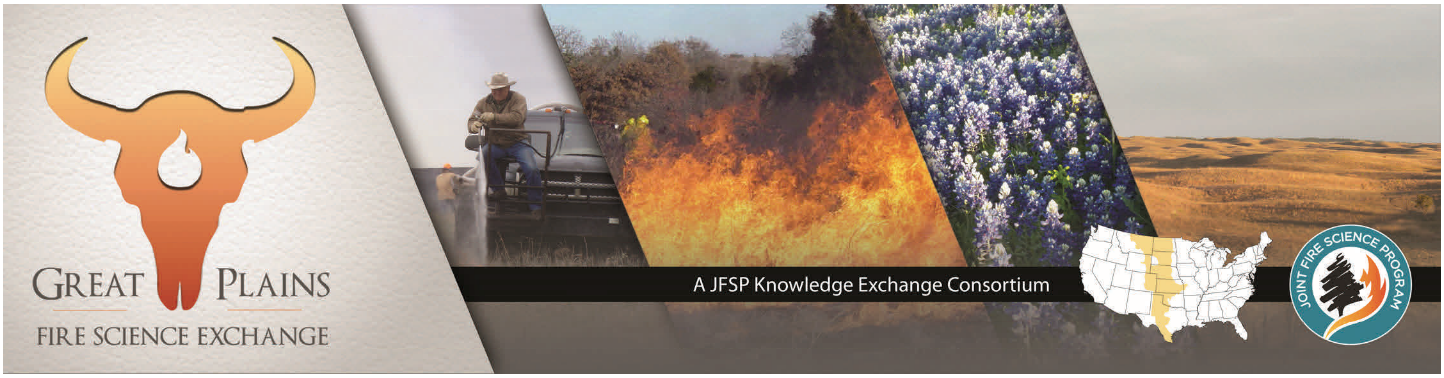

GPE publication 2015-1

Fire in the Northern Great Plains of North America

by Tom Bragg[1]

Spring burning in cool-season-grass-dominated prairies of the Northern Great Plains can be an effective land management option. The long-term benefits to plants and animals, however, come with a short-time generation of smoke columns often visible for great distances.

Author's affiliation:

[1] Department of Biology, University of Nebraska at Omaha, Omaha, NE 68182-0040 (tbragg@unomaha.edu).

INTENT

The following review is intended to summarize available literature in order to provide a state-of-the-art understanding of the effects of fire in the Northern Great Plains of North America. There are gaps in our knowledge so, where reasonable, fire effects are inferred from studies in other ecoregions. In addition, since no landscape is homogeneous, local conditions may elicit different responses by plants and animals to fire. This summary provides a starting place from which to make management decisions. However, monitoring is needed to ensure that management objectives are being met when using prescribed fire or when interpreting the response of biota to wildfire. Thanks to Dan Hoffmann who lay some of the groundwork for this review in a special topics course. Scientific nomenclature of plants follows Flora of North America (1993+). Constructive comments, additions to the literature, and any updates are encouraged by e-mailing tbragg@unomaha.edu.

THE NORTHERN GREAT PLAINS

The Northern Great Plains, as defined for this review, extends northwestward from northcentral Nebraska (exclusive of the Nebraska Sand Hills Prairie) through eastern Wyoming and western South Dakota, eastern Montana and western North Dakota and into southeastern Alberta and southwestern Saskatchewan (Fig. 1). Covering approximately 94 million acres (38 million hectares), the region incorporates short, mixed, and tallgrass prairie types, specifically including the wheatgrass-bluestem-needlegrass (*Agropyron-Andropogon-Stipa*) and the wheatgrass-needlegrass (*Agropyron-Stipa*) associations of Küchler (1985). These grasslands occur primarily on loamy glacial tills and clay to clay-loam soils.

