

# The Role of Fire in Managing for Biological Diversity on Native Rangelands of the Northern Great Plains

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**Abstract.**—A strategy for using fire to manage for biological diversity on native rangelands in the Northern Great Plains incorporates an understanding of its past frequency, timing and intensity. Historically, lightning and humans were the major fire setters, and the role of fire varied both in space and time. A burning regime that includes fires at various intervals, seasons and intensities, including midsummer burns, should be reinstated. However, burning to enhance rare systems and species and to discourage exotic species is also needed. The goal is to base plans on an understanding of historic processes and ecosystem interactions, and resist techniques that rely on unexamined conventions.

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## INTRODUCTION

“A common thread runs through the many definitions of biological diversity: variety of life and its processes in a given area” (Salwasser 1990). A management strategy for conserving biological diversity of any natural ecosystem must focus on saving all the components, including the structure, composition (including genetic diversity), and processes that characterize these systems (Kaufmann et al. 1994). Biological diversity is more than just the identifiable parts; it also includes the symbioses and synergisms that make nature work (Salwasser 1990).

The importance of disturbances in shaping native communities has recently received more attention. Ecosystems are dynamic entities whose patterns and processes are shaped and sustained on the landscape by successional processes and by abiotic disturbances such as fire, drought, and wind. To sustain these ecosystems, processes that characterize the variability found in native ecosystems should be present and

functioning, and management activities should conserve or restore historic disturbance patterns (Kaufmann et al. 1994). This paper describes a strategy for managing biological diversity of rangelands on the Northern Great Plains. The approach is based on restoring historical disturbance processes given the significantly altered landscape patterns of today. Plant nomenclature follows Great Plains Flora Association (1986) (table 1).

## SETTING

The Northern Great Plains region includes North Dakota, South Dakota and Nebraska, plus the eastern portions of Montana and Wyoming, and extends northward into Manitoba, Saskatchewan and Alberta. The climate of the region is characterized by an increase in precipitation and humidity and a decrease in periodic droughts during the summer from west to east (Risser 1990). This climate range influences not only the potential native vegetation but also the fire regime and effects. The shortgrass prairie on the Western and Southern portions of the region is the most arid type; the mixed-grass prairie occurs in the midsection of the region; and the tallgrass prairie on the Eastern edge receives the most precipitation (Risser et al. 1981).

The variation in precipitation across the region greatly influences the growth and expansion of woody plants. In the most Western portion of the region, big sagebrush occupies uplands; in the absence of fire it persists or expands (Wright and Bailey 1982). In the remainder of the shortgrass and mixed-grass portions of the region, woody plants are restricted to areas of increased elevation, such as the Black Hills, or to areas of increased moisture such as riparian zones, draws, and north-facing slopes. Escarpments, ridges, and outcrops in the Western portion support rosa pine and Rocky Mountain juniper (Wells 1965).

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**Table 1. Common and scientific names used in this report.  
Nomenclature follows GreatPlains Flora Association (1986).**

Common name	Scientific name
<b>Graminoids</b>	
big bluestem	<i>Andropogon gerardii</i>
smooth brome	<i>Bromus inermis</i>
cheatgrass	<i>Bromus tectorum</i>
Japanese brome	<i>Bromus japonicus</i>
buffalo grass	<i>Buchloe dactyloides</i>
threadleaf sedge	<i>Carex filifolia</i>
sand dropseed	<i>Sporobolus cryptandrus</i>
green needlegrass	<i>Stipa viridula</i>
<b>Forbs</b>	
leafy spurge	<i>Euphorbia esula</i>
western prairie fringed orchid	<i>Platanthera praeclara</i>
<b>Shrubs and trees</b>	
sagebrush	<i>Artemisia</i> spp.
dwarf sagebrush	<i>Artemisia cana</i>
big sagebrush	<i>Artemisia tridentata</i>
green ash	<i>Fraxinus pennsylvanica</i>
Rocky Mountain juniper	<i>Juniperus scopulorum</i>
Eastern red cedar	<i>Juniperus virginianus</i>
cactus	<i>Opuntia</i> spp.
ponderosa pine	<i>Pinus ponderosa</i>
plains cottonwood	<i>Populus deltoides</i>
aspen	<i>Populus tremuloides</i>
chokecherry	<i>Prunus virginiana</i>
bur oak	<i>Quercus macrocarpa</i>
willows	<i>Salix</i> spp.
snowberry	<i>Symphoricarpos occidentalis</i>

