

# Restoration Notes

Restoration Notes have been a distinguishing feature of *Ecological Restoration* for more than 25 years. This section is geared toward introducing innovative research, tools, technologies, programs, and ideas, as well as providing short-term research results and updates on ongoing efforts. Please direct submissions and inquiries to the editorial staff (mingram@wisc.edu and cmreyes@wisc.edu).

## Austin Is a Habitat Haven with National Wildlife Federation Certification

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Austin, Texas, is a city known nationwide for its live music, environmental awareness, and high standard of living. Now the city can also boast an improved quality of life for its feathered and furred residents by becoming the thirtieth community to receive the National Wildlife Federation's (NWF) Community Wildlife Habitat certification. It is the first Texas community, also the largest city and first state capitol in the country, to earn this special wildlife habitat designation. To date, over 113,000 individual habitats and 31 communities have been certified by the national environmental conservation organization.

The desire to make Austin wildlife friendly stemmed from the fact that the region is one of the fastest growing metropolitan areas in the country. Austin's current population of 774,000 is expected to reach over one million people by 2025 (Robinson 2009). The city wanted a plan to help wildlife and maintain the region's biodiversity and unique ecosystems, and NWF's Community Wildlife Habitat project gave the city a template to help meet several environmental conservation goals under one umbrella program. These goals include minimizing climate change, conserving water, enhancing the quality of wildlife habitat within the city, and improving air and water quality. In March 2007, Mayor Will Wynn and the City Council passed a resolution to obtain NWF certification and demonstrate the city's long-term commitment to creating new wildlife habitat within the city by educating citizens and encouraging natural, native landscapes community-wide and on city-owned sites.

Alpine, California, became the first-ever certified community in May 1998. The community-wide certification grew out of NWF's Certified Wildlife Habitat program that began in 1973 as a way to help habitat enthusiasts turn their yards and other garden spaces into enticing wildlife refuges. To qualify, a site needs the basic elements that



Figure 1. NWF certified wildlife habitat yard with snag log as "yard art." Photo courtesy of Cathy Nordstrom, San Souci Gardens

allow wildlife to flourish: food, water, cover, and places to raise young. Creating habitat is as simple as planting native plants that offer nectar, seeds, and berries year-round, including a reliable water source, and providing places for protection and rearing young such as evergreen shrubs or a birdhouse. Applicants must also practice sustainable gardening techniques, such as reducing or eliminating chemical fertilizers and pesticides, conserving water, planting native plants, removing invasive plants, harvesting rainwater, and composting.

The Community Wildlife Habitat certification is based on a point system determined by population size. Points are acquired by completing habitat, education, and community project goals. Austin needed to accumulate 1,000 total points. The most challenging goal was habitat certification, which required that a minimum of 600 homes, six schools and ten businesses, places of worship, or other locations in Austin be certified through NWF's Certified Wildlife Habitat program. When the city originally announced its plans to become a certified community, there were approximately 340 NWF-certified habitats in Austin, including 15 schools and 12 businesses, places of worship, and other common areas. A new Parks and Recreation Department program, Wildlife Austin, was created in February 2008 with a budget that included the salary of one staff person to lead the certification effort and approximately \$7,000 for program costs.



**Figure 2.** Father and son (Sam and Ethan Powers) helped save native grasses during the Austin Nature and Science Center's February 2008 native plant rescue from a pond before its liner was replaced. Photo by author

To generate awareness of the initiative and to earn habitat and community project points, Wildlife Austin started a Neighborhood Habitat Challenge. The contest lasted from May to October of last year. Participating neighborhoods were challenged to certify the most habitats within their boundaries, organize a community invasive plant removal effort, and promote gardening for wildlife through their newsletters, listservers, and web sites. The city gave a helping hand by making prepaid NWF habitat certification applications available to all Austin residents, ensuring everyone had an equal opportunity to participate in the program. The top three neighborhoods won prizes and were honored by the city council. Six neighborhoods took the challenge and countless other individuals certified their yards in support of the city's goal to become the first certified community in Texas and the largest in the country.

The challenge resulted in approximately 300 new certified homes. The habitat challenge, especially the invasive plant removal project, was instrumental in increasing consciousness about the value of restoring natural balance to our landscapes, while serving as an effective tool for neighborhood community building. The challenge concept helped spread the idea of transforming traditional lawns into natural yards, thus augmenting Austin's total area of green space enjoyed by people and animals alike (Figure 1). The Neighborhood Habitat Challenge is now an annual competition that offers a menu of challenging activities to further engage neighborhoods in making and improving homes for wildlife.

Encouraging neighborhood residents to change their yards into habitat havens was just one approach. High profile city sites have also gone wild: Austin City Hall became NWF's Habitat No. 99,000 in July 2008, the first city hall in Texas to be certified. Native landscaping and water features were installed in 2004 when the new city

hall building was completed. Planting additional natives and applying for habitat certification made it official.

The Parks and Recreation main office followed suit and converted the turf grass area in front of the building into a thriving habitat-demonstration garden. The garden also qualified as an education project, counting toward needed certification points. Native plants were chosen to bring in colorful butterflies, hummingbirds, and songbirds. The interpretative signage tells a story of habitat creation that will hopefully inspire more people to provide habitat for local wildlife. Other certified public sites include the Austin Nature and Science Center, a household hazardous waste facility, and Austin Water Utility's Center for Environmental Research.

Restoration efforts were also part of Austin's community project goal. In February 2008, the Austin Nature and Science Center had to replace a leaky pond liner and valuable native plants were slated to be taken out. Wildlife Austin organized a native plant rescue and volunteers were able to save plants that were later used to restore area creeks (Figure 2). Parks were also seeded with wildflowers as a tribute to Lady Bird Johnson's legacy of native wildflower beautification in Austin and throughout the country.

Austin met its education goals through a variety of outreach methods including presentations on gardening for wildlife, informational tables at local festivals, media coverage, and two NWF Habitat Steward Volunteer trainings that added 50 enthusiastic stewards to the volunteer network. A local Boy Scout organized a Backyard Habitat Expo at the nature center for his Hornaday Award project to educate the public on habitat elements and increase the city's certified habitat numbers.

Austin earned NWF Community Wildlife Habitat certification in November 2008 with over 1,550 points and more than 950 certified habitats throughout the city. Wildlife Austin will continue to educate and support the creation of new native landscapes and has begun long-term planning for maintaining the NWF certification. Next steps include implementing parkland habitat certification guidelines, establishing best management practices for parks, and habitat training for Parks and Recreation landscape maintenance staff. At the city department level, habitat components are being integrated into facility landscape designs and the issue of invasive plant species on city-owned property is being addressed through a comprehensive management strategy.

The creation of Wildlife Austin and the distinguished Community Wildlife Habitat certification are a testament to Austin's leadership in habitat education and conservation of urban biodiversity. Institutionalization of the Parks and Recreation program through the dedication of funds and staff was a major key to Austin's ultimate success. These progressive actions will benefit people and wildlife in Austin for generations to come. Austin is a model of what one city can do with a government and citizenry that care about



keeping wild places wild for its resident critters. To learn more about Austin's program visit, [www.keeptaustinwild.com](http://www.keeptaustinwild.com). For more information on NWF's habitat program, visit [www.nwf.org/gardenforwildlife](http://www.nwf.org/gardenforwildlife).

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## Native Sod Rescue—

### A Viable Business Model (Montana)

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The majestic natural landscapes of the American West host an expanding cultural landscape. One such new development, Mansion Heights, established on a hillside prairie overlooking the Missoula Valley, provided a bittersweet opportunity for plant rescue. In 2004, sponsored by the local Native Plant Society, a small group of people scrambled to save native plants moments before an excavator razed the ground surface at Mansion Heights. Our crew saved maybe 1% of the plants that day—the other 99%, including thousands of old-growth rough fescue (*Festuca scabrella*) comprising individuals over 80 years old, were scraped with a machine and piled in large mound. Once these now-dead plants were rotted (around six months), the soil was sold for \$15 per cubic meter; a typical dump truck holds approximately ten cubic meters.

The idea and original business plan for our small company, Native Yards, emerged while we were admiring these highly diverse old-growth grasslands (consisting of plants, their seed banks, and soil microorganisms) and then realizing how their legacy was wasted and lost in an inexpensive heap of dirt. In our minds, the value of the intact plant community that we could rescue in a few square feet of native sod with a shovel—or a few square meters if using mechanical extraction—was worth far more than the composted soil that was currently being sold (Figure 1). We approached about a dozen contractors working in areas with remnant grasslands to see if they might allow us to rescue some of the plants prior to development. Our requests received enthusiastic responses and invitations to extract plants for no charge.