Within the region, cool-season, C3 grasses dominate in the north but are increasingly replaced by warm-season, C4 species towards the south. Associations of taller plant species are often limited to lower slopes but transition to mid-height and then to shorter species associations on the dry hilltops (Barnes et al. 1983). Western wheatgrass (*Pascopyrum smithii*) is the common denominator species of the Northern Great Plains, even though it is not always a dominant (Gartner et al. 1986). Other common grasses include blue grama (*Bouteloua gracilis*), needle-and-thread (*Hesperostipa comata*), green needlegrass (*Nassella viridula*) and porcupine grass (*Hesperostipa spartea*). Forb productivity ranges from 0-40 percent of total net primary production (Handley 1969, Lura et al. 1988) but may vary considerably depending on grazing intensity (Whitman 1974). Several woody species, including western snowberry (*Symphoricarpos occidentalis*), fringed sagebrush (*Artemisia frigida*), eastern redcedar (*Juniperus virginiana*), and quaking aspen (*Populus tremuloides*) are among woody species that have replaced herbaceous species in some portions of the region, with quaking aspen the greatest concern towards the north and eastern redcedar the greatest concern towards the south (Wright and Bailey 1982, Kaul and Rolfsmeier 1993, Romo et al. 1993, Grant et al. 2004, Grant and Murphy 2005). Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*), both cool-season exotics, have increased since the 1970's, even with burning (Kirsch and Kruse 1973, Murphy and Grant 2005, DeKeyser et al. 2013) resulting in the loss of plant and animal diversity. This loss, however, is not the only consequence of the invasion of these introduced grasses. Nutrient pools, energy flow, soil invertebrate and mycorrhizal relationships, and the water cycle also can be altered significantly (Seastedt 1985, Bragg and Steuter 1996, Christian and Wilson 1999, Wilson 2002, Neary et al. 2005).

Fig. 1. The Northern Great Plains Ecoregion, one perspective (Forrest et al. 2004).

FIRE EFFECTS ON VEGETATION OF THE NORTHERN GREAT PLAINS

General: Historically, fires occurred frequently in the Northern Great Plains (Higgins 1984, 1986) with the number of years between fires ranging from 4-6 years in the south to greater than 20 years towards the north (Frost 1998, Guyette et al. 2011). Resident plants and animals are variously adapted to persist with fire, although responses differ considerably across the region as affected by local variables such as weather, topography, and species composition (Singh et al. 1983). Fire suppression results in accumulation of mulch which favors cool-season exotic species (Ode et al. 1980, Whisenant 1990) and most likely accounts for the active invasion of woody plants in the southern portion of the Northern Great Plains (Kaul and Rolfsmeier 1993, Grant and Murphy 2005).

In general, fire reduces standing crop (i.e annual production) of both cool-season and warm-season species on dry upland Northern Great Plains sites (e.g. Whisenant and Uresk 1989, Pylypec and Romo 2003), although standing crop for some species, such as threadleaf sedge (*Carex filifolia*), has been reported to increase on some sites after burning in wet years (e.g. Engle and Bultsma 1984). Recovery from fire to pre-burn productivity may take 1-3 years but fire may improve herbage quality (Willms et al.1980), decrease litter (Willms et al. 1986 and 1993), and increase bare ground allowing more light to penetrate the canopy during the growing season (Dix 1960), which in combination could enhance seedling success and early plant growth. The inability of fire to reduce western snowberry (*Symphoricarpos occidentalis*), however, suggests that fire alone is not a likely means of woody plant control for native resprouting species (Romo et al. 1993). Overall, reductions in net production and in individual species' primary production caused by fire vary depending on a number of site-specific and time-specific variables including: 1) lower plant and soil water potentials on burned sites (DeJong and MacDonald 1975), 2) weather conditions and the attraction of grazers to recently burned areas (Gartner et al. 1986), 3) differences in site productivity (Dix 1960, DeJong and MacDonald 1975, Whisenant and Uresk 1990), 4) the presence of significant amounts of native warm-season species (Schacht and Stubbendieck 1985), 5) topographic location, and 6) season of occurrence. In addition, studies in other grasslands observed bunch grasses to be more susceptible to fire damage than rhizomatous grasses (e.g. Pfeiffer and Steuter 1994, Engle et al. 1998), thus species composition may also affect the response of Northern Great Plains grasslands to fire.

Season of Burn: Plant responses that differ depending on the season in which fires occur have been widely reported (Dix 1960, Coupland 1973, Schacht and Stubbendieck 1985, Gartner et al. 1986, Steuter 1987, Biondini et al. 1989, Whisenant and Uresk 1990, Redmann et al. 1993) including some indicating different effects when fire is followed by drought (e.g. Engle and Bultsma 1984). In general, spring fires in the Northern Great Plains (i.e. those occurring early in the growing season) decrease overall yields, although they may improve range condition with increased yields of western wheatgrass, needle-and-thread, and blue grama and decreased yields for Kentucky bluegrass and green needlegrass (Gartner et al. 1986, White and Currie 1983, Engle and Bultsma 1984, Steuter 1987, Pylypec and Romo 2003). White and Currie (1983) also reported that, while fire reduced plant yield, the reduction was less with spring burning than with fall burning. Spring burns also were shown to shift production more towards warm-season species than summer and fall burns (Steuter 1987). Regarding the forb component of the Northern Great Plains, Biondini et al. (1989) reported that differences in composition were not drastic among burns conducted in the spring, summer, fall, or unburned treatments, although plant responses in unburned and spring treatments were more similar to each other than summer and fall burn treatments, which were more self-similar. Forb density was highest with fall and spring burns.

