winter, we had plants on our plots that were not seen in the previous two years. Most of the plants that were dormant during the drought were invasive species—both native and non-native. Their surprise germination affected the success of many our prairie species, which had to compete with the invasive species for resources. Not all the plots were affected, but two of them were overrun by the end of the summer. We were obliged to institute a removal plan and then re-seed with more native prairie species to ensure the overall success of the prairie restoration. What we recommend in the future is to take soil samples from the plots, put them in a nursery, and give them water and fertilizer to see exactly which species are dormant in the soil. This will give the resource manager a better idea of the species on his plot.

The success of the Dyess project stemmed from our use of straight native plant species that were ecotypes of the Abilene region. If we had not used this type of seed, it is unlikely the plants would have had such a high germination rate. Moreover, the future of the plots may rely upon the adaptive traits of this seed.

The mobile pollination units [MPU's] also contributed to our success by bringing important taxa onto the base plots that were not there when we started the project – mainly, aboveground nesting bees. These traps were not only full of nests but they were easy to use and helped augment the population tremendously.

Although we were less successful in public outreach, we can still recommend some of our techniques. Participating in National Public Lands Day and having the Boy Scouts involved in the trail and sign building was very good for the project in terms of establishing an educational component and getting the community involved. We also found that working closely with the local universities and landowners enabled us to learn a lot more about the past and present land use in the surrounding areas. This guided our restoration efforts and was partially responsible for the success.

Overall, we accomplished all of our goals. We have successfully restored the historical prairie habitat that was indicative of Taylor County, and we consequently increased the number of native bee species on the plots. In addition, several of the public areas have benefited from the aesthetic enhancement due to the prairie restoration.

Perhaps most importantly, our careful consideration of the local pollinator complex gives the Dyess restoration a chance for enduring success.

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Common Name	Scientific Name	Family	Description	Blooming	Range	Attracts
Jack-in-the-Pulpit	*Arisaema tryphyllum*	Arum Araceae	Perenn: brownish flower,6 or more petal-like parts	April to June	MN to New Brunswick, S. to Lousiana and N. Florida	Bird
Mayapple	*Podophyllum peltatum*	Barberry Barberidaceae	Perenn: white flower, 6 or more petal-like parts	April to June	S. MN, S. Ontario, S. NH S. to Georgia and E.	
Great Lobelia	*Lobelia siphilitica*	Bluebell Campanulaceae	Perenn:bright blue flowers, irregular petal-like parts	August to September	MN to VT, S. to E. Virginia, and W. NC	
Virginia Bluebells	*Mertensia virginica*	Borage Boraginaceae	Perenn:light-blue trumpet-shaped flowers	March to June	MN, W. NY & S. NC	
Wild Columbine	*Aquilegia canadensis*	Buttercup Ranunculaceae	Perenn:red and yellow flowers, five petals	April to July	MN to New Brunswick, S. to N. GA and NE Texas	Bird Hummingbird  
White Beneberry	*Actaea pachypoda*	Buttercup Ranunculaceae	Perenn:white flowers and shiny white berries	May to June	Nova Scotia S. to N. GA	Bird

Common Name	Scientific Name	Family	Description	Blooming	Range	Attracts
Black Cohosh	*Cimicifuga racemosa*	Buttercup Ranunculaceae	Perenn:white flowers four to fiive petals	June to September	WI to MA and S. to N. GA	
Bigleaf Aster	*Aster macrophyllus*	Daisy Asteraceae	Perenn:violet or lavander flowers w/ yellow to reddish centers	August to September	MN to Nova Scotia and S. to W. NC and IL	
Dutchman's-Breeches	*Dicentra cucullaria*	Fumitory Fumariaceae	Perenn:white flowers, irregular petal-like parts	April to May	ND to Nova Scotia, S. to N. GA, AL and MO	
Fringed Bleeding Heart	*Dicentra eximia*	Fumitory Fumariaceae	Perenn:Pink heart-shaped flowers, irregular petal-like parts	May to Agust	NY S. to GA and TN	  Hummingbird
Wild Geranium	*Geranium maculatum*	Geranium Geraniaceae	Perenn:lavender, five-petaled flowers	April to May	S. Manitoba to Maine, S. to N. GA and KS	
Herb Robert	*Geranium robertianum*	Geranium Geraniaceae	Bienn:pinkish purple flowers, five petals	May to October	S. Manitoba to Nova Scotia, S. to MD & IL	
Wintergreen	*Gaultheria procumbens*	Heath Ericacea	Perenn:white bell-shaped flowers	April to May	S. Manitoba to Newfoundaland, S. to N. GA and N. AL	Bird