We initially sold the extracted sod at a local farmers' market, charging \$6 to \$15 per square meter (depending on species assemblages). In general, sod prices reflected the diversity of the plant community, with grass-dominated sections being less expensive than ones that were forb dominated. Also, if there were "sexy" species represented, like bitterroot (*Lewisia rediviva*, the Montana state flower),

then those pieces of sod were in high demand and therefore sold at the higher price.

Marketing at the farmers' market was minimal but effective. We made a large color sign featuring prairie smoke (*Geum triflorum*) in bloom to serve as the backdrop for our booth. We also created informational pamphlets showing demonstration gardens created from extracted sod and outlining lists of native and invasive species. We freely gave advice regarding placement and short-term care of the native sod in the new owners' gardens, including basic information such as 1) weeding is most likely needed in the first months after installation owing to opportunistic, ubiquitous, wind-borne non-native seeds; 2) sod needs to be watered regularly in the first year; 3) after the first year, the watering regime can taper so that by the third year after installation each transplanted piece of native prairie will survive without water but will brown up and go dormant for the hot summer months; and 4) despite their water-wise nature, most native plants from this region will also respond well to some watering through the growing season by remaining green all season and even by going through second flowering events.

Most of our clients were from the local area. However, if someone wanted to take their sod to another community, we provided the rule of thumb that they should not take the sod anywhere beyond a three-hour drive, otherwise the plants may not be suited for their garden or local ecosystem. Most of our customers chose to install the sod on their own. However, in some instances, clients requested us to install the sod, especially if they wanted large portions of their yards to be composed of the native sod.

The success of our farmers' market endeavor and initial exposure to the community triggered a front page story in the local paper (Gadbow 2005), which became our main marketing reference. Today, five years later, we still have clients commenting on that article. Our marketing expanded when we decided to partner with a local nursery. First we approached several nurseries as potential native sod vendors. This sparked very positive responses, and our first choice even requested that we work solely with them. We set the same price used at the farmers' market and the local community continued to be receptive. The only marketing associated with the nursery consisted of their sending clients to us for installations or more details. In addition, the nursery posted our information and provided our pamphlets. Native Yards had all the work it could handle, so we did not seek any additional advertisement.

By undertaking two to four all-day salvage events a month, enough material could be obtained to make a living. However, the salvage events can be exhausting, especially if there are only two individuals working. We found that a crew of two was the bare minimum for extraction and quickly realized that hiring a few strong workers for the extraction was very worthwhile. Of course, a machine (skid-steer) can do the work of many people and would alleviate



Figure 1. Native plants and their sod saved from destruction near Missoula, Montana, by the local Native Plant Society in 2004: a) prairie junegrass (*Koeleria macrantha*); b) a day's work provided a trailer full of rescued native plants. Photos by G. Thelen

the need for extra hands, but then the cost of extraction is greatly increased, as are the costs of transporting and storing larger yields.

If provided shade and water, these sod chunks remained viable for at least six months and as long as one year while displayed at the nursery. However, if a nursery is not available, the salvagers would need to hold to hold the product themselves, which would require a large shaded area with available water. Once the sod is in storage, selling it and installing it can be a two-person job.

To summarize, two people, a truck or trailer, a handful of sturdy flat-bladed shovels, and cooperative landowners or contractors are the basic ingredients to start a business like this. With ambition and resources, expansion into mechanical extraction or a storefront can quickly follow. Even though Native Yards is not our primary means of employment, we are confident this type of business could sustain a family, at least for the eight months of the year the ground isn't frozen. Despite this optimism, we would like to share a few significant observations and important lessons.

First, we found that this is a niche market: the sod was easier to sell to general audiences in the spring when flowers were in bloom, whereas only those stoutly dedicated to native landscaping were prone to purchase the stark,

later season sections of sod. Second, we learned to have available native landscaping supplements, such as seeds or plugs of species, such as lupine (*Lupinus* spp.), that are too deeply taprooted to be extracted and transplanted or that are showy and reseed easily. Third, we cannot emphasize enough the importance of weeding. This proved to be a larger task than expected, especially when clients have the expectation that a "native yard" means a yard with no invasive species. In our early efforts, we learned some hard lessons about unwanted stowaways in the rescued sod. For example, we discovered that it was best not to harvest from areas that have greater than five percent weed infestation, because we had to fight them for a few years posttransplant. (The non-natives are the worst in the first years after transplant; by year three the native plants are established and maintenance weeding is minimal.) In addition, to ensure that our customers were satisfied and educated, we offered a free weeding session with every installation, returning the following spring to nip the first wave of weeds in the bud and to point out the difference between native and invasive seedlings to the clients.

Such learning curves were minor when compared to the broader implications of our mission to save the prairies one plant at a time. We not only saved the individual plants, but we also recovered each plant's close neighbors, their seed banks, and the rich community of microfauna in the soil. Most (about 85%) of the intermountain West's native grasses and broadleaf plants can be rescued by capturing about 15 cm of soil when extracting the sod (Figure 2). Unique communities of bacteria, fungi, nematodes, and other microfauna thrive in the soil, of which only 5% have been described and studied (Brady and Weil 2008). Forget deep space or deep oceans, shallow soils are the true last frontier for discovery!





**Figure 2.** By extracting 15 cm of soil with the target plant community, over 85% of grasses and broadleaf plants native to intermountain prairies can be saved. A 30-cm wide x 30-cm long x 15-cm deep section of sod, as seen above, can contain a range of 4–20 plant species. Photo by G. Thelen

We have heard of other similar businesses dedicated to plant rescue in areas with high rates of development (e.g., Bozeman MT and Portland OR), but there is still much more available to salvage than what these businesses can handle. Our own small business in Missoula has hardly scratched the surface. Even so, we were able to turn the prospect of plant rescue into a viable business plan with virtually no overhead, since contractors let us remove plants at no cost and because we worked with a nursery that stored and sold the sod. In the early days of Native Yards, then, our main costs included time and transport. We were able to use this primary business model as a springboard to expand the company's mission by adding native plant landscaping and design, research, and natural weed control by hand pulling. The latter has proven to be a surprisingly successful niche market with significant potential, but that is a topic for another Restoration Note.

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## A Plan for Landscape Fire Restoration in the Southwestern Borderlands

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Fires were prevalent in the Southwestern Borderlands of Arizona and New Mexico prior to the arrival of European-American settlers in the 1880s. The almost total exclusion of fires for more than 100 years has been linked to declines in biological diversity and a loss of productivity associated with the encroachment of woody vegetation into the grasslands and open woodlands. Private and public land managers agreed that reintroducing fire could improve or reverse these landscape changes. The Coronado National Forest developed the Peloncillo Programmatic Fire Plan after intense consultations with federal, state, and county agencies and the ranching community to reintroduce landscape level prescribed and managed fire into the Peloncillo Mountains (Allen 1999). The final plan helped streamline the management decision and approval processes that previously were delayed by long, complicated, and often contentious discussions. The Plan and the consultation process that led to consensus among diverse partners can serve as a model for the development of programmatic fire plans in other areas.

The Peloncillo Mountains, which are part of Madrean Archipelago or Sky Islands Province and straddle the Arizona–New Mexico border, are noted for their exceptional beauty and biological diversity (Figure 1). Much of the ecological decline is related to severe range deterioration linked to drought and late nineteenth-century overgrazing and to aggressive fire suppression on public lands. Climatic fluctuations, especially precipitation timing and amounts, also affect vegetation dynamics. Even if fires are ignited, they generally do not spread because of the lack of continuous ground cover. However, stand-replacing fires are possible under severe weather and fuels conditions.

Ranchers were concerned that the policy of aggressive fire suppression was overlooking the beneficial effects of fire on ecosystem health and was often an unnecessary and unwanted expense to the public. In 1992, ranchers, other landowners, members of the environmental community, individual federal employees, and other interested people from the area formed the nonprofit Malpai Borderlands Group (MBG) with the goal of restoring and maintaining natural processes that create and protect an unfragmented, healthy landscape to support a diverse community of human, plant, and animal life (McDonald 1995). This area of the Borderlands Region contains a 323,750-ha mixture of private and public lands. At about the same time, the



Figure 1. A typical oak savanna in the Southwestern Borderlands. This stand is on the eastern side of the Peloncillo Mountains in New Mexico with the Animas Mountains in the background. Photo courtesy of Daniel Neary

U.S. Forest Service (USFS) and other agencies reached a similar position on the value of reintroducing fire. In 1995, the Coronado National Forest began modifying its fire management plan in the Peloncillo Mountains from a policy of total suppression to fostering natural fire's role (USFS 2005).