Research to date on summer fires suggests they reduce productivity in dry sites of the Northern Great Plains (Dix 1960, Erichsen-Arychuk et al. 2002), although on wetter, more mesic sites, they do not substantively affect productivity. Where conditions are more mesic, summer fires increase both the relative importance of cool-season plant production and the relative contribution to cool-season species through reduction of warm-season grasses (Steuter 1987). Vermeire et al. (2011) observed similar results with an August burn in which productivity was not affected but where species composition was shifted to one dominated by native, cool-season perennial grasses with a concomitant decline in non-native annual grasses. Needle-and-thread grass and threadleaf sedge were among cool-season species that were resilient, declining the first year after the summer burn but recovering to pre-burn productivity the second year. Perennial warm-season grasses were generally unaffected by summer fire.

Fire and Invasive Plants: Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*), both cool-season exotics, have increased since the mid-1900's in the Northern Great Plains (Kirsch and Kruse 1972, Murphy and Grant 2005, Travnicek et al. 2005). DeKeyser et al. (2013) reported a similar invasion but found that, while both grazed and ungrazed areas maintained a high cover of Kentucky bluegrass, smooth brome cover was significantly lower in areas grazed by cattle than in those not grazed. Fire, however, has been shown to reduce the non-native invasive Kentucky bluegrass (Murphy and Grant 2005), although it also reduced the native, invasive purple threeawn (*Aristida purpurea*) (Russell et al. 2013). Summer fires, however, had a greater impact on purple threeawn than did fall fires (Strong et al. 2013). Steuter (1987) also reported a significant reduction in Kentucky bluegrass following dormant fall fires, although fall burning maintained or increased the native cool-season grass component. In contrast to these studies, whether occurring in the spring or the fall, fire has been unsuccessful in controlling smooth brome, one of the principal invasive grass of the Northern Great Plains, (Kirsch and Kruse 1972, Grilz and Romo 1994, Sieg 1996, Murphy and Grant 2005, DeKeyser et al. 2013).

FIRE EFFECTS ON FAUNA OF THE NORTHERN GREAT PLAINS

Birds: Bird species of the Northern Great Plains, as elsewhere, respond individualistically to fire. In the Northern Great Plains, passerine (a.k.a. perching) bird species reported to decrease in numbers immediately following a fire include sedge wren (*Cistothorus platensis*), clay-colored sparrow (*Spizella pallida*), Le Conte's sparrow (*Ammodramus leconteii*), Savannah sparrow (*Passerculus sandwicensis*), bobolinks (*Dolichonys oryzivorus*), Lark Sparrow (*Chondestes grammacus*), Grasshopper Sparrow (*Ammodramus savannarum*), and Western Meadowlark (*Sturnella neglecta*), although most recovered to pre-burn levels within 2-3 years (Tester and Marshall 1961, Forde et al. 1984, Grant et al. 2010). Other passerine species that recover quickly or increase following fire include cowbirds (*Molothrus* spp), Baird's Sparrow (*Ammodramus bairdii*), and Sprague's Pipit (*Anthus spragueii*) (Madden et al.1999, Danley et al. 2004). These results suggest that, in general, fire benefits passerine birds, for example by increasing both the amount and diversity of food as standing dead and litter is removed exposing seeds (Higgins et al. 1989). The effect of fire on non-passerine birds in the Northern Great Plains, which includes upland game birds, was not found to be widely reported in the literature but Kirsch and Kruse (1973) believe enough basic information is known to be able to use fire as an effective management tool. For example, fire size can be critical as demonstrated by a modeling study of a sagebrush plant community in Idaho in which frequent, large fires had the potential to threaten local extinction of populations of sage grouse (Pedersen et al. 2003). Similarly, the prevalence of annual burning across large portions of the Kansas Flint Hills is causing significant declines in Greater Prairie Chicken (*Tympanuchus cupido pinnatus)* (Svedarsky et al. 2000).