Common Name	Scientific Name	Family	Description	Blooming	Range	Attracts
Trumpet Honeysuckle	*Lonicera sempervirens*	Honeysuckle Caprifoliaceae	Perenn:trumpet-shaped flowers, scarlet outside and yellow inside	April to September	Iowa to MA, S. to FL and TX	  Bird Hummingbird
Wood Lily	*Lilium philadelphicum*	Lily Liliaceae	Perenn:cup-shaped orange flowers, three petals	June to August	British Columbia to Maine, S. to NC, AR and NM	Bird Hummingbird
Canada Mayflower	*Maianthemum canadense*	Lily Liliaceae	Perenn: minute white flowers	May to June	Manitoba to Labrador, S. to MD and Iowa	 Bird
Small Solomon's Seal	*Polygonatum biflorum*	Lily Liliaceae	Perenn:one to four paired greenish yellow flowers	May to June	NB to S. Ontario and CT, S. to FL and E. TX	
Partridgeberry	*Mitchella repens*	Madder Rubiaceae	Perenn:white tubular flowers	June to July	MN to Newfoundland, S. to FL and E. TX	Bird
Yellow Lady's Sliper	*Cypripedium calceolus*	Orchid Orchideaceae	Perenn:yellow pouch-shaped lip flanked by two petals	April to July	British Columbia to Newfounland, S. to GA and AR	

Common Name	Scientific Name	Family	Description	Blooming	Range	Attracts
Pink Ladys Slipper	*Cypripedium acaule*	Orchid Orchideaceae	Perenn:pink flower, irregular petal-like parts	April to June	Nova Scotia, S. to N. GA and TN	
Wild Lupine	*Lupinus perennis*	Pea Fabaceae	Perenn:blue five-petaled pealike flowers	April to July	MN to Maine, S. to FL and LO	 
Starry Campion	*Silene stellata*	Pink Caryophyllaceae	Perenn:five white petals compose individual flowers	July to September	MN to MA, S. to GA and E. TX	
Fire Pink	*Silene virginica*	Pink Caryophyllaceae	Perenn:red five petal-like flowers	April to June	MN to S. Ontario, S. to GA	Hummingbird
Shooting Star	*Dodecatheon meadia*	Primrose Primulaceae	Perenn:pink, lilac, or white flower and five petal-like parts	April to June	WI to PA, S. to GA and E. TX	
Spring Beauty	*Claytonia virginica*	Purslane Portulacaceae	Perenn: white flowers, five petals striped with rose-pink	March to May	MN to S. Quebec, S. to GA and TX	

Common Name	Scientific Name	Family	Description	Blooming	Range	Attracts
Downy False Foxglove	*Aureolaria virginica*	Figwort Scrophulariaceae	Bienn:funnel-shaped yellow flowers with five flared lobes	June to August	Michigan to NH, S. to N. FL and LO	
Trumpet Creeper	*Campsis radicans*	Bignonia Bignoniaceae	Perenn:trumpet-shaped orangish-red flowers	July to September	Michigan to MA, S. to FL and TX	 Bird Hummingbird
Common Blue Violet	*Viola papilionaceae*	Violet Violaceae	Perenn:bilaterally symmetrical purple lavander flowers	March to June	ND to Maine, S. to FL and TX	 Bird
Smooth Yellow Violet	*Viola pensylvanica*	Violet Violaceae	Perenn:yellow bilaterally symmetrical flowers	April to June	Manitoba to Nova Scotia, S. to NC and OK	 Bird
Sweet White Violet	*Viola blanda*	Violet Violaceae	Perenn:white bilaterally symmetrical flowers	April to June	MN to Quebec, S. to N. GA and TN	 Bird
Bloodroot	*Sanguinaria canadensis*	Poppy Papaveraceae	Perenn:bright white flowers with four petals	March to May	Quebec to Manitoba, S. to FL and TX	

Common Name	Scientific Name	Family	Description	Blooming	Range	Attracts
Yellow Wood-Poppy	*Stylophorum diphyllum*	Poppy Papaveraceae	Perenn:bright yellow four petal flowers	March to May	PA to Wisconsin S. to VA, TN and MO	
Wild Blue Phlox	*Phlox divaricata*	Phlox Polemoniaceae	Perenn:blue or light violet flowers, petals fused into funnel	April to June	MN to Quebec, S. to FL and SE. TX	  Hummingbird