The Malpai Borderlands Group recognized that it could more easily achieve its goals if it developed partnerships with like-minded governmental agencies and the environmental community. In addition to the Forest Service, partners include the USDA Natural Resources Conservation Service (NRCS), the USDI Fish and Wildlife Service (FWS), USDI Bureau of Land Management (BLM), land and natural resource agencies of the states of Arizona and New Mexico, The Nature Conservancy, and others. As a result of the cooperation, several joint fire planning activities for public and private lands were developed (Allen 1999).

An interagency, interdisciplinary team led by the Forest Service began work on the Peloncillo Programmatic Fire Plan in 1997 to address fire management issues on approximately 48,565 ha administered by the Coronado National Forest and the BLM, which had delegated its local fire suppression responsibilities to the Forest Service in 1995 (Allen 1999). The plan attempted to address all of the environmental issues related to a program of prescribed burning and managed wildfires on federal lands in one document so that managers would not have to repeat the process for each prescribed burn. The team proposed actions to address each identified issue, including the impacts on vegetation communities, private lands and improvements, livestock management, grassland productivity, biological diversity, soil and water, air quality, and heritage resources. The team also identified six threatened or endangered species that would require FWS consultations before the program could be initiated.

The interdisciplinary team recognized 91 species of plants and animals that could be affected by the fire program. The main concerns were the threatened New Mexico ridge-nosed rattlesnake (*Crotalus willardi obscurus*), which is rare in the Peloncillo Mountains, and the Palmer agave (*Agave palmeri*), which provides nectar for the endangered lesser long-nosed bat (*Leptonycteris curasoae*). Holycross and his associates (1999) found that a prescribed burn did not result in a statistically significant reduction in the snake population. However, there was concern that prescribed fires in wooded canyons, which are preferred snake habitats and often contain high fuel accumulations, would adversely affect the limited snake population. Research by Slauson and her associates (1999) indicated that a prescribed fire did not result in differences in agave fruit set and overall resources for bats between burned and unburned sites. Discussions with representatives of the NRCS, FWS, USFS Rocky Mountain Research Station, the Arizona Game and Fish Department, and the New Mexico Game and Fish Department resulted in recommendations to conduct cooler burns in critical snake habitats, limit ignitions after rains (when the snakes are most active), and develop protocols on handling snakes found during burning operations. An allowable level of mortality was established for agave that would not negatively impact the bats.

A scoping report was prepared and distributed to 54 individuals and organizations for public comment in 1998; approximately 50 percent responded. In addition, Interdisciplinary Team Leader Larry Allen personally visited each ranch in the planning area and met with each grazing permittee/landowner to discuss plan alternatives. The Hidalgo County New Mexico Planning Group and the MBG also were consulted. While most local ranchers favored allowing an increase in fire frequency in the region, coupled with appropriate controlled burning, there were some who saw fire as a threat to forage availability. Hidalgo County wanted closer collaboration with local landowners and governments. Overall, several new issues emerged and resulted in the development of four alternatives. The final decision consisted of a blend of fire suppression, prescribed burning, and supervised/monitored wildfire as considered appropriate to maximize resource benefits and reduce management costs (USFS 2005). Prescribed fire would be used to augment the natural fire regime and encourage desired vegetation conditions, protect and enhance critical habitats, and protect resources or improvements from natural ignitions. The plan addressed many of the concerns raised by Hidalgo County, including assurances that landowners and local governments would be consulted in suppression decisions. The Peloncillo Fire Management Plan was merged into the Coronado National Forest Land and Resource Management Plan (LRMP) in 2005. This document has been modified since then, but many aspects of the Peloncillo Plan are included in the current LRMP (USFS 2007).

Public and private partners have conducted four landscape-scale prescribed fires. The fires were designed to begin ecological restoration in the southern Peloncillo Mountains by reducing the density of woody species and improving herbaceous cover, restoring wildlife habitats and historic biological diversity, improving watershed stability and hydrological function, and creating a fuels mosaic that would allow fire to resume a more natural role in the ecosystem (Helbing 1995). The project areas are generally at elevations above 1,525 m that support mixtures of oak (*Quercus*), juniper (*Juniperus*), shrub, and herbaceous species. The objectives for the series of landscape fires included burning about 65% of the area, reducing the population of smaller mesquite and juniper by 40% to 50%, and protecting larger oak trees and riparian areas. The first prescribed burn occurred in 1995 on 2,430 ha in Baker Canyon near the U.S./Mexico border; the second burn was the 1997 Maverick Burn. This was followed by the Baker II Burn in 2003, which was planned to cover about 19,285 ha of federal, state, and private lands. The landowner compensated the government for treating approximately 4,330 ha of private lands that were within the burn boundary. The final surveys indicated that about 14,365 ha actually burned. Baker II was considered, at that time, to be the largest successful prescribed fire conducted in the United States. In 2007, a fourth landscape burn covered 2,185 ha in the adjacent Cottonwood Canyon.

Planning and implementation of large landscape burns require close coordination among many partners to meet objectives and to ensure safety. The Baker II Burn, for example, was conducted by personnel from the Coronado National Forest, other national forests, BLM, FWS, National Park Service, and the Animas Foundation, which operates the Diamond A Ranch. The Rocky Mountain Research Station and NRCS assisted with planning, and the Mexican government sent observers. The four prescribed burns generally have been successful in achieving the landscape restoration objectives of reducing the densities of woody species and fuel accumulations and creating mosaics of open grass and tree-covered areas.

Monitoring was conducted on the ground using transects, permanent or temporary plots, and strategically located photo points and remotely by using aerial observations or satellite imagery. Several research studies were initiated to answer questions raised in the development of the Peloncillo Plan about fire management and fire effects (Gottfried and Edminster 2005).

The Peloncillo Programmatic Fire Plan is a successful proactive model for restoring landscape-scale fire. The plan was developed by the Coronado National Forest with consideration of the views of the other federal and state agencies and the local ranching communities. The consultations with the U.S. Fish and Wildlife Service and state game and fish departments were critical to the acceptance

of the plan and set the framework for future consultations on the Coronado National Forest. Documentation and consultations are still necessary before a prescribed fire is ignited. However, the programmatic plan allows land management agencies to implement prescribed fires or to manage wildfires in the Peloncillo Mountains without the previous need for intense, complicated, and time-consuming procedures.

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## Restoring Burned Areas at Zion National Park (Utah)

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In June 2006, the Kolob Fire ignited in an area heavily infested with cheatgrass (*Bromus tectorum*) in Zion National Park, located in southwest Utah. The semiarid environment ranges from 1,219 m to almost 2,438 m in elevation. The landscape is dominated by towering sandstone and limestone cliffs with eroded slopes beneath. The area's average precipitation is 406 mm. The average high temperature is 23°C, with highs in July and August averaging 39°C. The cheatgrass fuel allowed the fire to grow rapidly and it burned 4,259 ha in Zion (7,135 ha total), the largest fire in the park's recorded history. The fire burned through an area dominated by an established pinyon (*Pinus edulis*) and juniper (*Juniperus osteosperma*) forest interspersed with sagebrush (*Artemisia tridentata*)—dominated shrublands with a presuppression historic regime of infrequent fire return intervals of 35 to more than 100 years, with mixed severity intensities and mosaic landscape patterns (USDI, NPS 2005).

The National Park Service Burned Area Emergency Response (BAER) program conducted the initial assessment of fire impacts and found that the native plant community and historic fire regimes were both threatened by postfire cheatgrass expansion. This invasive annual grass, with its prolific seed production, ability to germinate in the fall or spring, and preemptive use of water due to early germination (Billings 1994), has strikingly changed ecosystems over vast areas of the West by creating an environment where fires are easily ignited, spread rapidly, cover large areas, occur frequently, and have increased intensity (Reid et al. 2006). In turn, a large-scale disturbance such as wildfire leaves the ideal conditions for cheatgrass emergence and growth—an increase in light and space and a temporary surge in available soil nutrients. Since native grasses, shrubs, and trees are slower to reestablish after fire, an increased fire frequency eventually eliminates the majority of them from the landscape (Brooks 1999).

