

HABITAT GUIDELINES FOR MULE DEER

GREAT PLAINS ECOREGION



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THE AUTHORS:

LLOYD B. FOX
KANSAS DEPARTMENT OF WILDLIFE AND PARKS
P.O. BOX 1525
EMPORIA, KS 66801, USA

AL A. ARSENAULT
SASKATCHEWAN MINISTRY OF ENVIRONMENT
112 RESEARCH DRIVE
SASKATOON, SK S7K 2H6, CANADA

CLAY E. BREWER
TEXAS PARKS AND WILDLIFE DEPARTMENT
301 MAIN STREET
BROWNWOOD, TX 76801, USA

LEN H. CARPENTER
WILDLIFE MANAGEMENT INSTITUTE
4015 CHENEY DRIVE
FORT COLLINS, CO 80526, USA

BERT JELLISON
WYOMING GAME AND FISH DEPARTMENT
700 VALLEY VIEW DRIVE
SHERIDAN, WY 82801, USA

JONATHAN A. JENKS
DEPARTMENT OF WILDLIFE AND FISHERIES SCIENCES
SOUTH DAKOTA STATE UNIVERSITY
BROOKINGS, SD 57007, USA

WILLIAM F. JENSEN
NORTH DAKOTA GAME AND FISH DEPARTMENT
100 N. BISMARCK EXPRESSWAY
BISMARCK, ND 58501, USA

THOMAS W. KEEGAN
IDAHO DEPARTMENT OF FISH AND GAME
P.O. BOX 1336
SALMON, ID 83467, USA

DAVID J. KRAFT
NATURAL RESOURCE CONSERVATION SERVICE
3020 W. 18TH, SUITE B
EMPORIA, KS 66801, USA

DARYL W. LUTZ
WYOMING GAME AND FISH DEPARTMENT
3030 ENERGY LANE, SUITE 100
CASPER, WY 82604, USA

CALVIN L. RICHARDSON
TEXAS PARKS AND WILDLIFE DEPARTMENT
4500 W. ILLINOIS, SUITE 203
MIDLAND, TX 79703, USA

BRUCE D. TRINDLE
NEBRASKA GAME AND PARKS COMMISSION
2201 N. 13TH STREET
NORFOLK, NE 68701, USA

ADAM P. SCHMIDT
SASKATCHEWAN MINISTRY OF ENVIRONMENT
P.O. BOX 2170
MELVILLE, SK S0A 2P0, CANADA

THOMAS S. STIVERS
MONTANA FISH, WILDLIFE AND PARKS
P.O. BOX 938
LEWISTOWN, MT 59457, USA

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INTRODUCTION

Mule and black-tailed deer (collectively called mule deer, *Odocoileus hemionus*) are icons of the American West. Probably no animal represents the West better in the minds of Americans than the mule deer. Because of their popularity and wide distribution, mule deer are one of the most economically and socially important animals in western North America. A survey of outdoor activities by the U.S. Fish and Wildlife Service (2001) indicated that over 4 million people hunted in the 18 western states. In 2001 alone, those hunters were afield for almost 50 million days and spent over \$7 billion. Each hunter spent an average of \$1,581 in local communities across the West on lodging, gas, and hunting-related equipment. Because mule deer are closely tied to the history, development, and future of the West, this species has become one of the true barometers of environmental conditions in western North America.

Mule deer are distributed throughout western North America from the coastal islands of Alaska, down the west coast to southern Baja Mexico and from the northern border of the Mexican state of Zacatecas, north through the Great Plains to the Canadian provinces of Saskatchewan, Alberta, British Columbia, and the southern Yukon Territory. With this wide latitudinal and geographic range, mule deer occupy a great diversity of climatic regimes and vegetation associations, resulting in an incredibly diverse set of behavioral and ecological adaptations that have allowed this species to succeed.


Within the geographic distribution of mule deer, however, areas can be grouped together into “ecoregions” within which deer populations share certain similarities regarding the issues and challenges that managers must face. Within these guidelines we have designated 7 separate ecoregions: 1) California Woodland Chaparral, 2) Colorado Plateau Shrubland and Forest, 3) Coastal Rain Forest, 4) Great Plains, 5) Intermountain West, 6) Northern Forest, and 7) Southwest Deserts (deVos et al. 2003).