Overall, fire is important for maintaining prairie habitat since grassland birds appear to be well adapted to periodic fires that approximate those of the historic prairie (Murphy 2008). Thus, land managers in the Northern Great Plains should not be overly concerned about fire's effect on bird abundance, which is generally limited to the year or two after burning (Grant et al. 2010). A greater concern is the absence of fire, which has other more deleterious consequences. For example, decades of fire prevention to manage for duck nesting habitat in the Drift Prairie of North Dakota resulted in dominance by Kentucky bluegrass and smooth brome and a decline in populations of grassland dependent birds (Murphy and Grant 2005). Only 3-4 species of breeding grassland passerines persisted while at least six other grassland dependent species of passerines declined or were no longer found (Madden et al. 1999, Murphy and Sondreal 2003). Declining species included the endemic Sprague's pipit (*Anthus spragueii*), which is associated with native bunch grasses and avoids broad-leaved, introduced grasses, such as smooth brome (Wilson and Belcher 1989, Madden et al. 1999).

Mammals: Published studies on the effect of fire on small mammals specifically in the Northern Great Plains appear to be limited, although studies elsewhere suggest likely effects (Higgens et al. 1989). In general, studies on small mammals and fire in other grassland-dominated ecosystems suggest that their response is more a reaction to fire-altered habitat than it is to direct mortality during burning. Most small mammals readily find shelter from fire underground in burrows (e.g. Lawrence 1966, Quinn 1979, Geluso and Bragg 1986). From 2-4 years after burning, primary production gradually declines while litter gradually accumulates. This creates a dynamic change in habitat and food sources over time resulting in shifts in small mammal species composition and density since small mammals respond individualistically to the fire regime (Dix 1960, Vogl 1965, McGee 1982, Smith 2000). For example, across a broad range of post-burn habitats, a variety of studies show significantly higher populations of deer mice (*Peromyscus maniculatus*) in recently burned areas than in unburned areas (Cook 1959, Tester 1965, Beck and Vogl 1972, McGee 1976, Kaufman et al. 1983). Deer mice remain the dominant species for 2-4 years until the accumulated litter becomes too dense for optimum habitat (Rickard 1960, McGee 1976). The western harvest mouse (*Reithrodontomys megalotis*), a granivore, generally follows deer mice in post-fire succession. It will inhabit a recently burned area but tends not to invade until some vegetative cover is established (Cook 1959, Kaufman et al. 1983). Voles (*Microtus* spp.) are among the last to move into a once-burned area so populations usually are low for the first 2-4 years or until litter accumulations reach that of unburned areas (Cook 1959, Rickard 1960, McGee 1976, Vacanti and Geluso 1985). Jumping mice (*Zapus* spp) are also found mostly in unburned areas where cover and food are available (McGee 1976).

Invertebrates: The effect of fire on invertebrates is likely to vary with season of occurrence, although few studies have been conducted in the Northern Great Plains to verify this assumption. Studies in the more mesic Tallgrass Prairie region to the south and east suggest possible effects. For example, Rice (1932) assessed the effects of fire on invertebrates in a Tallgrass Prairie and noted different responses for different groups finding, for example, a decrease in spiders but an increase in ants. Similarly, Arnett (1960), Nagel (1973), and Lussenhop (1976) reported an increase in arthropod biomass and density in Tallgrass Prairie following burning. For grasshoppers, Branson (2005) noted that a fall fire in the Northern Mixed-Grass Prairie resulted in a decline in population density the year following burning but that densities recovered two years thereafter. No difference in grasshopper diversity was detected between burned and unburned treatments. For spring burning, however, Knutson and Campbell (1976) noted different effects of burning in the Tallgrass Prairie depending on when in the spring a burn occurs. Early spring fire induced earlier emergence and greater numbers and diversity of grasshoppers than fires later in the spring.

SUMMARY

Although fire in the Northern Great Plains may reduce standing crop (i.e. annual production) and alter community composition and diversity patterns, these responses are indicative of a grassland biota well adapted to fire (e.g. Steuter 1987, Biondini et al. 1989). In addition, the range of variability in plant composition resulting from spring, summer, and fall burns is further affected by variables such as annual fluctuations in weather (Biondini et al. 1989) or soil condition (e.g. Piper 1995). However, without fire, litter accumulates, cool-season exotic species increase, and prairie faunal diversity declines. While the Northern Great Plains grasslands are adapted to fire (e.g. Moore 1972, Higgens et al. 1989), the variability of weather, soil, and topography across this expansive ecoregion requires careful and continuous monitoring of observed effects of fire at any particular location in order to ensure meeting land management objectives.

LITERATURE CITED

Arnett, W. H. 1960. Responses of acridid populations to range land practices and range sites. Ph.D. Dissertation. Kansas State University, Manhattan, 114pp.

Balch, J. K., B. A. Bradley, C. M. D. Antonio, and J. Gómez-Danz. 2013. Introduced annual grass increases regional fire activity across the arid western USA (1980B2009). Global Change Biology (2013) 19, 173B183 (doi: 10.1111/gcb.12046).