Recommendations for rehabilitation of the Kolob Fire were shaped by a 2005 collaborative USGS/NPS Zion Canyon vegetation research project that found postfire fall application of imazapic (Plateau) to be most effective at combating non-native annual grasses after a fire disturbance (Matchett et al. 2007). Imazapic is a preemergent herbicide that primarily targets annual plants and is

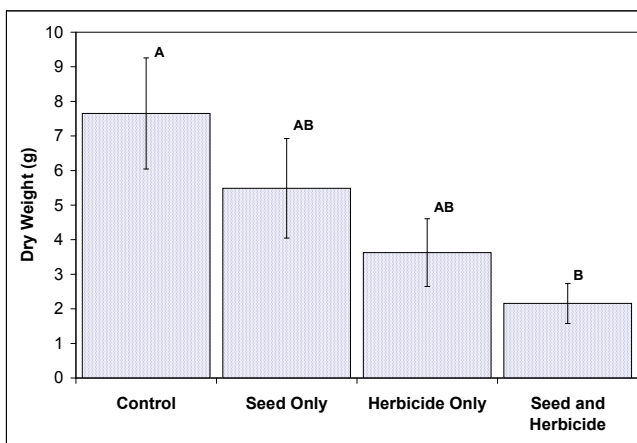


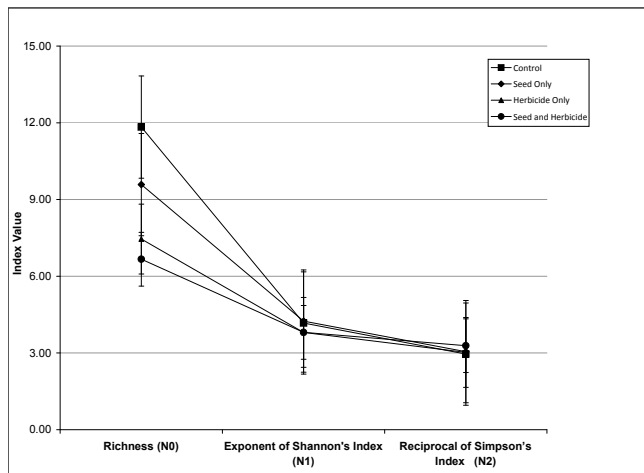
Figure 1. A significant reduction ( $p < 0.05$ , interaction  $p = 0.736$ ) in brome (*Bromus tectorum* and *B. rubens*) biomass was found at the pinyon-juniper Kolob Terrace Road (KTR) site in Zion National Park from both the imazapic and native seed applications. Tukey's HSD found the untreated control to be significantly ( $p < 0.05$ ) different from the plots receiving both treatments (indicated by different letters).

considered nontoxic to a wide range of animals. There is little potential for bioaccumulation and little evidence of lateral movement in the soil, where it is moderately persistent (1–3 years), allowing for full-season control of targeted species. Imazapic may be applied pre- or postemergence, but is more effective as a preemergent in controlling cheatgrass (Vollmer and Vollmer 2006). Nontarget plants affected by imazapic vary greatly by location, but the Zion Canyon study showed little or no negative effect on perennial natives; production was in fact increased owing to decreased competition from exotics. It also controlled several other annual and biennial non-natives (Matchett et al. 2007).

As a result of late-season rains in fall 2006 and the National Environmental Policy Act (NEPA) planning timelines pushing the imazapic application past ideal timing, cheatgrass had already begun to emerge on portions of the fire area beginning in October, prior to application. The aboveground biomass removed by the fire allows the herbicide to reach the soil surface directly, for more thorough absorption and effectiveness. Following BAER recommendations, our restoration efforts included an application by helicopter of imazapic, so as to cover large areas in a timely manner, achieve efficient spray application patterns, and maneuver over difficult terrain. We chose 0.24 L of herbicide diluted with 8 L of water mixed with the surfactant Liberate as the application rate per hectare for the purposes of preventing damage to the seeding effort and promoting successful native plant recovery over 3,577 ha of the Kolob Fire.

A 200-ha area that was heavily infested with cheatgrass before the fire was additionally seeded with native grass and forb species to provide a native seed bank for post treatment germination. These species, bottlebrush squirreltail (*Elymus elymoides*), sand dropseed (*Sporobolus cryptandrus*),





**Figure 2.** At the Kolob Terrace Road (KTR) pinyon-juniper site in Zion National Park, Hill's diversity series showed differences in diversity across the four treatment types. When moving from richness (N0, sensitive to uncommon species) to N1 and N2 (measures of abundant and dominant species, respectively), these differences disappear, showing that the differences in diversity between treatments are being driven by the species encountered less frequently.

scarlet globemallow (*Sphaeralcea ambigua*), and Palmer's penstemon (*Penstemon palmeri*), will not be affected by the herbicide, come from local seed sources, have long seed viability, germinate with little soil contact, and are known for their ability to compete with cheatgrass. A concurrent project funded by the Joint Fire Science Program will address seed contamination, and our sampling assesses the establishment and survival rates of the four seeded species, which will allow Zion to conduct a cost-benefit analysis of the seeding treatment.

Monitoring is a critical component of this ecosystem restoration project. We have established a network of plots at three sites within the burn to determine the long-term efficacy of the herbicide and seeding treatments. In this paper, we address the Kolob Terrace Road (KTR) site, which received both treatments. All plots are located in a pinyon-juniper forest with a cinder/basalt soil type that experienced moderate to high burn severity. We established 48 plots (5 m × 30 m brush belts) in blocks of four (control, seeded, sprayed, and seeded and sprayed). Plots were buffered by 15 m on all sides in an attempt to allow helicopter herbicide operations to cover required areas while avoiding control and seed-only plots. Droplet size from the helicopter spray boom was adjusted to assure proper application patterns over the treatment area and research plots.

First-season data (spring 2007) from this site were analyzed as an unbalanced randomized complete block design with two factors, herbicide and seeding. We ran a two-way ANOVA that showed significant treatment effects (Figure 1). Since the herbicide was applied postemergence, the reduction in biomass is to be expected from a stunting effect. However, density measures followed the same trend,

implying that the herbicide caused the death of some of the fall 2006 seed crop. We did not expect a significant seeding effect this first season because seedlings had not yet emerged at the time of sampling. Although this result is only from five months post-treatment, it has implications for sites similar to KTR (high prefire cheatgrass abundances, low native component); although each treatment may separately cause significant reductions in cheatgrass biomass, the combination of both may be necessary to achieve desired rehabilitation results.

We collected biomass from 28 species at this site, and although there were only four non-native species, they comprised 67.5% of the total biomass. To analyze treatment effects on community diversity, we used Hill's (1973) series of diversity indices because both species evenness and richness are incorporated into one number reflecting the "effective number" of species (ES) within a community. Progressing through the set, each index is most sensitive, respectively, to species that are rarer (N0, species richness), more abundant (N1, the exponent of Shannon's index), and more dominant (N2, reciprocal of Simpson's index). At KTR, N0 was lower in treatment plots (Figure 2). Of the twelve least common species, six are listed as uncommon in the park but none is listed as rare in Utah. Since fires in the park's pinyon-juniper communities have rarely occurred in the last 100 years, several native species uncommon or unconfirmed in the park were released from the seed bank throughout the burn and within different treatment plots, which will be reflected in analysis of subsequent seasons' data. Although the decrease in species richness seen in this first season is not a desired result, our goal was to prevent sacrificing the whole ecosystem to a cheatgrass-driven grass-fire cycle. We hypothesize that the species reduced this season will rebound in the future owing to reduced competition from brome species.

Preliminary results from the other two sites within the Kolob Fire and from a network of plots within the Dakota Hills Complex fires (also in Zion) do not necessarily follow the same biomass reduction trends, indicating that prefire vegetation condition has a large impact on success of imazapic and seeding treatments. We will also run additional analyses on density and cover estimates from all sites for treatment effect and use this information to ascertain the relationship between biomass and these two measures at capturing treatment effects.

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## Restoring Native Sedge Meadow Vegetation with a Combination of Herbicides (Illinois)

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Monotypic stands of reed canary grass (*Phalaris arundinacea*) are common in disturbed wet meadows, especially where a history of livestock grazing combines soil disturbance and excessive nutrients, both of which increase the aggressiveness of canary grass (Maurer et al. 2003). Efforts to control it with prescribed fire have shown promise only in areas of remnant sedge meadow vegetation, and here the spread of native sedges and subsequent reduction in canary grass have been slow. Past experience of the Natural Resource Management Crew indicated that mature canary grass is not difficult to kill with glyphosate herbicide. The problem comes with regrowth from seed and dormant rhizomes, usually overwhelming the developing native plant community in restorations. The challenge then was to develop a method that allowed for follow-up treatment of the canary grass without interfering with the growth of native plants. After talking with Beth Jarvis, MCCD Plant Ecologist at the time, I chose a combination of Poast, a post-emergent grass herbicide containing the active ingredient sethoxydim, diluted to 0.9% a.i. and a native sedge-meadow seed mix without grass species.