Woody draws (narrow woodlands occurring in ravines) are examples of communities in more arid portions of the region that are restricted to sites with greater soil moisture. The most common woody plants in these draws are green ash and chokecherry. Riparian zones along streams and rivers support plains cottonwood, willows, and dwarf sagebrush (Severson and Boldt 1978). These woodlands may also expand in the absence of fire, but the expansion is restricted to sites with adequate moisture and the expansion rate is slower than in the tallgrass region. Further, many deciduous species, such as chokecherry and willows, sprout vigorously following burning (Wright and Bailey 1982). Only very frequent fires (i.e., every 1 to 5 years) would favor grasses over these species.

In contrast to more arid portions of the region, mesic prairies in the Northern, Eastern and South-eastern portions of the region are characterized by precipitation amounts high enough to support the expansion of woody plants onto uplands. It is in these areas that frequent fires slow the expansion of woody plants on uplands (Bragg and Hulbert 1976). In the

Northern portion of the region, aspen replaces ponderosa pine on outcrops and expands into the Canadian prairies (Wright and Bailey 1982). Eastern red cedar replaces Rocky Mountain juniper in the South-eastern part of the region where it readily expands onto uplands (Gehring and Bragg 1992). In the eastern tallgrass prairies, woody species, such as willows and bur oak, invade grasslands, and only frequent fires slow their expansion (Anderson 1990). Plains cottonwood and willow dominate floodplains in the more mesic portions of the Northern Great Plains; green ash and bur oak are common on higher terraces along major rivers (Johnson et al. 1976).

In addition to climatic factors, herbivores also influence the region's vegetation and fire regimes. However, it is difficult to distinguish the particular influence each force has on vegetation (Henderson and Statz 1995). Fire is often associated with periodic drought, and fire and grazing are sometimes interrelated. For example, recently burned grasslands often attract grazers; yet, heavily grazed areas usually resist fire until dead litter reaccumulates (Steuter et al. 1990, Vinton et al. 1993). Therefore, the influences of grazing and drought must be a part of a discussion of historical fire effects (Henderson and Statz 1995).

## FIRE HISTORY

An understanding of the frequency, timing, and intensities of past fires is necessary before fire can be incorporated into a strategy to conserve prairie systems. Based on data from adjoining ponderosa pine forests, which indicated that fire frequency varied from 2 to 25 years, Wright and Bailey (1982) estimate that on level-to-rolling topography, a fire frequency of 5 to 10 years in the Northern Great Plains is reasonable. On topography more dissected with breaks and rivers, they estimate a fire frequency of 20 to 30 years. Wendtland and Dodd (1992) agree with this range, based on their examination of historical documents and fire records from the Scotts Bluff National Monument area in northwestern Nebraska. Dendrochronology data in the Devils Tower region northwest of the Black Hills reveal that before 1770 the mean interval between fires was 27 years; from 1770 to the fire return interval was 14 years (Fisher et al. 1987). Brown and Sieg (1996) report a mean fire frequency in the south-central Black Hills of 16 years for the period 1388 to 1918.

In the more mesic portions of the Northern Great Plains, the average fire return interval was shorter. Collins and Gibson (1990) estimate a frequency of every 1 to 5 years in the tallgrass portions of this region. In northcentral Nebraska, the fire return interval averaged 3.5 years between 1851 and 1900 (Bragg 1985).

Historically, the major ignition sources for prairie fires were lightning and American Indians. Lightning was, and is, an important ignition source in the Northern Great Plains. In northwestern South Dakota, lightning-set fires occur an average of 6 to 25 times per year, and most commonly occur in July and August (Higgins 1984); fewer occur in April, May, June, and September. Wendtland and Dodd (1992) note that of 10 fires described in historical documents between 1824 and 1934, and of 26 fires officially recorded between 1934 and 1969 in the Scotts Bluff National Monument area, over 70 percent occurred in July and August.

