Tools for Diversity

Fire, Grazing and Mowing on Tallgrass Prairies

by Coleen Davison and Kelly Kindscher

Two practitioners reflect on the literature and their own experience.

As restorationists working on tallgrass prairie we frequently encounter sites that have been invaded by trees, shrubs, and nonnative herbaceous species (Packard, 1994; Kline, 1987; Holtz and Howell, 1986). Citing the absence of fire and overgrazing by domestic livestock as reasons for the degradation, we often recommend annual spring burns and the exclusion of grazers in the hope that this will increase the diversity of native species and restore other features of the ecosystem.

But as we reintroduce fire to a site, do we fully consider how the timing and frequency of fires and other kinds of disturbance will affect the structure and composition of the community? Although restoration practitioners have adopted frequent dormant season burns as a key component of their strategy for conserving tallgrass prairies, there are good reasons to believe that a more varied burning regime, in combination with grazing—and, in some cases, even mowing—is not only more accurate historically, but would also benefit a wider array of plant species (Howe, 1999; Howe, 1994; Bragg, 1991; Higgins, 1986).

We realize that including grazing in the prescription for the restoration and management of tallgrass prairie is controversial (Williams, 1997; Harrington, 1998; Henderson, 1998). But we suspect that practitioners' qualms about grazing are, in part, culturally conditioned and reflect the experience of restorationists in the northern and eastern parts of the prairie region where grazing by domestic animals is mainly confined to pastures that are usually dominated by cool-season grasses. In Kansas, where we work, projects are generally larger, and use of native grasslands for grazing is common. Possibly for this reason restorationists in this region have more experience with grazing native prairie than their colleagues in Wisconsin, Illinois, and Indiana, and have been less reluctant to include grazing in their projects. In any case, experience in our area makes it clear that grazing most certainly can play an important, even a key, role in restoration of tallgrass prairies under certain conditions.

Although overgrazing can degrade grasslands, it is not grazing itself that reduces species diversity, but the grazing regime imposed by land managers (Williams, 1997; Launchbaugh, 1967; Smith, 1967). As Henry Howe noted in the last issue of this journal (Howe, 1999), tallgrass prairie evolved under the influence of grazing by a multitude of species, including bison, pronghorn, elk and deer, all of which must have influenced its ecology (also see Shaw and Lee, 1995; Haugen and Shult, 1972). At the ecosystem level, then, attempts to re-create the tallgrass prairie must somehow replicate these influences.

Prairie, after all, is no longer viewed as an unchanging community of climax species as ecologists such as John Weaver defined it two generations ago (Weaver, 1954), but rather as a dynamic mosaic of vegetation patches scattered across the landscape (Kindscher and Wells, 1995; Glenn and others, 1990; Loucks and others, 1985). These patches are composed of hundreds of plant species in various combinations, are of various sizes and ages,

Grazing by bison and other large herbivores has been the subject of growing interest on the part of restorationists and ecologists working on the prairies of the central United States and Canada. In this article the authors extend this discussion to consider the role of fire and its interaction with grazing in the dynamics of these ecosystems. *Photo courtesy of the USDA Natural Resources Conservation Service*

and overlap and change through time. The resulting mosaic depends on natural disturbances to maintain its diversity. Climate, soils and topography interact to determine which plant communities develop, but disturbances such as fire, grazing and drought significantly affect those plant communities (Anderson, 1979). Other disturbances such as badger mounds, prairie dog towns, and buffalo wallows also affect plant species composition by disrupting the vegetation and by exposing mineral soil, creating sites suitable for invasion by pioneer species (Collins and Barber, 1985; Bonham and Lerwick, 1976; Platt, 1975; Weaver, 1954).

Since all of these disturbances played a part in the dynamics of prairies in the past, they clearly have a role to play in our efforts to restore and conserve them. In his article, Howe explored the literature that describes the relationship between grazing and species diversity on grasslands in some detail. Here we extend this discussion to consider the role of fire and the interaction between grazing and fire, drawing on our experience and on the published research we have found to be most relevant to our work. Our aim is to summarize this literature from the perspective of our experience, and to consider how restorationists can use this information in their attempts to guide the composition of prairies toward that characteristic of the historic prairies.