I settled on two methods of sethoxydim application: early application when most canary grass blades are 15–30 cm high, and allowing the grass to grow to 1–1.5 m height, then mowing to 30–50 cm before application. At the

MP		MP		MP				
8	7	6	5	4	3	2	1	
9	10	11	12	13	14	15	16	
24	23	22	21	20	19	18	17	
25	26	27	28	29	30	31	32	EP
40	39	38	37	36	35	34	33	
41	42	43	44	45	46	47	48	EP
56	55	54	53	52	51	50	49	
57	58	59	60	61	62	63	64	EP

Figure 1. Experimental layout: each square experimental unit is 10 × 10 m. Bold numbers indicate operational experimental units; smaller numbered units were not used owing to flooding in spring 2006. MP (gray) = summer mow and Poast (sethoxydim) spray; EP (cross-hatched) = early Poast application.

time of mowing, the grass had achieved nearly its mature height, but inflorescences were not fully formed. The Poast herbicide label does not specify use on canary grass, but it does list a number of perennial grasses and suggests spraying most species at a maximum height of 15–20 cm. Two managers I regularly communicate with suggested the second method, and I felt that application later in the growing season was worth trying because sethoxydim cannot be used over standing water, such as spring floods. The experimental treatments were laid out such that we could evaluate the independent effect of either of the two herbicide treatments and any possible interaction.

The seed mix I used contained the following native wetland species: porcupine sedge (*Carex hystericina*), lance-fruited oval sedge (*C. scoparia*), common fox sedge (*C. stipata*), common tussock sedge (*C. stricta*), brown fox sedge (*C. vulpinoidea*), Torrey's rush (*Juncus torreyi*), dark green bulrush (*Scirpus atrovirens*), great angelica (*Angelica atropurpurea*), swamp milkweed (*Asclepias incarnate*), sneeze-weed (*Helenium autumnale*), black-eyed susan (*Rudbeckia hirta*), cup plant (*Silphium perfoliatum*), and blue vervain (*Verbena hastata*). Species names follow Swink and Wilhelm (1994).

In 2005, I chose an experimental area (80 × 80 m) located in a monotypic stand of reed canarygrass in the Nippersink Creek floodplain within the boundaries of the 1,400-ha Glacial Park. Nippersink Creek here runs through an old glacial lake plain, and the soil is developed in deep fine-textured alluvium over clayey lake sediments, varying from very poorly drained to somewhat poorly drained. The pre-European settlement vegetation in this area was





Figure 2. Experimental unit 48, sprayed with Poast (sethoxydim) herbicide in summer 2006 and spring of 2007 and 2008 when the reed canary grass (*Phalaris arundinacea*) was 15–30 cm tall. In the background is an area of untreated canary grass. Photo by author

sedge meadow and wet prairie. The site was in some form of agricultural land use from the 1850s to the 1970s, most recently as a dairy farm.

The Natural Resource Management Crew burned the experimental area in early March 2006, then sprayed it with Rodeo (an aquatic formulation of glyphosate herbicide) diluted to 1% a.i. on May 10, when the canary grass was 15–30 cm tall, using an ATV-mounted boom sprayer. The March burn left a cover of thatch on the ground that I felt would interfere with the germination of the native seed, so my summer interns and I burned the thatch off on June 8. Of the 64 experimental units in the original experimental area, only 24 were dry enough to burn on June 8 (Figure 1), so we conducted the remainder of the experiment using only these. By this time it was obvious that the glyphosate had not killed canary grass in areas deeply inundated at the time of spraying, probably because insufficient leaf surface was exposed above the water. These low, wet areas corresponded to the areas we were unable to burn. On June 15, we seeded the 24 units with the sedge-forb mix at a rate of 9.0 kg/ha and raked the seed into the surface soil.

The canary grass was slow to develop this first year, so we waited to spray sethoxydim (broadcast with backpack sprayers) until August 15, when the leaves were about 15 cm high. This first spraying may have been particularly important given the observation by Adams and Galatowitsch (2005) that canary grass puts much of its early growth into aboveground biomass. The resulting large leaf surface and small root mass may make the plant more susceptible to foliar herbicide. On August 15 and again one week later, we treated an outbreak of Canada thistle (*Cirsium canadense*) with spot application of Transline (clopyralid herbicide). We broadcast with sethoxydim in the springs of 2007 (May 18) and 2008 (May 6). For the second treatment approach, we summer mowed the canary grass

only in 2007 (June 4) and sprayed it two weeks later (June 20). We burned the entire area again on April 18, 2008.

On July 23–24, 2008, I recorded the aerial cover of all plant species within four 1-m<sup>2</sup> quadrats in each experimental unit. I separately summed the canary grass and native graminoid cover in each quadrat, arcsine-transformed the data, and performed one-way ANOVAs (SPSS, vers. 11.0, Chicago IL), with canary grass cover and native graminoid cover as the dependent variables and Early-Poast and Late-Poast-and-Mow as fixed factors.

Application of sethoxydim when the canary grass was less than 15–30 cm high resulted in an increase in native graminoid cover from 9.5% (control) to 86.7% and a drop in canary grass cover from 88.3% for the control to 14.4% (significant in both ANOVAs at  $p < 0.001$ ). The summer mowing and sethoxydim treatment performed poorly, producing only 9.5% native graminoid and 87.8% canary grass, and was not significant in either ANOVA ( $p > 0.05$ ). The combination of the two treatments (77.4% native graminoid and 15.6% canary grass) performed no better than the early sethoxydim treatment alone.

When I was designing the experiment, I expected some degree of canary grass control from both treatments. I expected the early treatment to be more effective, both from the anecdotal experiences of other managers and because this early sethoxydim protocol follows the herbicide label directions more closely. I was, however, surprised by the magnitude of the difference. If both techniques had proved ineffective or both had succeeded but in differing degrees, I would have been less surprised.

In the early-sethoxydim-treated experimental units, the most abundant native species in order of aerial cover were dark green bulrush (38%), lance-fruited oval sedge (28%), brown fox sedge (7%), porcupine sedge (4%), Torrey's rush (3%), monkey flower (*Mimulus ringens*) (2%), common fox sedge (2%), and swamp milkweed (1%). In all likelihood, areas not receiving this treatment will revert to monotypic stands of canary grass in a few years.

Sethoxydim herbicide offered effective control of canary grass when applied to grass 15–30 cm high, typically early to mid-May in northeastern Illinois (Figure 2). Annen (2008) indicated that sedoxydim offered only partial control of canary grass, but he did not use a pretreatment of glyphosate. Summer application of sethoxydim after mowing had no effect on canary grass or native graminoid cover.

Early sethoxydim application while the canary grass leaves were small combined with a sedge-broadleaf seed mix may hold promise as a means of reestablishing native sedge meadow vegetation in monotypic stands of canary grass, but only within a narrow hydrologic range. Because sethoxydim is not approved for aquatic application, the method is feasible only in areas that dry out before the canary grass puts on much height growth. Limiting the method on drier sites is the fact that a sedge meadow seed

mix is appropriate only for sites with poorly to very poorly drained soil. Another potential pitfall is the number of years that follow-up sethoxydim application may be necessary for canary grass control. Only longer term trials will answer this last question. After three growing seasons, many areas of the early sethoxydim treatment host a dense stand of native sedges, rushes, and bulrushes and are almost free of canary grass (Figure 2). While these communities lack the diversity of native sedge meadows, they may be able to resist reinvasion of canary grass (Lindig-Cisneros and Zedler 2002).

Our hope is that with regular prescribed fire and spot application of glyphosate to canary grass clumps, this restored sedge meadow vegetation may become relatively stable. It would have been logistically difficult to include prescribed burning as a treatment in this experiment, but by excluding it as a treatment I do not mean to imply that it is not important. As with prairies and oak savannas, regular prescribed fire is essential to managing graminoid wetlands for the long term. Burning monotypic stands of canary grass does little to reduce the grass; however, fire often tips the competitive balance in favor of the sedges when they are present.

Canary grass that survived in the early sethoxydim treatment units did so in clumps rather than as scattered small plants. A quick elevation survey with an auto-level indicated that at least some of these clumps sat in small depressions. These lower areas may have been flooded during the spring 2006 glyphosate application. These clumps may also be the result of particularly large or aggressive rhizomes that broke dormancy afterward.

Because sethoxydim cannot be used over standing water, I feel the early treatment will be of limited use in basin wetlands where standing water is typically present during early canary grass growth. Wetlands in which the early sethoxydim treatment may prove useful include hillside fens, stream floodplain terraces that dry down early, and any wetland where managers can control the water levels. Managers need to evaluate the hydrology of their own sites to determine whether to give this method a try. We have selected a degraded 4-ha hillside fen site for a management trial beginning in summer 2009. Adams and Galatowitsch (2006) report that late summer and early fall application of glyphosate is more effective than spring application, so our plans are to spray the canary grass twice during the growing season of 2009 with an aquatic formulation of glyphosate herbicide, burn the site in the spring of 2010, and then apply seed after the burn. Early sethoxydim treatments will follow the protocol we developed in this experiment.