Higgins' (1986) review of 300 historical accounts written between 1673 and 1920 reveals that fires accidentally or intentionally set by American Indians were common in the Northern Great Plains. He found that although Indians set fires in nearly every month of the year, April, September and October were their peak fire-setting times. The majority of the 97 fires described were scattered, single events of short duration and small extent; only 10 fires burned longer than 1 day.

American Indians had many uses for fire. These included attracting and herding wild animals, signaling threats and warnings, improving pasturage masking and eliminating personal signs at camps and along trails, and for pleasure, warfare and ceremonies (Higgins 1986). During their 10,000-year occupation of this region, the timing of fires set by American Indians did not mirror lightning-set fires; therefore, these Indian-set fires can be considered additive to lightning fires (Higgins 1986).

A combination of periodic droughts, high temperatures and strong winds in the region provide the components necessary for fire spread (Collins 1990). The end result of the erratic climate, flammable fuels, topographic relief and other factors, such as grazing animals, was that the role of fire was not constant in time or space (Anderson 1990).

With the arrival of non-native settlers came fire suppression policies and, in many areas, a shift in the timing of fires. Near Devils Tower, Wyoming, after

1900, the fire return interval increased to every 42 years, versus less than every 27 years previously (Fisher et al. 1987). In the south-central Black Hills, Brown and Sieg (1996) record a 104-year fire-free period in ponderosa pine stands between 1890 and 1994, and note that most of past fire occurred late in the growing season or after growth had ceased for the year. Higgins (1984) suggests that the recent extent and spread of lightning fires has been modified by cultural features such as roads; further, the fire regime has also been altered by differing patterns of grazing animals (first bison, then cattle). In contrast to the late summer ignitions that commonly burned before 1935 near Scotts Bluff, Nebraska, the 46 fires recorded since 1935 dramatically shifted to spring occurrences (Wendtland and Dodd 1992). Lengthening the interval between fires, shifting from summer to early spring burning, and/or reducing fire intensity by prescribing cooler fires may alter species composition to favor fire-intolerant species (Wendtland and Dodd 1992) such as cactus and non-sprouting woody species like sagebrush (Wright and Bailey 1982).

## **DEVELOPING A FIRE MANAGEMENT STRATEGY TO CONSERVE DIVERSITY**

The fire strategy most likely to manage diversity on native rangelands of the Northern Great Plains is based on two premises: 1) processes that mimic, as much as possible, the variability found in native ecosystems should be present and functioning; and 2) management activities should conserve or restore historical disturbance patterns (Kaufmann et al. 1994). This management strategy should reflect the differing roles that fire historically played in the various portions of the region. However, this strategy must also address the fundamental changes that have occurred in the landscape such as drastically different landscape patterns imposed by species changes and management unit boundaries.

Wendtland and Dodd (1992) recommend a scenario that mimics the presettlement fire history. For the Scotts Bluff, Nebraska area, they infer this strategy including high intensity summer fires on a return interval of 5 to 30 years. Shifting burning programs from all spring or fall burns to include some mid-summer burns should favor some species not enhanced by spring or fall burns (Howe 1994). For

example, an April fire burns early foliage critical for root production of cool-season plants, leaving late-season plants unscathed; an August fire burns the largely inactive foliage of cool-season species, while consuming foliage and reproductive stems of warm-season species (Howe 1994). However, historically, fires occurring after fuels have cured in the fall or in the early spring before green-up may have been more significant than summer fires. High fuel moisture in July and August and concurrent slow rates of spread result in a smaller area being burned by an individual fire, compared to those fires occurring when fuels are cured in the fall (Steuter 1988). Given the highly variable fire regime in the past, burns of varying intensities at differing seasons are appropriate. Further, the interval between fires should be varied to best restore fire disturbance patterns of the Northern Great Plains. The strategy should avoid a uniformity in timing of burns or in intervals between burns that artificially simplifies what was probably a more complex system (Howe 1994).