Timing of Burns

In the pre-contact era, prairie fires occurred throughout the year, though the frequency of fires apparently varied considerably with the seasons (Bragg, 1982; Moore, 1972; Jackson, 1965). Higgins reported that a majority of fires that were started by lightning occurred in July and August on the northern Great Plains (Higgins, 1986). This is the season when lightning is most common on the northern Great Plains, as in most of the continental United States (Orville, 1991; Westover, 1976; Komarek, 1966). On the other hand, fires started by Indians occurred in spring (March through May, with a peak in April) and late summer and fall (July through November, with a peak in October). A similar pattern seems to have prevailed on the southern Plains, but spring burns were infrequent and the Indians burned most commonly between September and November, with a peak in October (Shaw and Lee, 1995). As a result, the season of anthropogenic burns, motivated primarily by the Indians' resource management considerations, to some extent complemented the season of lightning-caused fire, so that fires occurred during much of the year, though perhaps least frequently in winter and early summer.

The practice of burning the prairies mainly during the spring and fall, when fuel loads and combustibility were highest, continued with the European settlers, as it does today, both in range management and in restoration contexts. Most range managers favor spring burns because they have found that late spring burns improve forage quality resulting in increased weight gains by cattle (Woolfolk and others, 1975; Anderson and others, 1970; Owensby and Anderson, 1967; Smith and others, 1960).

The goals of restorationists, however, are often different from those of livestock producers. A frequently stated objective of prairie conservation is to approximate the burning patterns that existed prior to European settlement. Managers attempting to simulate the historic fire regime consider both summer fires started by lightning and dormant-season fires set by Indians to be "natural." Despite the fact that, historically, fires occurred throughout the year, prairie conservationists often do most or all of their burning in late spring, just as the dominant warm-season grasses begin growth (Henderson, 1997; Solecki and Toney, 1987; Hulbert, 1972).

It is now clear, however, that the way species respond to fire depends heavily on the timing of the fire relative to their phenological development. In general, plants that are actively growing, flowering, or setting seed at the time of the fire, tend to decline over time, either because they are set back phenologically or because they are prevented from setting seed. The species that benefit most from a burn are generally those that are just beginning growth, and so are not set back by the fire and are in a position to take advantage of the growing space cleared by the fire, which gives them an advantage over later-emerging species that have to compete with them.

Over time, then, a burn at any particular point in the phenological cycle of a prairie essentially resonates with species that happen to be commencing growth at that time, favoring them and increasing their dominance at the expense of other species. In fact, researchers at Kansas State University have found that burning at various dates over a period of years did shift floristic composition significantly (Towne and Owensby, 1984). Data collected over a period of 48 years show that plant species responded differently to burns conducted in winter (December 1), early spring (March 20), midspring (April 10) and late spring (May 1). Burning in late spring significantly increased both big bluestem (*Andropogon gerardi*), and Indiangrass (*Sorghastrum nutans*), warm-season dominants that green up late. Kentucky bluegrass, (*Poa pratense*), an exotic cool-season

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perennial that greens up very early, was essentially eliminated by fire, regardless of the burning date, because it was actively growing and susceptible to injury. Most annual grasses in the tallgrass prairie are cool-season, early growing species, and these were also reduced by burning on all dates. Sedges, which also green early, increased with winter and early spring burns, but were essentially eliminated by late spring burns. Perennial forbs responded similarly: burning in late spring significantly reduced many perennial forbs, while burning in winter and early spring favored them. Similarly, research at the Konza Prairie in eastern Kansas has shown that burning in April favors big bluestem and Indiangrass at the expense of most perennial forbs, whereas burning in November and March allows many forbs to increase (Gibson, 1989).

As might be expected, however, the response to fire is complicated and cannot be accounted for by any simple model. This is clear from research on the responses of individual species of forbs. Lovell and his colleagues in Wisconsin found, for example, that both prairie violet (*Viola pedatifida*) and blue-eyed grass (*Sisyrinchium campestre*), both of which emerge early, were set back by late spring burns, but exhibited enhanced flowering and fruit production following fall and early spring fires (Lovell and others, 1983). Behaving similarly, but for different reasons, prairie coneflower (*Ratibida columnifera*), whose growth cycle coincides with that of the dominant grasses, declined under a regime of late spring burns that increased the grasses (Hartnett, 1991). The reason seems to be that the coneflower does not compete well against the grasses. Prairie coneflower's growth cycle coincides with the dominant grasses, and the enhanced growth of the dominant grasses due to the fire may have resulted in a reduction in resources available to other species.