The diversity among the ecoregions presents different challenges to deer managers and guidelines for managing habitat must address these differences (Heffelfinger et al. 2003). In many ecoregions, water availability is not a major limiting habitat factor. However, in others, such as the Southwest Deserts Ecoregion, water can be important. Winterkill is a significant factor affecting deer population fluctuations in northern forests. Winterkill is not a problem in the Southwest Deserts, but overgrazing and drought detrimentally impact populations. In the Great Plains,

summer range conditions that are dependent upon moisture received from July to April the previous year are important to reproductive success (Wood et al. 1989). The open nature of habitats of this ecoregion can make hunters a key mortality factor and the availability of topographic features such as badlands appears to be one of the most important factors influencing mule deer distribution and habitat use (Wood 1987).

Adapting the best management for various vegetation associations is a key to appropriate mule deer management throughout their range. Some vegetation associations are fire-adapted and some are not. The shrubs that deer heavily rely on in the Intermountain West are disappearing from the landscape. Invasions of exotic plants like cheatgrass (*Bromus tectorum*) have increased fire frequency, resulting in more open landscapes. In contrast, the California Woodland Chaparral and many forested areas lack the natural fire regimes that maintain open canopies and provide for growth of important deer browse plants. Prescribed fire can also be an important habitat management tool in the Great Plains Ecoregion (GPE) because decades of fire suppression has greatly altered native habitats. Managers must work to restore ecologically appropriate fire regimes. Deer populations normally respond positively to vegetation in early successional stages; however, an intact forest canopy is important in some northern areas of coastal rainforests to intercept the copious snow that falls in that region and impacts black-tailed deer survival.

Mule deer habitats are facing unprecedented threats from a wide variety of human-related developments. Habitat management for mule deer across vast blocks of public land in the western states and provinces is primarily the responsibility of federal and provincial land management agencies. However, in the Great Plains just the opposite is true as most of the land base is privately owned, so government programs available to private landowners will have important influence on the future of these habitats for mule deer. If mule deer habitats are to be conserved, it is imperative that government agencies, private landowners, and private conservation organizations are aware of key habitat needs and fully participate in habitat management for mule deer. Decades of habitat protection and enhancement in the name of “game” management benefited countless other nonhunted species. A shift away from single-species management toward an ecosystem approach to the management of landscapes has been positive overall; however, some



economically and socially important species are now de-emphasized or neglected in land use decisions. Mule deer have been the central pillar of the American conservation paradigm in most western states, and thus are directly responsible for supporting a wide variety of conservation activities that Americans value.

The core components of deer habitat - water, food, and cover are consistent across the different ecoregions. Juxtaposition of these components is an important aspect of good mule deer habitat; they must be interspersed in such a way that a population can derive necessary nutrition and cover to survive and reproduce. Over time we have learned much about mule deer foods and cover, but more remains to be learned. For example, we have learned that cover is not a simple matter; the improvement that vegetation and topography provide under highly variable weather conditions is a key aspect of mule deer well being. Mule deer have basic life history requirements that weave a common thread throughout the many issues facing them.

Mule deer are primarily browsers, with a majority of their diet comprised of forbs and browse (leaves and twigs of woody shrubs). Deer digestive tracts differ from cattle (*Bos taurus*) and elk (*Cervus elaphus*) in that they have a smaller rumen in relation to their body size, so they must be more selective in their feeding. Mule deer also have differences in their gastrointestinal morphology compared to white-tailed deer (*Odocoileus virginianus*). The gastrointestinal tract of mule deer is larger than in white-tailed deer and increases in volume in response to the nutritional demands of lactation. It also can respond to habitat change, such as improvement in vegetation quality after fire (Zimmerman et al. 2006). Instead of eating diets with large quantities of low quality forage like grass, deer must select the most nutritious plants and parts of plants. Because of this, deer have more specific forage requirements than other larger ruminants.