Barnes, P. W., L. L. Tieszen, and D. J. Ode. 1983.Distribution, production, and diversity of C3 and C4-dominated communities in a mixed prairie. Canadian Journal of Botany 61:741-751.

Beck, A. M. and R.J . Vogl. 1972. Effects of spring burning on rodent populations in a brush prairie savanna. Journal of Mammalogy 53:336-346.

Biondini, M. E., A. A. Steuter, and C. E. Grygiel. 1989. Seasonal fire effects on the diversity patterns, spatial distribution and community structure of forbs in the Northern Mixed Prairie, USA. Vegetatio 85:21-31.

Bragg, T. B., and A. A. Steuter. 1996. Prairie Ecology: The Mixed Prairie. Pages 53-66 in F.B. Sampson and F.L Knopf (editors) Prairie Conservation: Preserving North America's Most Endangered Ecosystem, ed. FB. Sampson and FL. Knopf, 53-66. Island Press, Covelo, California.

Branson, D. H. 2005. Effects of fire on grasshopper assemblages in a Northern Mixed-Grass Prairie. 1109-1113.

Christian, J. M. and S. D. Wilson. 1999. Long-term ecosystem impacts of an introduced grass in the northern Great Plains. Ecology 80:2397-2407.

Cook, S. F. Jr. 1959. Effect of a fire on a population of small rodents. Ecology 40:102-108.

Coppedge, B. R., D. M. Engle, C.S . Toepfer, and J. M. Shaw. 1998. Effects of seasonal fire, bison grazing and climatic variation on tallgrass prairie vegetation. Plant Ecology 139:235B246.

Coupland, R. T. 1973. Producers: 1. Dynamics of aboveground standing crop. Matador Project, Canadian IBP Program, Technical Report 27. Saskatoon, Saskatchewan.

Danley, R. F., R. K. Murphy and E. M. Madden, E. M. 2004. Species diversity and habitat of grassland passerines during grazing of a prescribe-burned, Mixed-Grass Prairie. Western North American Naturalist 64:72-77.

Dejong, E. and K. B. MacDonald. 1975. The soil moisture regime under native grassland. Geoderma 14:207-221.

DeKeyser, E. S., M. Meehan, G. Clambey, and K. Krabbenhoft. 2013. Cool Season Invasive Grasses in Northern Great Plains Natural Areas. Natural Areas Journal 33:81-90

Dix, R. L. 1960. The effects of burning on the mulch structure and species composition of grasslands in western North Dakota. Ecology 41:49B56.

Engle, D. M. and P. M. Bultsma. 1984. Burning of Northern Mixed Prairie during drought. Journal of Range Management 37:398-401.

Engle, D. M., R. L. Mitchell, and R. L. Stevens. 1998. Late growing-season fire effects in mid-successional tallgrass prairies. Journal of Range Management 51:115-121.

Erichsen-Arychuk, C. E., E. W. Bork, and A. W. Bailey. 2002 Northern dry mixed prairie responses to summer wildlife and drought. Journal of Range Management 55:164B170.

Flora of North America Editorial Committee, (editors). 1993+. Flora of North America North of Mexico. 18+ vols. New York and Oxford.

Forde, J.D., N.F. Sloan, and D.A. Shown. 1984. Grassland habitat management using prescribed burning in Wind Cave National Park, South Dakota. The Prairie Naturalist 16:97-110

Forrest, S. C., H. Strand, W. H. Haskins, C. Freese, J. Proctor and E. Dinerstein. 2004. Ocean of Grass: A Conservation Assessment for the Northern Great Plains. Northern Plains Conservation Network and Northern Great Plains Ecoregion, WWF-US, Bozeman, MT.

French, M. G. and S. P. French. 1996. Large mammal mortality in the 1988 Yellowstone fires. in 2nd Biennial conference on the Greater Yellowstone Ecosystem. International Association of Wildland Fire, Yellowstone National Park, WY, 113-115.

Frost, C. C. 1998. Presettlement fire frequency regimes of the United States: a first approximation. Pages 70-81 in T. L. Pruden and L. A. Brennan (editors.) Fire in ecosystem management: shifting the paradigm from suppression to prescription. Tall Timbers Fire Ecology Conference Proceedings, No. 20. Tall Timbers Research Station, Tallahassee, FL.

Fuhlendorf, S. D. and D. M. Engle. 2001. Restoring heterogeneity on rangelands: ecosystem management based on evolutionary grazing patterns. BioScience 5:625-632.

Fuhlendorf, S. . and D. M. Engle. 2004. Application of the fire -grazing interaction to restore a shifting mosaic on tallgrass prairie. Journal of Applied Ecology 41:604-614.