Despite the dominance of the warm-season perennial grasses, tallgrass prairie is composed of several hundred plant species (Knapp and Seastedt, 1986). More than 300 species of vascular plants have been documented in prairie remnants in Iowa (Hill and Platt, 1975), and larger tracts, such as the Konza Prairie and Taberville Prairie in western Missouri, contain more than 400 species (Freeman and Hulbert, 1985; Solecki and Toney, 1987). Since these species exhibit a wide range of life forms, phenologies and ecologies, it seems that the best way to ensure the survival of all of them is to vary the timing of burns, including an element of randomness to reduce the likelihood of encouraging some species at the expense of others. The dormant season and late spring burns that are the mainstay of many prairie restoration and management programs clearly promote the dominance of the large warm-season grasses, squeezing hundreds of other species down to small populations that are vulnerable to local extinction (Howe, 1994). Burns conducted at other times of the year may encourage the growth and reproduction of the early and mid-season flowering species by reducing the dominance of warm-season perennials.

Ewing and Engle (1988) found that burning tallgrass prairie in Oklahoma late in the summer reduced the dominance of warm-season grasses and enhanced the growth of many forbs. Similarly, Biondini and his colleagues found that summer burns in South Dakota resulted in the highest diversity of forbs in the northern mixed prairie (Biondini and others, 1989). Bragg (1991) concurs that it is important to burn at various times throughout the year to maintain the long term diversity of the tallgrass prairie.

Frequency of Burns

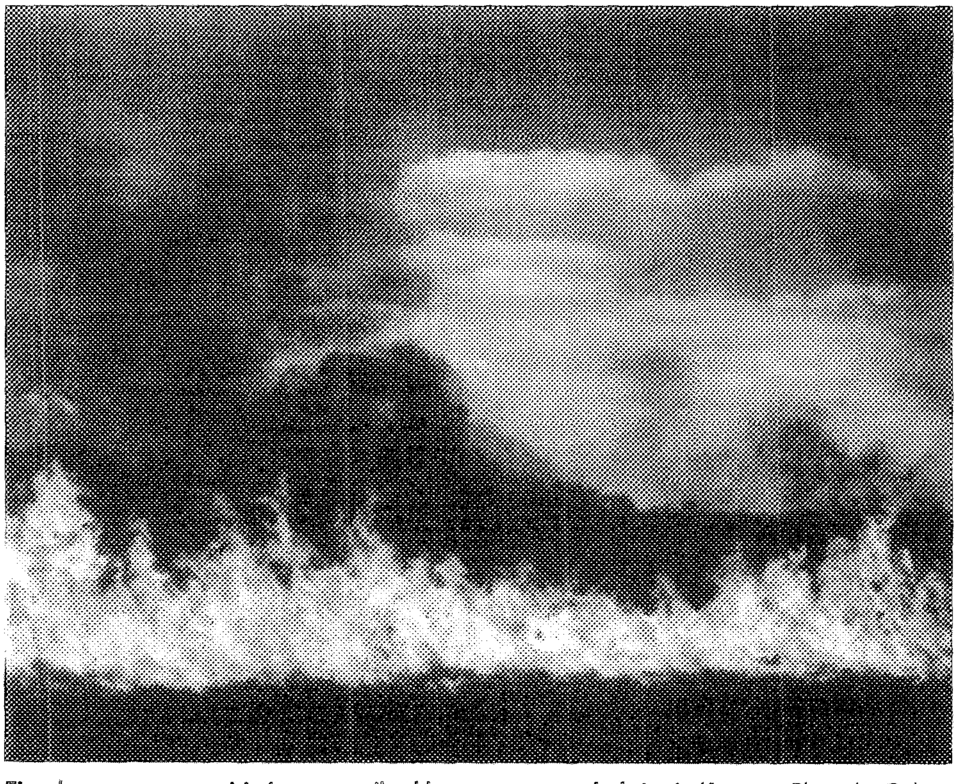
Restorationists can also increase the diversity of plant species by varying the frequency of burns. Researchers at the Konza Prairie in Kansas have shown that burning annually increases the relative dominance of warm-season grasses. Less frequent burning increases plant species diversity by increasing the relative contribution of forbs and cool-season grasses (Knapp and others, 1992). Abrams and his colleagues (1986) reported that the biomass of graminoid species was 40 percent lower and that of forbs was 200 to 300 percent higher in unburned than in annually burned sites. When prairie is left unburned, the proportion of warm-season species declines along with overall grass cover; concomitantly forb and woody species cover increases. Although big bluestem remains the most abundant species, the cool-season grasses increase in abundance as do the forbs, resulting in higher species diversity on unburned sites (Gibson and Hulbert, 1987).