The presence and condition of the shrub component is an important factor affecting mule deer populations in the various ecoregions. Shrubs occur mostly in early successional habitats; that is, those recently disturbed and going through the natural processes of maturing to a climax state. This means disturbance is a key element to maintaining high quality deer habitat. In the past, different fire cycles and human disturbance, such as logging, resulted in higher deer abundance than we see today. Although weather patterns, especially precipitation, drive deer populations in the short-term, only landscape-

scale habitat improvement will make long-term gains in mule deer abundance in many areas.

If deer populations remain at or above carrying capacity, they begin to impact their habitats in a negative manner. The manager must also be aware of carrying capacity for deer. In the case of drought, return to previous carrying capacity may be delayed; long-term impacts such as prolonged drought and vegetation succession can exacerbate the return to previous capacity for several years, or even decades, depending on severity and resultant habitat change. This may well be the situation in many mule deer habitats in the West and managers must be cognizant of this factor.

Habitat conservation requires active habitat manipulation or conscious management of other land uses. An obvious question to habitat managers will be—at what scale do I apply my treatments? This is a legitimate question and obviously hard to answer. Treated areas must be sufficiently large to produce a “treatment” effect. There is no one “cookbook” rule for scale of treatment. However, managers should realize the effect of properly applied treatments is larger than the actual number of acres treated. Deer will move in and out of treatments and thus treatments will benefit a larger area of habitat. In general, several smaller treatments in a mosaic or patchy pattern are more beneficial than 1 large treatment in the center of the habitat. Determining the appropriate scale for a treatment should be a primary concern of managers. Treatments to improve deer habitat should be planned to work as parts of an overall management strategy. For example, priority treatments should begin in an area where the benefit will be greatest and then subsequent habitat improvement activities can be linked to this core area.

The well-being of mule deer, now and in the future, rests with the condition of their habitats. Habitat requirements of mule deer must be incorporated into land management plans so improvements to mule deer habitat can be made on a landscape scale as the rule rather than the exception. The North American Mule Deer Conservation Plan (Mule Deer Working Group 2004) provides a broad framework for managing mule deer and their habitat.

Mule deer management encompasses far more than habitat management. Issues and practices such as hunter harvest management, and population monitoring programs are vital to sound stewardship of this resource but outside the bounds of these guidelines. New understanding is being



added to our base on limiting factors influencing mule deer populations. Factors such as predation may be important in some areas and under specific conditions (Ballard et al. 2001). However, all management depends on a secure habitat base.

These habitat management guidelines, and those for the other ecoregions, tier off that plan and provide specific actions for its implementation. The photographs and guidelines here are intended to communicate important components of mule deer habitats across the range of the species and suggest management strategies. This will enable public and private land managers to execute appropriate and effective decisions to maintain and enhance mule deer habitat.



Photo provided by NEBRASKAland Magazine/Nebraska Game and Parks Commission.

DESCRIPTION

The Great Plains is the largest grassland ecosystem in North America, extending north to south from the boreal forest of central Manitoba and Saskatchewan to southern Texas (Severson 1981) and west to east from the Rocky Mountains of Alberta, Montana, Wyoming, Colorado, and New Mexico to the tallgrass prairies of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas (Fig. 1). Most of the area lies between 2,000 and 6,000 feet above sea level. This ecoregion constitutes the eastern edge of mule deer distribution. Mule deer in this ecoregion inhabit areas primarily classified as mixed grass or shortgrass prairies, steppe, and shrub savanna. The ecoregion includes potential native vegetation communities of Wheatgrass-Needlegrass shrub-steppe, Mesquite savanna, Foothills prairie, Grama-Needlegrass-Wheatgrass, Grama-Buffalo Grass, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Wheatgrass-Grama-Buffalo Grass, Bluestem-Grama prairie, Sandsage-Bluestem prairie, Shinnery, and Nebraska Sandhills prairie (Kuchler 1964). Climate is arid to semi-arid with extreme temperature variations and high evaporation rates. Annual precipitation is low (< 4-20 in.) and highly variable, often produced in violent summer storms or winter blizzards. High wind and excessive water erosion is and has been a common feature of this region.