Gartner, F. R., J. R. Lindsey, and E. M. White. 1986. Vegetation responses to spring burning in western South Dakota. Pages 143-146 in G. K. Clambey and R. H. Pemble (editors). The prairie: past, present and future: Proceedings of the ninth North American prairie conference, Moorhead, MN. Fargo, ND: Tri-College University Center for Environmental Studies.

Geluso, K. N. and T. B. Bragg. 1986. Fire avoidance behavior of meadow voles (*Microtus pennsylvanicus*). American Midland Naturalist 116:202-205.

Grant, T. A., E. M. Madden, and G. B. Berkey. 2004. Tree and shrub invasion in northern mixed-grass prairie: implications for breeding grassland birds. Wildlife Society Bulletin 32:807-818.

Grant, T. A. and R. K. Murphy. 2005. Changes in Woodland Cover on Prairie Refuges in North Dakota, USA. Natural Areas Journal 25:359-368.

Grant, T. A., E. M. Madden, T. L. Shaffer, and J. S. Dockens. 2010. Effects of prescribed fire on vegetation and passerine birds in Northern Mixed-Grass Prairie. Journal of Wildlife Management 74:1841-1851.

Grilz, P. L. and J. T. Romo. 1994. Water relations and growth of *Bromus inermis* Leyss (smooth brome) following spring or autumn burning in a fescue prairie. American Midland Naturalist 132:340-348.

Guyette, R. P., M. C. Stambaugh, and J. M. Marschall. 2011. A quantitative analysis of fire history at national parks in the Great Plains. A report prepared for the Great Plains Cooperative Ecosystem Studies Unit and National Park Service. 78 pp.

Handley, C. O. 1969. Fire and mammals, Pages 151-159 in Proceedings of the Annual 9th Tall Timbers Fire Ecology Conference. Wildlife and Management and Fire, Tallahassee, FL. Tall Timbers Research, Inc., Tallahassee.

Higgins, K. F. 1984. Lightning fires in North Dakota grasslands and in pine-savanna lands of South Dakota and Montana. Journal of Range Management 37:100-103.

Higgins, K. F . 1986. Interpretation and compendium of historical fire accounts in the northern Great Plains. Resource Publication 161. Washington, D.C.: U.S. Dept. of the Interior, Fish and Wildlife Service.

Higgins, K. F., A. D. Kruse, and J. L. Piehl. 1989. Effects of fire in the Northern Great Plains. U.S. Fish and Wildlife Service and Cooperative Extension Service, South Dakota State University, Brookings, South Dakota. Extension Circular 761. Jamestown, ND: Northern Prairie Wildlife Research Center http://www.npwrc.usgs.gov/resource/habitat/fire/index.htm (Version 16 May 2000).

Kaufman, D. W., G. A. Kaufman, and E. J. Finck. 1983. Effects of fire on rodents in tallgrass prairie of the Flint Hills region of eastern Kansas. Prairie Naturalist 15:49-56.

Kaul, R. B. and S. B. Rolfsmeier. 1993. Native Vegetation of Nebraska. Map. Conservation and Survey Division.

Kinter, C. L., B. A. Mealor, N. L. Shaw, and A. L. Hild. 2007. Postfire invasion potential of rush skeletonweed (*Chondrilla Juncea*). Rangeland Ecology and Management 60:386-394.

Kirsch, L. M., and A. D. Kruse. 1973. Prairie fires and wildlife. Proceedings of the 13th Tall Timber Fire Ecology Conference, Fire in Grasslands and Prairies 12:289-303.

Knutson, H., and J. B. Campbell. 1976. Relationships of grasshoppers (Acrididae) to burning, grazing, and range sites of native tallgrass prairie in Kansas. Proceedings of the Tall Timbers Conference on Ecological Animal Control by Habitat Management 6:107-120.

Komarek, E. V., Sr. 1969. Fire and animal behavior. Pages 161-207 in Proceedings of the Annual 9th Tall Timbers Fire Ecology Conference, Wildlife and Management and Fire. Tallahassee, FL. Tall Timbers Research, Inc., Tallahassee.

Küchler, A. W. 1964. Potential natural vegetation of the conterminous United States. Special Publication Number 36, American Geographical Society, New York, New York, USA.

Lawrence, G. E. 1966. Ecology of vertebrate animals in relation to chaparral fire in the Sierra Nevada foothills. Ecology 47: 2728-291

Lura, C. L., W. T. Barker, and P. E. Nyren. 1988. Range plant communities of the Central Grasslands Research Station in south central North Dakota. Prairie Naturalist 20:177 -192.