The data from Konza Prairie show that the maximum species diversity occurs six to seven years after a fire, then declines, suggesting that periodic, but infrequent, fires are the best way to maintain maximum species diversity (Knapp and others, 1992). The optimum burn frequency is site-specific, however, and depends heavily on the likelihood of one or a handful of species, native or exotic, assuming dominance. Konza Prairie is a large tract of land, surrounded by tens of thousands of acres of tallgrass prairie, most of which is relatively free of weedy species or woody vegetation. Burning Konza once every six years may be adequate to maintain the grassland. Smaller prairies, on the other hand, or prairies surrounded by woods or areas dominated by weedy or aggressive species may require more frequent burns to prevent invasion. The resulting balancing act can be tricky. Restorationists in our area, for example, commonly recommend burning a site every three to five years after the prairie is well established to maintain grass dominance as well as to maintain the species diversity typical of a native prairie community (Lekwa, 1984; Bragg, 1978; Kucera, 1970). However, researchers at the University of Kansas have found that burning even as often as every third year was not sufficient to control woody species in a fragmented environment (Fitch, 1978).

Fire and Grazing

Although restorationists frequently use fire as a management tool, they rarely include mammalian grazing in the management of remnant prairies (Williams, 1997). We often view grazing, particularly by domestic livestock, as counterproductive to tallgrass prairie conservation (Eddy, 1990). But fire and grazing by large ungulates were both important influences on the structure and function of grasslands in pre-contact times. Their influence, however, is complex because the effects of fire and grazing influence each other in complicated ways.

Tallgrass prairie vegetation is dominated by a few common matrix-forming species, such as big bluestem and Indiangrass, which form the dominant C_4 grass guild (Kindscher and Wells, 1995). These species occupy the majority of space in the community. Numerous interstitial species occur in the spaces between the larger dominants. Different disturbances have different effects on the matrix species, which in turn affect the interstitial species in complex ways (Collins, 1990). Burning, especially frequently and in late spring, reduces the species diversity by increasing matrix dominance. This



Fire dances across prairie in a prescribed burn on a reseeded site in Kansas. *Photo by Coleen Davison and Kelly Kindscher* reduces both the richness and the evenness components of species diversity. In contrast, large ungulates such as bison and cattle generally graze grasses in preference to forbs (Peters, 1997; Plum and Dodd, 1993; Schwartz and Ellis, 1981; Weaver and Tomanek, 1951)), which reduces the dominance of matrix species. As a result, grazing generally enhances species diversity by increasing the space available for interstitial species. Protection from grazing also reduces diversity because of the thick vegetation canopy and heavy litter layer that develops when standing vegetation is not removed. Herbivory of the dominant C_4 grasses can improve species diversity by providing space and habitat for forbs and other species inhibited by grass litter buildup. Grazing reduces both litter accumulation and standing dead vegetation and so reduces the necessity for frequent fires to maintain productivity (Knapp and Seastedt, 1986).

Grazers also affect floristic composition directly by favoring some species over others (Dyksterhuis, 1958; Weaver, 1954). The result is more heterogeneous than the effects of fire because animals graze selectively and use the available area unevenly (Glenn and others, 1992), grazing and often regrazing some areas while leaving other areas ungrazed (Vinton, 1990; McNaughton, 1984). This results in a heterogeneous vegetation, influencing the behavior of fire, which burns ungrazed areas more thoroughly than grazed areas with smaller fuel loads (Steuter, 1986). Since burned areas are more attractive to grazers, however, fire can act almost like a grazing manager, shifting grazing pressure to ungrazed areas, over a period of years, giving grazed areas a chance to recover (Vinton and Hartnett, 1992; Anderson and others, 1970; Duvall and Whitaker, 1964). The result is a dynamic patchwork of grazed unburned and ungrazed burned areas that supports maximum biodiversity at the landscape level (Hamilton, 1996).