### Acknowledgments

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## Postsettlement Alluvium Removal: A Novel Floodplain Restoration Technique (Wisconsin)

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While soil conservation practices have greatly reduced erosion rates in southwestern Wisconsin since the midtwentieth century, stream-floodplain ecosystems still suffer from the legacy of floodplain sedimentation that buried presettlement wet prairies and sedge meadows. A new management technique is being developed that involves first identifying the contact between the post-settlement alluvium and the presettlement floodplain surface, and then removing this deposit to restore stream-floodplain connectivity and the presettlement hydrologic conditions. The goals of this restoration are to 1) reestablish wetland vegetation by reducing the water table depth and increasing soil moisture; 2) improve water quality by reducing bank erosion sediment sources and enhancing nutrient retention by increasing the active floodplain area; 3) increase flood storage by lowering the floodplain elevation; and 4) improve habitat for native biota (e.g., fish and amphibians).



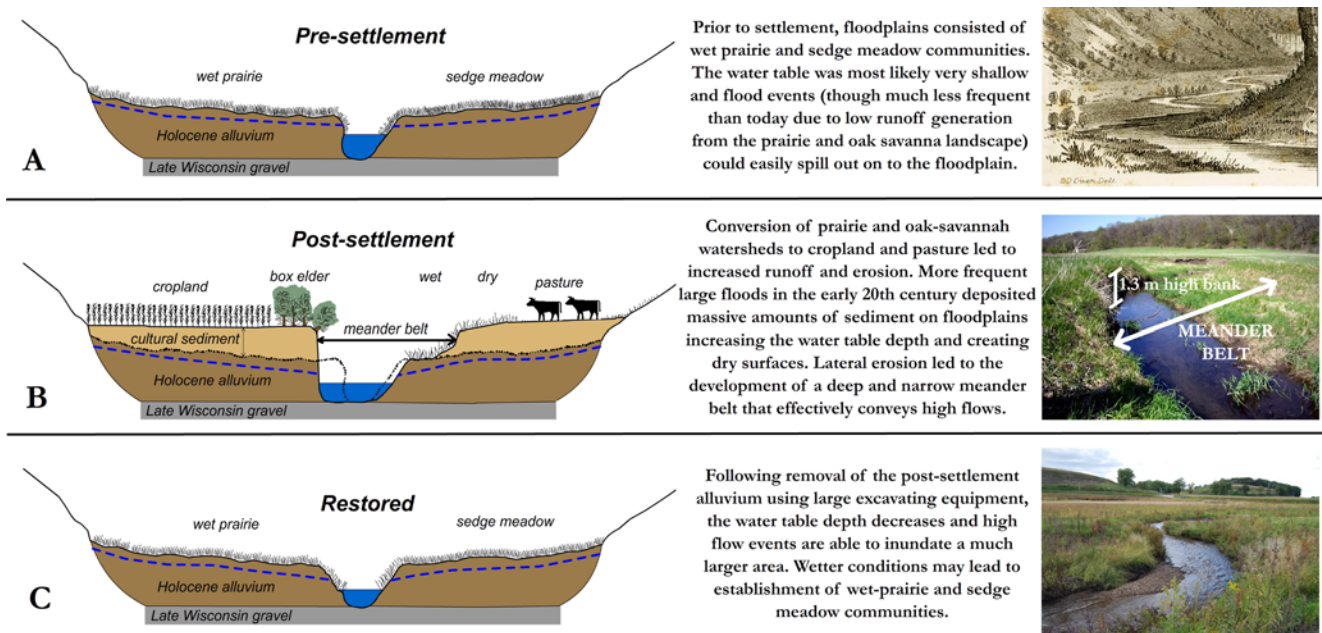


Figure 1. Conceptual model of stream-floodplain change A) before settlement; B) after settlement; and C) following restoration. Dashed line represents the water table.

This technique has been implemented at two sites (both approximately 800 m in stream length) owned by The Nature Conservancy and located near Barneveld, Wisconsin, in the headwaters of the East Branch Pecatonica River. The watersheds of the two sites (10 and 12 km<sup>2</sup>) are within the “Driftless Area” of southwestern Wisconsin, a region of deeply incised valleys and relatively high relief that is geologically unique from the surrounding Upper Midwest in that it remained unglaciated during the Pleistocene.

Before Euro-American settlement, Driftless Area watersheds were dominated by prairies, oak savannas, and forests with high infiltration capacities in the uplands and riparian wetlands in the valleys (mostly wet prairie/sedge meadow with some bottomland forest) (Figure 1A). In the early nineteenth century, Euro-American settlers, attracted to the region because of its lead and zinc resources, converted the prairie and forest landscape into cropland and pasture. The result of this extensive land-use transformation has been considered the most important hydrologic change in the region over the last 10,000 years (Knox 2006). Decreased infiltration capacity associated with the land conversion (e.g., cropland produces more surface runoff than prairie) combined with steep topography led to a dramatic increase in soil erosion, extreme flooding, and floodplain sedimentation that has been extensively documented (see review by Knox 2006). In 1935, the Soil Conservation Service began to encourage the use of soil conservation practices including contour strip cropping, replacement of steep cropland and pasture with deciduous forest, longer crop rotations, and gully stabilization, which led to a substantial reduction in soil erosion (Trimble and Lund 1982) and flooding (Potter 1991).

Despite modern improvements, the legacy of poor agricultural practices remains owing to eroded soil stored as floodplain alluvium within small watersheds (e.g., Trimble 1999). The stream-floodplain geometry of intermediate watersheds (10–200 km<sup>2</sup>) now consists of a narrow meander belt (Knox 2006), which encompasses the channel and an inset floodplain, bounded by a terrace composed of the post-settlement alluvium (Figure 1B). The channel is now largely disconnected from the historical terrace, so that high flows are confined to the flume-like meander belt, which very effectively conveys these flows downstream, adding to regional flooding concerns (Knox 2006). Furthermore, sedimentation increased the depth to the water table, leaving a drier surface available for cropland, pasture, and box elder (*Acer negundo*) colonization. As a result, wet prairie/sedge meadow communities and the many native species associated with this unique habitat have substantially declined in this region.

Restoration efforts in the region have historically focused on in-stream habitat creation and fish stocking programs to improve fisheries, which now support a valuable angling industry. The conservation and restoration of prairie ecosystems has also been important for decades, particularly in the East Branch Pecatonica River watershed where grassland, pasture, and forest make up nearly two-thirds of the total land use today. Recently, local nonprofit groups (e.g., The Nature Conservancy, Wisconsin Waterfowl Association, and Trout Unlimited) and the Wisconsin Department of Natural Resources (WDNR) have been working in the East Branch Pecatonica River watershed to integrate watershed-wide practices (e.g., prairie restoration) with restoration along the riparian corridor, an approach recommended by the academic community (Wohl et al. 2005).



Figure 2. Floodplain surface where postsettlement alluvium was recently removed (left) and a postsettlement floodplain surface (right) before sediment removal.

Restoration of the first site began in August 2006 when large excavating equipment was used to dig trenches lateral to the stream to identify the top of the presettlement surface. These trenches verified the sediment depth at the locations of 13 soil cores that were collected during the planning process. Next, between 30 and 120 cm of postsettlement alluvium was removed along one side of approximately 800 m of stream length to an average lateral distance of 100 m, restoring the topography to presettlement conditions including variations of the ground surface to promote diverse microhabitats (Figure 1C). The removed sediment (approximately 8,400 m<sup>3</sup>) was donated to the Iowa County Highway Department and more than 50 neighboring landowners willing to pay for the transportation costs for a variety of uses, including highway embankment improvement, soil conservation practices, and landscaping. The demand for the topsoil demonstrated that beneficial reuse of the excavated soil is feasible.

Immediately following the sediment removal, biodegradable erosion matting (Figure 2) was laid down along the stream banks, and all bare surfaces were seeded with cover crops of oats and rye. Germination tests of differing layers of the presettlement soil cores collected during the planning process did not show a viable seed bank. At selected locations, live native sod clumps were harvested and transplanted on-site to quickly establish some cover. Diverse sedge meadow, wet prairie, and mesic prairie seed mixes were drilled into all bare surfaces in late autumn. The native seed mixes were obtained from commercial sources, donations from The Prairie Enthusiasts, and on-site sources. In addition, approximately 400 prairie cordgrass (*Spartina pectinata*) plugs were planted in summer 2007, followed by a supplemental broadcast of native seeds in the autumn.

Another reach approximately 1.6 km farther upstream was similarly restored in August/September of 2008. In this second project, the presettlement surface was precisely delineated before construction using roughly 200 sediment

cores scattered across the floodplain. Sediment that was removed to a distance of approximately 40 m lateral to the stream on each side was purchased by a local excavating company for beneficial reuse, which helped offset some of the restoration costs.