Madden, E. M., A. J. Hansen, and R. K. Murphy. 1999. Influence of prescribed fire history on habitat and abundance of passerine birds in Northern Mixed-Grass Prairie. The Canadian Field-Naturalist 113:627-640.

McGee, J. M. 1976. Some effects of fire suppression and prescribed burning on birds and small mammals in sagebrush. PhD Thesis, University of Wyoming, Laramie. 145 p.

McGee, J. M. 1982. Small mammal populations in an unburned and early fire successional sagebrush community. Journal of Range Management 35:177-180.

Moore, C.T. 1972. Man and fire in the central North American grasslands 1535-1890: a documentary historical geography. Ph.D. dissertation. University of California, Los Angeles. 155 pp.

Murphy, R. K. 2008. Fire is for the Birds in Northern Mixed-Grass Prairie. http://www.firescience.gov/projects/briefs/01-3-2-09_fsbrief9.pdf. Accessed. 5 Jan. 2015.

Murphy, R. K. and T. A. Grant, T. A. 2005. Land management history and floristics in Mixed-Grass Prairie, North Dakota, USA. Natural Areas Journal 25:351-358.

Murphy, R. K., and M. L. Sondreal. 2003. Breeding bird abundance and habitat along the Des Lacs River valley, North Dakota. Blue Jay 61:82-94.

Nagel, H. G. 1973. Effect of spring prairie burning on herbivorous and non-herbivorous arthropod populations. Journal of the Kansas Entomological Society 46:485-496.

Neary, D. G., K. C. Ryan, and L. F. DeBano (editors). 2005 (revised 2008). Wildland fire in ecosystems: effects of fire on soils and water. RMRS-GTR-42-vol.4. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 250 p.

Ode, D.J ., L. L. Tieszen, and J. C. Lerman. 1980. The Seasonal Contribution of C_3 and C_4 Plant Species to Primary Production in a Mixed Prairie. Ecology 61:1304-1311.

Pedersen, E., J. W. Connelly, J. R. Hendrickson, W. E. Grantschac. 2003. Effect of sheep grazing and fire on sage grouse populations in southeastern Idaho. Ecological Modeling 165:23-47.

Pfeiffer, K. E. and A. A. Steuter. 1994. Preliminary response of Sandhills prairie to fire and bison grazing. Journal of Range Management 47:395-397

Piper, J. 1995. Composition of prairie plant communities on productive versus unproductive sites in wet and dry years. Canadian Journal of Botany 73:1635-1644.

Pylypec, B. and J. T. Romo. 2003. Long-term effects of burning *Festuca* and *Stipa-Agropyron* grasslands. Journal of Range Management 56:640-645.

Quinn, R. D. 1979. Effects of fire on small mammals in chaparral in D.L. Koch (editor) Cal-Neva Wildlife Transactions. Western Section of the Wildlife Society, Smartsville, California.

Redmann, R. E., J. T. Romo, B. Pylypec, and E. A. Driver. 1993. Impacts of burning on primary productivity of *Festuca* and *Stipa-Agropyron* grasslands in central Saskatchewan. American Midland Naturalist 130:262-273.

Rice, L. 1932. Effect of fire on prairie animal communities. Ecology 13:392-401.

Rickard, W.H. 1960. Distribution of small mammals in relation to the climax vegetation mosaic in eastern Washington and northern Idaho. Ecology 41:99-106.

Romo, J. T., P. L. Grilz, R. E. Redmann, and E. A. Driver. 1993. Standing crop, biomass allocation patterns and soil-plant water relations in *Symphoricarpos occidentalis* Hook. following autumn or spring burning. American Midland Naturalist 130:106-115.

Russell, M. L., L. T. Vermeire, N. A. Dufek, and D. J. Strong. 2013. Fire, defoliation, and competing species alter *Aristida purpurea* biomass, tiller, and axillary bud production. Rangeland Ecology and Management 66:290-296.

Schacht, W., and J. Stubbendieck. 1985. Prescribed burning in the Loess Hill mixed prairie of southern Nebraska. Journal of Range Management 38:47-51.

Seastedt, T. R. 1985. Maximization of primary and secondary productivity by grazers. American Naturalist 126:621-633.

Sieg, C.H. 1996. The Role of Fire in Managing for Biological Diversity on Native Rangelands of the Northern Great Plains. Pages 31-38 in D.W. Uresk, G.L. Schenbeck, and J. T. O'Rourke (Technical Coordinators) Conserving Biodiversity on Native Rangelands: Symposium Proceedings, RM-GTR-298. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 38 p.