Emblem of the prairie, a compass plant (*Silphium laciniatum*) towers above a recently mowed hayfield, pointing out the importance of timing management activities to maximize species' diversity. *Photo by Greg Swarthout*

Collins (1987) studied the effects of both burning and grazing by cattle on the plant species abundance and community structure of a site in Oklahoma. He found that burning stimulated the growth of big bluestem, the dominant grass. Without grazing, many of the forbs that were present were eliminated due to competitive exclusion by big bluestem, resulting in the lowest species diversity on the ungrazed burned sites. In contrast, the highest plant species diversity occurred when grazing was combined with fire. Big bluestem is very palatable to cattle, and on grazed areas the cattle selectively grazed it and reduced its dominance in the stand. This opened up space for less vigorous competitors. The increased diversity is due to the increased survival of forbs as dominance by matrix grasses is reduced by grazing.

In similar studies with bison at Konza Prairie, Vinton and her colleagues (1993) show that bison also graze nonrandomly, generally preferring big bluestem and other tall, warm-season grasses over forbs, and that their use of grazing areas varied with both season and fire regime. Bison preferentially grazed recently burned areas in the spring and summer. During the fall and winter, bison grazed more uniformly regardless of fire history, but grazed more intensively on infrequently burned areas with large stands of cool-season grasses. Vinton suggested that this pattern probably decreases the competitive dominance of big bluestem and other matrix-forming grasses, enhancing the growth and increasing the survival of other species and increasing species diversity.

A number of studies suggest that, for a given site, there is an optimum grazing intensity that will result in maximum species diversity. Below this optimum level, the dominance of some grasses reduces diversity. Above it, grazing reduces diversity by limiting the number of species able to survive to a few, mostly aggressive and unpalatable ones (Milchunas and others, 1988; Naveh and Whittaker, 1979). At intermediate intensities, herbivory increases diversity by decreasing the capacity of the competitive dominants to exclude other species (Archer and others, 1987). Light-to-moderate levels of grazing in the tallgrass prairie usually result in a richer mix of plant species than do either heavy grazing or no grazing at all (Risser and others, 1981). Hartnett and others (1996) document that both plant species diversity and spatial heterogeneity were significantly higher in a tallgrass prairie with moderate grazing by bison than in a comparable ungrazed site.

Implications for Practice

Grazing is obviously impractical for many restoration sites because of their small size. However, carefully managed grazing of even small sites may produce substantial benefits. Although overgrazing can severely damage a prairie over time, so can grazing deprivation. If grazers are reintroduced to a site, grazing intensity must be carefully controlled to protect conservative species (such as perennial *Helianthus* and *Silphium* species). The challenge is to determine a pattern and intensity of grazing that reduces dominance by a few species without eliminating the more conservative species. Scale is often a critical consideration. Large sites allow the restorationist to incorporate different management regimes on various areas in an attempt to mimic the natural patchiness of the historic prairie. These can include complex combinations of grazing, burning and even mowing on various schedules and at varying levels of intensity, and also leaving some areas undisturbed for limited periods to serve as refugia for insects and other grassland fauna. These areas will accumulate large fuel loads and will eventually burn intensely when ignited. Overall, the result is a shifting patchwork of areas in various stages of succession that provides habitat for the full array of native species.

Achieving this is obviously more difficult—and may even be impossible—on smaller sites. Grazing may not be practical on small sites due to the need for fencing, water, and animal-handling facilities. In eastern Kansas, for example, we believe that approximately 40 to 60 acres is the minimum size necessary to allow grazing by large ungulates. This minimum size will vary, however, depending on the climate and on individual site characteristics such as soils, drainage and topography. Although grazing may not be an option for some restoration sites, where it is feasible, land managers should consider grazing as an important management tool for the restoration and conservation of prairies. Where grazing is impossible or impractical, restorationists can increase plant species diversity on small sites by the skillful use of fire. Prescribed burns can be conducted at various times throughout the year. Instead of burning exclusively in the late spring, we can burn in the early spring, in the fall or during the growing season to benefit a wider array of plant species, varying both the timing and the frequency of burns to maintain the full complement of species characteristic of the community.

Fire can act almost like a grazing manager, shifting grazing pressure to ungrazed areas over a period of years, giving grazed areas a chance to recover.

Mowing and haying are also common management practices that land managers can use to affect plant species composition regardless of the size of the site. In many ways, mowing and removing the clippings is similar in its effects to burning, since it both removes vegetative cover and increases surface light intensity (Gibson, 1989). In fact, there is evidence that the effect of mowing in various seasons closely parallels the effects of burning. Thus mowing during the growing season may be an effective alternative to burning on sites where midseason burns are impractical. Again, as with fire and grazing, the key is to be both flexible and attentive to the results, timing the treatment to maximize the benefits to a variety of species.

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