The ecoregion is essentially an arid grassland and steppe system that separates the forested West from the forested East. However, environmental conditions form gradients across the Great Plains. There is an eastward tilt to the plain with elevations decreasing from west to east. The growing season is shorter and winter is more severe in the north than the south. Annual rainfall generally increases from west to east. Warm-season prairies with C4 species occur in the southern areas and grade into cool-season prairies with C3 species dominating in the north. Occasionally, topographic or soil-type anomalies cause dramatic changes in habitat within relatively short distances, however, the overriding

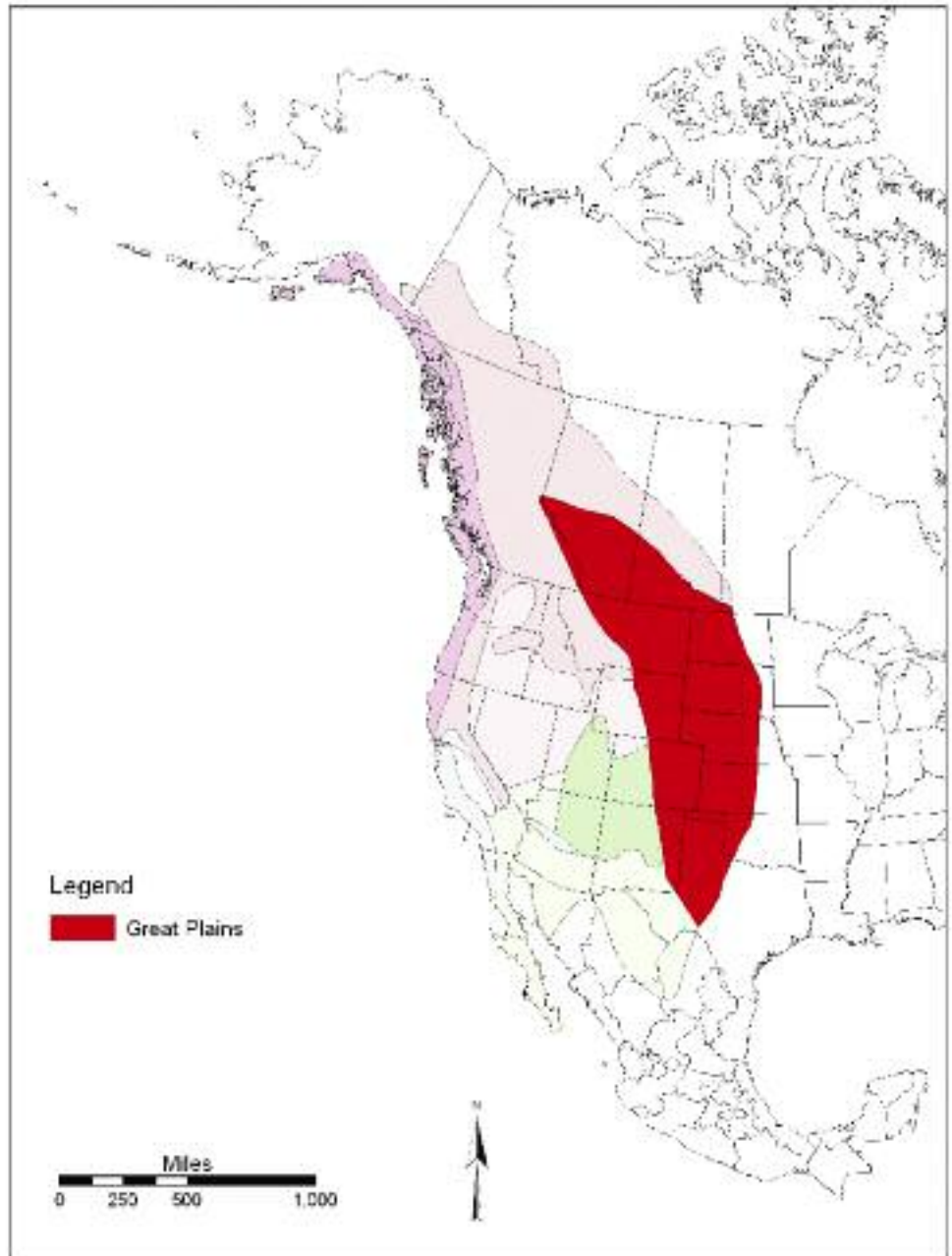


Figure 1. The Great Plains Ecoregion, shown in red, encompasses the grassland and steppe habitats of the eastern portion of the mule deer distribution. (Prepared by Sue Boe/Arizona Game and Fish Department).

trend in the ecoregion is the gradual changes that occur across the landscape.