### **SPECIAL HABITATS AND SENSITIVE SPECIES**

Reinstituting a fire regime based on historical processes that includes burning at varying intervals and in differing seasons is the first step in developing a strategy for using fire to manage biological diversity on native rangelands in this region. The second step involves assessing the direct and indirect impacts of fire on special habitats and sensitive species. Special habitats are native biological communities or ecosystems that are rare, unique, or highly productive elements of regional landscapes (Salwasser 1990). Sensitive species include those native species currently in danger of extinction or those whose population trends are negatively affected by human actions (Salwasser 1990). The burning strategy should also consider the potentially different historical fire disturbance regimes in these sensitive ecosystems, minimize potential negative influences of fire, and maximize conditions favorable to the expansion of these systems and species.

The special habitats in the Northern Great Plains (wetlands, lowlands, and riparian areas) contain high numbers of listed vulnerable species (Finch 1992, Finch and Ruggiero 1993). Although each of these habitats constitutes a relatively small percentage of the total land area, each contributes disproportion-

ately to the diversity of native rangelands in this region (Finch and Ruggiero 1993). If sensitive communities such as these occur within a management unit, burning programs should be examined relative to their impacts on these habitats. The range in frequency, timing, and intensity of burns suitable to upland habitats may not provide optimum conditions for sustaining these distinctive systems.

Wetlands, lowlands, and riparian woodlands in this region are examples of communities that, because of higher moisture, likely burned less frequently than uplands. Riparian zones throughout the region, and woody draws in the more arid portions, tend to be green throughout most of the growing season, have higher relative humidities than adjacent grasslands, and often have running water or moist soils that slow the spread of fire into these communities. In most years, prairie fires would skip over or only burn lightly through these narrow woodlands (Severson and Boldt 1978). However, the narrow configuration and close contact of these woodlands with flammable grassland fuels suggest that historically they were exposed to a high number of grassland fires. Fire inevitably entered these woodlands, especially in dry years on hot and windy days.

Given that the species composition in woody draws includes a number of deciduous species, such as snowberry and chokecherry, that sprout following burning (Wright and Bailey 1982), and that several woody species establish best in mineral soils, fire probably functioned as a regeneration mechanism in these systems. Further, since these communities stay green longer than uplands, fires probably burned late in the growing season when there were adequate levels of cured, fine fuel. Repeated, annual fires, especially during droughts, tend to favor the growth of grasses over woody plants (Wright and Bailey 1982). Fires occurring infrequently when plants dormant, followed by high precipitation, may enhance woody plant growth (Wright and Bailey 1982, Sieg 1991). If the goal is to regenerate woody plants in woody draws and/or to mimic historical fires, prescriptions should be set to achieve high intensities (Sieg 1996).

Rocky Mountain juniper woodlands are an example of a relatively uncommon community in the Western portion of the Northern Great Plains that rarely burned. In this region, Rocky Mountain juniper grows best on steep barren slopes (Noble 1990) where the sparse understory vegetation is rarely

adequate to sustain a fire. In areas where fine fuels are sufficient to carry a fire, the high volatile oil content of the foliage combined with Rocky Mountain juniper's inability to sprout following topkilling, results in high mortality rates (Wright and Bailey 1982).

Threatened or endangered species are examples of sensitive species whose needs cannot be ignored. Because they are the first species to drop out of ecosystems, they are considered the weakest link in the conservation of native biological diversity (Finch and Ruggiero 1993). Providing habitats in an appropriate spatial and temporal arrangement is necessary to maintain viable populations of sensitive species. Thus, vegetation management is a major tool for maintaining and restoring biodiversity, and for delisting or avoiding listing of threatened and endangered species (Kaufmann et al. 1994).