Because of the novelty of this restoration technique, combined hydrologic and ecological monitoring and assessment is valuable. How does the hydrology change and influence the establishment of wetland vegetation once this layer is removed? How is the flood regime affected by the change in stream-floodplain geometry? Will increased floodplain inundation more effectively remove sediment and nutrients from the stream? To address these questions, the East Branch Pecatonica Restoration Observatory, a collaborative research effort at the University of Wisconsin–Madison, is analyzing extensive hydrologic and ecological data, which will continue to be collected at each site through 2010. Current field research efforts are monitoring the following: water table depth (15 wells/site); soil moisture (2 fixed locations and 3 transects); stream-flow (upstream and downstream boundaries of each site); meteorological conditions (on-site weather station); wetland vegetation (across each site using ground-based and remote sensing methods); stream temperature (5 sensors/site); biogeochemistry (stream and groundwater sampling); fish and aquatic invertebrate populations; and reptile and amphibian populations. The second site will be evaluated based on pre- and postrestoration datasets. The first site, which lacks extensive prerestoration data, will be used to compare pre- and postrestoration cases between the two paired sites under the same environmental conditions from May 2007 to August 2008.

An interdisciplinary approach is critical for investigating the complex processes associated with floodplain ecosystems and the wide-ranging set of ecosystem services they provide. Results from this research effort will advance the relatively young science of stream-floodplain restoration



and aid regional watershed managers so that future restoration projects can be designed effectively and sustainably using the best available science. In addition, the observatory serves as an outdoor classroom for undergraduate and graduate students to learn about monitoring and characterizing floodplain ecosystems. More information about the East Branch Pecatonica Restoration Observatory can be found at <http://hydroecology.cee.wisc.edu/EBP>.

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## The Effect of Disturbance History on Hawkweed Invasion (Montana)

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Orange hawkweed (*Hieracium aurantiacum*) is listed as a noxious weed in five states (USDA 2007), including Montana, where it is still in the early—and possibly

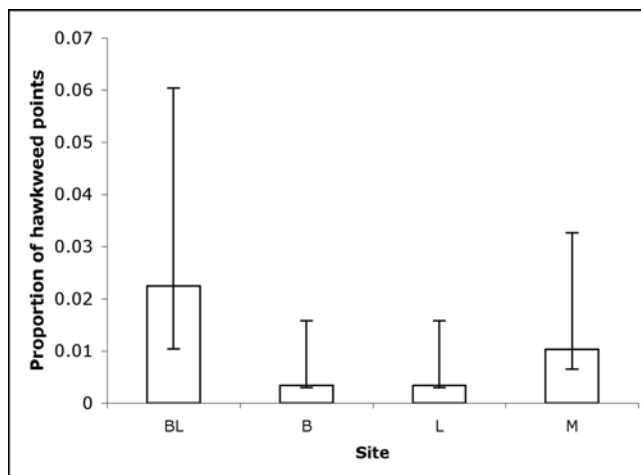


Figure 1. Probability of orange hawkweed (*Hieracium aurantiacum*) presence in each land cover type in the area burned by the Little Wolf Fire. Burned and salvage logged (BL); burned (B); logged (L); meadow (M). Bars equal 95% confidence intervals.

controllable—stages of invasion. The species forms dense clonal mats that exclude natives from the area; moreover, the wind-borne seeds are viable in the soil for seven years and have a high germination rate. Here, we document current densities and habitat associations of this potential invasive species in northwest Montana as a basis for future monitoring and management. Studies of other *Hieracium* species found that land management history and propagule pressure significantly influence hawkweed invasion (e.g., Rose and Frampton 1999). Although it is believed that orange hawkweed grows in open, disturbed areas such as roadsides and meadows, there are no studies of the specific factors that influence its distribution.

In addition to documenting the distribution of orange hawkweed, we test whether reproductive resource allocation differs among land cover types, since the proportion of seed to vegetative reproduction is often a plastic response to the environment (e.g., Van Kleunen et al. 2002). For example, mouse-eared hawkweed (*Hieracium pilosella*) allocates more to vegetative growth in high-quality habitats than to reproduction by seeds (Stöcklin and Winkler 2004). Orange hawkweed also reproduces through rhizomes, stolons, and seeds. Studying reproductive resource allocation can provide clues about which habitat types induce orange hawkweed's more invasive vegetative form.

Our research took place in the Little Wolf Fire region, which burned approximately 6,000 ha of Kootenai National Forest in 1994, in successional pine forest dominated by lodgepole pine (*Pinus contorta*). We evaluated orange hawkweed abundance and resource allocation in four land cover types: logged (L), burned (B), burned and salvage logged (BL), and meadows (M). Specifically, we addressed two questions: 1) Does abundance of orange hawkweed vary with disturbance history or ground cover? 2) Does reproductive resource allocation differ between high- and poor-quality habitats, as defined by hawkweed abundance?

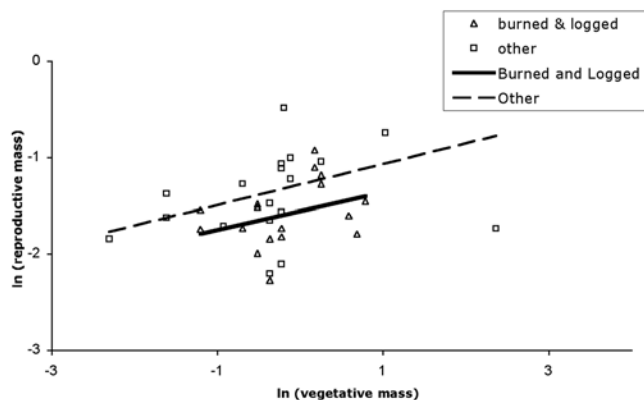


Figure 2. Allometric relationship between natural log of orange hawkweed (*Hieracium aurantiacum*) vegetative and reproductive mass. Comparison is between plants in burned-and-logged sites and the other three site types (meadow, logged, and burned) in the Little Wolf Fire area.

We chose individual sites after visual assessment of land cover type, but without prior knowledge of hawkweed presence. For each of the four land cover types, we selected three noncontiguous study sites 1–5 km apart. Within each site we sampled 50 stratified random plots in a  $5 \times 10$  grid of points regularly spaced every 10 m, with plots offset randomly from each point by 0–5 m. In each of the 1-m<sup>2</sup> plots ( $n = 600$ ), we recorded the presence or absence of hawkweed, collected data on overstory canopy cover using a spherical densiometer, and surveyed ground cover by visually estimating the percentage of thatch, bare ground, rocks, grass, forbs, pine needles, shrubs, dead wood, and moss.

We used discriminant function analysis to test whether plot variables and land cover type were associated with orange hawkweed presence. The only significant association with land cover was a higher probability of orange hawkweed presence in burned and logged (BL) sites ( $p = 0.002$ ). Out of the other three land cover types, less disturbed sites (L and B) showed marginally significantly lower probabilities of hawkweed occurrence relative to meadows ( $0.075 > p > 0.05$ ; Figure 1). Three ground cover variables were significant predictors of orange hawkweed: thatch was negatively associated with presence in a site ( $p = 0.041$ ), while both forbs ( $p < 0.001$ ) and moss ( $p = 0.015$ ) were positively associated.

We compared total mass and resource allocation of plants in BL sites (high-quality sites, as defined by the highest orange hawkweed abundance) to those in the other three land cover types. We collected up to five flowering plants per site, selected randomly from plants encountered in the surveys ( $n = 36$ ; 17 in BL, 11 in M, 4 in L, and 4 in B). Collected plants were washed and air-dried in the lab, then separated into reproductive (flowers and stems) and vegetative (rosettes and roots) biomass. We compared the average total mass and resource allocation among habitat types using ANOVA. In addition, we analyzed vegetative

versus reproductive mass using allometric relationships as indicated by the slopes of resource allocation between BL sites and the other sites.

Total biomass did not differ significantly between BL and the three other habitats (B, L, and M). Vegetative and reproductive biomass had a positive allometric relationship ( $p = 0.055$ ); although larger plants produced more reproductive biomass, less of their total mass was allocated to flowers. Plants in BL sites allocated proportionately fewer resources to seed production, as indicated by a lower intercept in the fecundity-vegetative biomass relationship ( $p = 0.075$ ; Figure 2). Orange hawkweed appears to be genetically uniform within North America (Loomis 2007), so this response suggests phenotypic plasticity. This plasticity seems to be adaptive, with plants allocating more resources to long-distance dispersal in lower-quality environments, and more resources to vegetative spread in higher-quality environments.