This ecoregion consists of broad, flat expanses, rolling hills, areas of extensive riparian relief, and localized geologic features (escarpments and buttes). The rough topography of these features provides valuable mule deer habitat (Severson 1981). Badlands are locally common and are characterized by steeply sloping, rough, broken areas that are at times devoid of plant cover but are interspersed with shrub or wooded draws and areas of diverse forb and grass



communities. This uneven terrain provides much of the necessary cover for mule deer. Low areas create local moisture conditions and water sources that support growth of shrubs and trees that provide critical forage and cover, especially in winter.

The Great Plains is frequently referred to as one of the “bread baskets” of the world. The region produces > 60% of the wheat (*Triticum aestivum*), 87% of the grain sorghum (*Sorghum bicolor*), 54% of the barley (*Hordeum vulgare*) and 36% of the cotton (*Gossypium* spp.) produced in the United States (Skold 1997). Agricultural activities and programs significantly influence habitats available to mule deer. Much of the area, especially the flatter, more fertile, and watered sites has been converted from native vegetation to cultivated crops. Cultivated crops and planted forage may provide supplementary forage for mule deer, but this frequently leads to conflicts and intolerance for mule deer by farmers and ranchers, and potential competition with white-tailed deer.

Rich grasslands of the GPE provided grazing resources for large ungulates and smaller herbivores for thousands of years. Some of these grasslands are fragile and prone to drought or the effects of overgrazing. The Nebraska Sandhills is the largest dune system in the United States that is covered by grasslands (Ostlie et al. 1997). Nearly 75% of the grain-fed beef produced in the United States comes from the Great Plains (Skold 1997). Areas not suited for crops, such as the Sandhills, are generally grazed by livestock.

The High Plains (Ogallala) aquifer is one of the largest freshwater aquifers in the world, occupying approximately 174,000 mi² under parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. The aquifer has been an important water source that fed streams flowing eastward, supporting critical riparian vegetation of the Great Plains. In recent years the aquifer has been developed and exploited as a source of agricultural irrigation water, and more recently, ethanol production. This exploitation has resulted in reduction or elimination of stream flow in many areas. The Great Plains is also an area rich in minerals and sources of energy. These resources attract people interested in extraction, creating potential for development and habitat fragmentation.

Although the GPE includes some significant forest resources, such as those in the Black Hills and Cypress Hills, these habitat management guidelines will focus on grasslands and steppe, and the converted habitats in those areas. Forest management that benefits mule deer is addressed in the habitat guidelines for Northern Forest and the Colorado Plateau ecoregions.

ECOREGION-SPECIFIC DEER ECOLOGY

As pointed out by Severson (1981), mule deer are generally not thought of as animals associated with the Great Plains. One of the earliest references to mule deer in the Great Plains was that of Meriweather Lewis in 1805, who noted that mule deer preferred “hills or open country” (Severson 1981). Even the musculature and stotting gait of mule deer appears more adapted to evasion of predators in steep terrain than on flat country (Mackie et al. 1998).

Although mule deer abundance in the plains during the period of exploration (1800-1880) is poorly understood, most agree that deer of either species were nearly extirpated by 1900. Deer populations did not begin to increase until the 1930s, and apparently reached relatively high densities in the late 1960s and early 1970s (Severson 1981). Several reasons have been advanced to explain the rapid repopulation: a significant reduction in human population associated with the Depression, predator control during the 1940s, better enforcement of game laws, and development of livestock watering impoundments (Severson 1981). Many factors are tied together in a complex manner related to human population levels. This is particularly important with the combination of habitats, predation, and legal harvest factors on mule deer populations in the Great Plains. However, as a result, mule deer are considered quite common in many parts of the ecoregion today.