Adjusting fire management programs to meet the needs of threatened and endangered species requires an understanding of the role of fire in the long-term sustainability of the ecosystems supporting these species, and in the life history and habitat needs of individual species. For example, the western prairie fringed orchid is a federally listed threatened plant species associated with swales (low-lying often wet land) of the tallgrass prairie (U.S. Fish and Wildlife Service 1989). Although the tallgrass prairie is prone to burn every 1 to 5 years (Collins and Gibson 1990), it is unlikely that swales supporting orchids burned as often, especially during years when they were flooded. Vogl(1969) describes a "quasi-equilibrium" of a Wisconsin lowland maintained by floods during wet periods and fires during droughts. Lowlands supporting orchid populations likely burned throughout the growing season during prolonged droughts; however, fires that occur when orchids are actively growing are apt to injure or kill them. Since fall burning allows orchids to complete their life cycle, and dry conditions and lightning are inclined to occur late in the growing season, fall fires are a better choice than spring burning to sustain orchid populations and their associated habitat (Bjugstad-Porter 1993).

## MANAGE INTRODUCED SPECIES

The introduction of exotic species to new environments without their associated parasites and pests may be humankind's greatest environmental manipulation (Young and Evans 1976). Many invasive

exotic species have characteristics that enable them to vigorously compete with native plants and to exploit disturbed areas (Parker et al. 1993). In addition to reviewing impacts of existing non-native species and preventing the introduction of new ones (Kaufmann et al. 1994), management plans should address how to manage these species; fire is a useful tool in this arena. Problem species include those purposely planted, such as smooth brome, and a variety of species accidentally introduced, such as cheatgrass, Japanese brome, and leafy spurge (Lym 1991).

Although burning is not a panacea for discouraging introduced species, with careful planning it can be a useful tool, especially if native species are not adversely affected. Burning at a time when plants are most vulnerable is useful for suppressing undesirable species. For example, burning in mid-or late May, when smooth brome tillers are either elongating or heading, reduces tiller density of smooth brome by 50 percent when compared to unburned plots in Nebraska (Willson 1992). Burning in May also enhances production of flowering culms of some native warm-season grasses such as big bluestem (Willson 1992). However, burning is not a cure-all for reducing persistent species such as smooth brome, and the outcome is strongly dependent on other factors such as climate and precipitation patterns. Subsequent burning in Pipestone, Minnesota failed to significantly reduce smooth tiller density (Willson and Stubbendieck 1996).

In addition to killing or injuring individual exotic plants, burning can be used to make the habitat less conducive to a species expansion. Spring burning in western South Dakota killed Japanese brome seedlings for one growing season, and by reducing litter accumulations, decreased future germination rates (Whisenant and Uresk 1990). In this case, spring burning was detrimental to the production of one native species, green needlegrass; enhanced production of two others, buffalo grass and sand dropseed; and did not change the production of a fourth, threadleaf sedge (Whisenant and Uresk 1990).

A combination of burning and other management tools may be valuable in managing invasive species. For example, picloram plus 2,4-D applied in the fall followed by spring burning reduced the stem density and germination rates of leafy spurge in North Dakota more than any other treatment tested (Wolters et al. 1994). The key to success in managing invasive species is to begin treatment before

sive spread occurs and to focus as much as possible on the invaded ecosystem rather than on the invader (Hobbs and Humphries 1995).

## SUMMARY

A strategy for using fire to manage native biological diversity on rangelands in the Northern Great Plains should consider natural disturbance patterns. Fires historically occurred as often as every 1 to 5 years in the more mesic portions of the region, but less frequently in areas of rough topography and in lowlands. Lightning, a major ignition source in this region, caused fires most often in July and August. American Indians accidentally or intentionally set fires in nearly every month of the year; however, the greatest number were set in April, September, and October. The end result of the erratic climate, fuels, topographic relief and factors such as grazing animals, was that the role of fire was not constant in time or space.

Reinstituting a fire regime based on historical processes, including burning at varying intervals (to reflect climatic patterns) and in differing seasons, is the first step in developing a strategy for using fire to manage for biological diversity on native rangelands in this region. Including mid-summer burns, rather than concentrating all prescribed burning in the spring and fall, would better mimic natural disturbance patterns. The second step involves adjusting fire regimes to best sustain special habitats, such as wetlands and riparian zones, and sensitive species, especially threatened and endangered ones. Third, fire prescriptions should be planned so that burning does not enhance the spread of invasive species. The overall goal is to base the fire management strategy on an understanding of historic processes and ecosystem interactions, and resist techniques that rely on unexamined conventions (Howe 1994).

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