Our results indicate that the common perception of orange hawkweed as primarily a roadside and meadow weed of minor importance is flawed. We found that the species is actually most abundant in areas that have been burned and salvage logged—combining the best of low competition, sunlight, and disturbance, indicating that it is important to test habitat associations in new areas. This study also shows that where orange hawkweed is highly abundant, it is most problematic owing to dense mats caused by vegetative spread that may exclude other species. However, in land cover types with lower local abundance, plants produce more wind-borne seeds to spread to new sites. This makes any site where orange hawkweed exists a potential problem.

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## Reducing Grouse Collision Mortality by Marking Fences (Oklahoma)

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A number of grouse species collide frequently with power lines, overhead cables, and fences. Because grouse fly fast these collisions are often immediately fatal, but likely a considerable number of birds either succumb later to injuries or become incapacitated and more vulnerable to predation. A multiyear radio-tracking study of the lesser prairie-chicken (*Tympanuchus pallidicinctus*) in Oklahoma found that collisions, primarily with stock fences, were the leading cause of mortality (Wolfe et al. 2007). Several other species of grouse, including the greater sage-grouse (*Centrocercus urophasianus*) in North America and black grouse (*Tetrao tetrix*) and western capercaillie (*Tetrao urogallus*) in Europe, also suffer high mortality rates because of fence collisions (e.g., Catt et al. 1994). In an effort to reduce this unnatural mortality, we explored various ways of marking fences to improve their visibility. Ideal marking material would be easily affixed, inexpensive, durable, and safe for livestock, and would add little or no weight or wind resistance to fences.

The lesser prairie-chicken has declined markedly in both extent of occupied range and population density. After being petitioned in 1995 under the Endangered Species Act, the U. S. Fish and Wildlife Service (USFWS) determined that protection was “warranted but precluded,” so the lesser prairie-chicken remains only a candidate for listing. In 1999, we began a long-term study of the species in northwestern Oklahoma and eastern New Mexico to determine causal factors of the decline. In the past ten years, we have captured over 900 lesser prairie-chickens on spring and (sometimes) fall leks. We radio-tagged most males and all females, using a bib-mounted, tuned, looped transmitter with a mortality signal that allows early carcass recovery. All radioed birds were tracked at least weekly until transmitter batteries expired (roughly two years) or until the bird died. For each carcass, we attempted to determine the probable cause of mortality using established criteria (Dumke and Pils 1973) and measured distance to the nearest fence, road, and power line (we estimated distances >100 m).



Figure 1. Side view of fence marker cut from vinyl undersill. Photo by Donald H. Wolfe

Fence collisions accounted for over 40% of the mortality (Wolfe et al. 2007). Although some carcasses lay immediately below a fence, the majority resulting from collisions were from several to 30 meters from a fence, suggesting that the bird plummeted or tumbled after impact. Much of the rangeland in northwestern Oklahoma is fenced in 65 ha (1/4 section) pastures, and because county roads usually run along every section line, there is often at least 6 linear miles of fence per square mile (3.8 linear km/km<sup>2</sup>). We concluded that fence marking could be an important conservation tool for this species.

European efforts to mark fences to reduce grouse collision rates met with success, reducing collisions across species by roughly 70% (e.g., Baines and Andrew 2003). However, material used in Europe—strips of barrier (safety) fence—was both expensive and susceptible to deterioration by ultraviolet radiation. Additionally, whereas strips of barrier fence could be attached to woven wire fences, there is no practical way to attach it to barbed-wire stock fences. The vast majority of fences in our focus area are 5-strand, high-tensile, barbed-wire type, with a typical spacing of 3.7 m between fence posts. Summers and Dugan (2001) evaluated different materials used to mark fences, but the most effective are cost prohibitive if used on a large scale. We therefore experimented with a number of materials and methods, including strips of polypropylene webbing attached to fence posts running parallel to fence wires, strips of aluminum flashing suspended from one wire, and pieces of polypropylene rope wrapped from the top wire to the second wire. All of these methods were either too labor intensive, not visible enough to be effective, or not durable.

Other materials and marking methods likely can be utilized, but we eventually hit upon a solution that met our criteria for cost, ease of application, durability, weight,

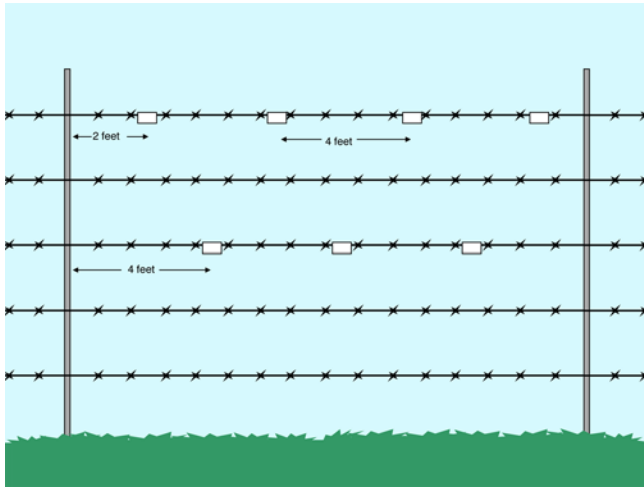


Figure 2. Schematic of suggested fence marker placement.

and visibility. Vinyl siding has become a popular building material for residential structures in the United States. Siding manufactured by Georgia Pacific (and likely other manufacturers) includes “undersill” strips, used for trimming along the bottom edges of houses and around windows and doors. Undersill strips have a molded lip (Figure 1) that can be snapped easily onto a barbed-wire fence. We cut 7.5 cm strips using an abrasive blade on a cut-off or miter saw. For smaller marking efforts, strips can be cut using tin snips.

In an effort to discourage birds from attempting to fly under the top wire, we usually mark both the top and the middle wires. We judged that spacing fence markers about 1.2 m (4 ft) apart renders fences sufficiently visible. Thus, with the typical 3.7-m (12-ft) distance between fence posts, the first marker is placed on the top wire approximately 0.6 m (2 ft) from a fence post, the second 1.2 m (4 ft) from it, and the third marker another 1.2 m away (roughly 0.6 m from the next post). We place two markers on the middle (third) wire, each 1.2 m from a fence post and each other (Figure 2). We deploy approximately 1,250 markers for each linear kilometer (2,000 per linear mile) of fence, although the number of markers can be reduced in low-lying areas or where dense brush or trees obscure the fence. The material costs can vary considerably, depending on suppliers, but generally run about \$130/km. Life expectancy for this application remains unknown, but the material is rated for 20 years in normal applications (construction siding). We have had some markers in place for nearly three years, and no visible wear or deterioration has been observed. It is doubtful that this material would survive fire, but as prescribed fire is extremely rare and wildfires are usually suppressed immediately within lesser prairie-chicken range, we feel that this is of minor concern.

From March 2006 through December 2008, we marked 179 km of fences in portions of four counties in northwestern Oklahoma and two counties in the Texas Panhandle.

Our earliest marking efforts concentrated on areas where documented collisions are frequent. We thereafter expanded our efforts into other areas where lesser prairie-chickens occurred. A major obstacle has been that we work almost exclusively on private land, so we must secure permission from landowners. In many cases two different landowners shared a fencerow, meaning permission from both was necessary, and some landowners proved reluctant to allow us to mark fences. Common reasons were that they did not believe fence collisions to be a major problem for the prairie-chicken, they had concerns over additional strain on fences or that marking fences would identify the presence of prairie-chickens on their land, or they simply felt the markers were unsightly. However, the Natural Resources Conservation Service and USFWS have begun requiring local landowners to mark fences as part of projects that these agencies fund. Moreover, the U.S. Forest Service and Bureau of Land Management have begun marking fences on some of their properties.

We have also removed approximately 57 km of unnecessary fences in the same areas. Without doubt, removing fences would better assure fewer collision, but it is time consuming and costly (approximately \$600/km if outsourced) and would only slightly reduce fence density, since fences are vital to containing livestock.

We have continued to radio-track lesser prairie-chickens throughout the duration of our fence-marking efforts. Along some “high-collision” reaches, we recovered one collision mortality carcass per mile (1.2 km) annually prior to marking fences. After 30 months, we have yet to recover a carcass from a collision along a marked fence. Carcasses continue to accumulate along unmarked fences. We are thus hopeful that our marking efforts will continue to be supported by agencies and landowners because it appears likely that we have a real chance to increase lesser prairie-chicken survivorship and in turn allow dwindling populations to recover in western Oklahoma.

## Acknowledgments

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## Restoration I

9-11-08

*two lovers late restore their love  
in dark enraptured repetition—  
their metaphors of moments past  
offered not in sorrow  
but in joyful resignation.*

O.A.