Mule deer habitats in the GPE are very diverse and often characterized by drainages with deciduous trees and shrubs and north slopes dominated by coniferous or evergreen trees (Severson 1981). A wide variety of plant species occur across the ecoregion and Severson (1981) suggested use of plains habitats by mule deer often appears to center on cover requirements rather than food.

Factors that limit the eastern distribution of mule deer in the Great Plains are unclear, but may include some combination of temperature, humidity, physical features, predation, diseases, or parasites. Perhaps distribution of a parasitic nematode like meningeal worm (*Paraelaphostrongylus tenuis*) plays a role (Jacques and Jenks 2004). Potential for competition with elk exists where they are sympatric with mule deer. Along the eastern edge of mule deer range, white-tailed deer are considered the most likely competitor, but Wood et al. (1989) reported direct resource competition apparently was not a factor determining differences in spatial distribution between the 2 deer species on the eastern Montana prairie.

Fawn recruitment in prairie systems is highly variable depending on amount and timing of precipitation. There was a significant correlation between total



precipitation occurring in the eastern Montana prairie from July through April prior to fawning and fawn recruitment the following year (Wood et al. 1989). Lomas and Bender (2007) reported that mule deer fawn survival in northeastern New Mexico was driven by an interaction between total and seasonal precipitation and its effect on plant production, which consequentially affected female nutrition, and ultimately, fawn birth attributes. Highest fawn survival occurred in the year of greatest annual and seasonal precipitation. Adult does in New Mexico were able to accrue only 6-9% body fat in autumn, indicating very poor summer forage conditions (Bender et al. 2007). In addition to drought, Bender et al. (2007) attributed poor forage conditions to low levels of forbs and shrubs (< 6.0% of the plant community). Urness et al. (1971) and Pederson and Harper (1978) demonstrated the importance of forbs and shrubs in providing needed nutrients for mule deer. Riley and Dood (1984) found that during years with below normal precipitation and poor forb production, does shifted their diet from forbs to browse earlier in the season and fawns shifted their home ranges to areas with denser woody cover.

Obviously, not all Great Plains habitats are as severely diminished of forbs and shrubs as the New Mexico study area described by Bender et al. (2007), but their findings demonstrate that, in grass-dominated systems, diverse plant communities are important to mule deer nutrition, particularly during dry periods. When managing for mule deer, land and wildlife managers should strive to provide this diversity on a landscape scale.

MAJOR IMPACTS TO MULE DEER HABITAT IN THE GREAT PLAINS

Plant species composition has been modified.

Vast areas of this ecoregion have been converted from native habitat, much of which supported mule deer, to cropland. Grazing by livestock resulted in overuse of native vegetation from time to time. Excessive herbivory decreases preferred forage species and increases prevalence of less desirable species. Noxious or invasive species have proliferated, especially on disturbed sites, and expanded into native plant communities. These changes have frequently reduced species richness or replaced native flora communities with near-monocultures. More subtly, less desirable species have become more abundant at the expense of more desirable species (e.g., eastern redcedar [*Juniperus virginiana*] replacing rubber rabbitbrush [*Ericameria nauseosa*]).

Vegetation structure has been modified.

The frequency and intensity of natural processes, such as periodic fires and floods, have changed. In some cases, this has resulted in establishment of undesirable woody cover at the expense of desirable and diverse herbaceous species. In other cases, changes in these natural processes have resulted in loss of critical woody species, reducing food resources and cover critical to mule deer during some portion of the year.

Nutritional quality has decreased.

Agricultural crops undoubtedly play a significant role in bioenergetics of mule deer in the Great Plains; however, few studies have been conducted on areas dominated by private property and agricultural areas. Livestock grazing, especially in riparian areas, influences quantity and quality of native browse species. Nutritional quality of mature and senescent woody shrubs in steppe habitats is lower than it could be if management was designed to periodically rejuvenate these communities. Lowering of the ground water table as a result of extensive irrigation has placed some riparian tree and shrub communities in jeopardy.

Loss and fragmentation of usable habitat due to human encroachment and associated activities.