Singer, F. J. and P. Schullery. 1989. Yellowstone wildlife: populations in process. Western Wildlands 15:18-22.

Singh, J. S., W. K. Lauenroth, R. K. Heitschmidt, and J. L. Dodd. 1983. Structural and functional attributes of the vegetation of northern mixed prairie of North America. The Botanical Review 49:117-149.

Smith, J. K (editor). 2000. Wildland fire in ecosystems: effects of fire on fauna. RMRS-GTR-42-Vol. 1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 83 p.

Steuter, A. A. 1987. C3/C4 production shift on seasonal burns: northern mixed prairie. Journal of Range Management 40:27B31.

Strong, D.J ., L. T. Vermeire, and A. C. Ganguli. 2013. Fire and nitrogen effects on purple threeawn (*Aristida purpurea*) abundance in Northern Mixed-Grass Prairie old fields. Rangeland Ecology and Management 66:553-560.

Svedarsky, W. D., R. L. Westemeier, R. J. Robel, S. Gough, and J. E. Toepher. 2000. Status and management of the greater prairie-chicken *Tympanuchus cupido pinnatus* in North America. Wildlife Biology 6:277-284.

Tester, J. R. 1965. Effects of a controlled burn on small mammals in a Minnesota oak-savanna. American Midland Naturalist 74:240-243.

Tester, J. R., and W. H. Marshall. 1961. Study of certain plant and animal interrelations on a native prairie in northwestern Minnesota. Occasional Papers: Number 8, Minnesota Museum of Natural History, The University of Minnesota Press, 51 p.

Travnicek, A. J., R. L. Lyn, and C. Prosser. 2005. Fall-prescribed burn and spring-applied herbicide effects on Canada thistle control and soil seedbank in a Northern Mixed Grass Prairie. Rangeland Ecology and Management 58:413-422.

Vacanti, P. L., and K. N. Geluso. 1985. Recolonization of a burned prairie by meadow voles (*Microtus pennsylvanicus*). Prairie Naturalist 17:15-22.

Vermeire, L. T., J. L. Crowder, and D. B. Wester. 2011. Plant community and soil environment response to summer fire in the northern Great Plains. Rangeland Ecology and Management 64:37-46.

Vogl, R. J. 1965. Effects of spring burning on yields of brush prairie savanna. Journal of Range Management 18:202-205.

Whisenant, S. G. 1990. Postfire population dynamics of *Bromus japonicus*. Journal of Range Management 43:205-208.

Whisenant, S. G. and D. W. Uresk. 1989. Burning upland mixed prairie in Badlands National Park. Prairie Naturalist 21:221-227

White, R. S. and P. O. Currie. 1983. Prescribed burning in the northern Great Plains: Yield and cover responses of 3 forage species in the Great Plains Prairie. Journal of Range Management 36:179-183.

Whitman, W. C. 1974. Influence of grazing on the microclimate of Mixed Grass Prairie. Pages 207-218 in Plant Morphogenesis as the basis for scientific management of range resources. U.S. Department of Agriculture Miscellaneous Publication: 1271, Washington D.C.

Willms, W. D., A. W. Bailey, and A. McLean. 1980. Effects of clipping or burning on some morphological characteristics of *Agropyron spicatum*. Canadian Journal of Botany 58:2309-2312.

Willms W. D., S. Smoliak, and A. W. Bailey. 1986. Herbage production following litter removal on Alberta native grasslands. Journal of Range Management 39:536-540.

Willms, W. D., S. M. McGinn, and J. F. Dormaar. 1993. Influence of litter on herbage production in the Mixed Prairie. Journal of Range Management 46:320-324.

Wilson, S. D. 2002. Prairies. Pages 443-465 in A.J. Davy and M.R. Perrow (editors), Handbook of Ecological Restoration. Cambridge University Press, Cambridge, U.K.

Wilson, S. D. and J. W. Belcher. 1989. Plant and bird communities of native prairie and introduced Eurasian vegetation in Manitoba, Canada. Conservation Biology 3:39-44.

Wright, H. A., and A. W. Bailey. 1982. Fire ecology: United States and southern Canada. John Wiley and Sons, Inc. New York, 501 pp.

GETTING HELP

Additional information can be found in a summary of the 2014 workshop on cool-season invasive grasses of the Northern Great Plains available from the products page of the Great Plains Fire Science Exchange website.. The Great Plains Fire Science Exchange has resources on fire, fire effects, monitoring, and more at http://GPFireScience.org.

GREAT PLAINS
FIRE SCIENCE EXCHANGE

For more information: gpfirescience.org