As suburban areas expand, mule deer habitat is lost. Mule deer habitats are fragmented when areas are developed for energy or commercial uses, including transportation and motorized recreation. Presence of people and their activities may also displace mule deer from otherwise suitable habitat.



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CONTRIBUTING FACTORS & SPECIFIC HABITAT GUIDELINES

LONG-TERM FIRE SUPPRESSION

BACKGROUND

No ecoregion in North America has been influenced more by fire than the Great Plains (Wright and Bailey 1982). However, the GPE was shaped and maintained by a number of interacting factors, including moisture regime and the grazing patterns of an estimated 30-60 million bison (*Bison bison*) that roamed the region (Samson and Knopf 1996). Limited rainfall, seasonal distribution of precipitation, and evaporation rates favor growth of grasses and forbs over woody plants (Webb 1931, Sieg 1997). Bison influenced grasslands by grazing intensively in some areas and creating patches of open habitat that differed from areas with temporary or low use (Samson and Knopf 1996). Bison herds contributed to habitat diversity by creating a shifting mosaic across the landscape. Vast colonies of prairie dogs (*Cynomys* spp.) also shaped fire effects, especially the “dog towns” that stretched for miles. Vegetation was closely cropped as forage and to improve visibility, which influenced fire intensity, frequency, and burn patterns (Webb 1931).

Historical influence of fire on vegetation communities of the Great Plains was not constant in time or space (Anderson 1990). Erratic climate, flammable fuels, topographic relief, and other factors, such as the shifting grazing patterns of millions of bison, combined to produce vegetation communities diverse in composition, biomass, and structure. Although the long-term effect of these interacting factors was maintenance of a grassland-dominated ecoregion, the constantly shifting influences had a positive effect on vegetation diversity, wildlife diversity, and the diverse needs of mule deer.

Historically, the major ignition sources of fires were lightning and Native Americans (Wright and Bailey 1982, Sieg 1997). Although some historical-fire researchers discount the human role in their fire-interval conclusions, there is abundant evidence that Native Americans changed the character of the landscape with fire (Botkin 1990). Higgins’ (1986) review of 300 historical-fire accounts from 1673 to 1920 indicated fires were common in the Great Plains and that many were set intentionally and accidentally by Native Americans. Historians have documented numerous reasons for intentionally setting fires, including hunting, pest management, crop management, insect collection, warfare, promoting vegetative diversity, improving growth and yield, and promoting environmental stability (Lewis 1985, Williams 2001). Purposeful fires differed from natural (lightning caused) fires in frequency, intensity, and seasonality of burning. For example, lightning-caused fires most commonly occur in July-August in South Dakota (Higgins 1984) and Nebraska (Wendtland and Dodd 1992), whereas peak burning months for American Indians in the northern Great Plains were April and September-October.

By the late 1800s the “natural” fire regime (the regime that had existed for the past 10,000 years of Native American occupation) had been altered. Many native tribes were confined to reservations, and bison numbers had been substantially reduced. Grazing patterns of roaming herds of bison were being replaced with different grazing regimes of the cattle industry, which altered fire frequency, timing, and intensity. Extent and spread of lightning fires also were altered by roads and other human developments that served as barriers. Continued settlement and fire-suppression policies caused an increase in fire-return intervals. For example, near Devils Tower, Wyoming, fire frequency averaged 42 years after 1900 compared to 27 years historically (Fisher et al. 1987).

Although numerous factors influenced historical fire frequencies in the Great Plains, including bison grazing patterns and intensity, a complex interaction among 3 major factors greatly affected the average interval between fire occurrences on a regional basis: 1) herbaceous production, 2) topographic relief, and 3) moisture regime. Fire-return intervals were shortest (2-5 years) in mesic areas of the tallgrass prairie and longest (20-30 years) in the most arid areas of the shortgrass prairie. Along this biomass production-moisture gradient, terrain further influenced fire frequencies. Fire intervals were longer in terrain dissected by draws, ridges, and outcroppings, and shorter in flat and rolling terrain. The extreme range of these gradients from north to south and east to west, combined with the patchiness that can occur within any sub-region, contribute to the broad range of fire frequencies and effects within the GPE.

ISSUES AND CONCERNS

The habitat requirement most often limiting for mule deer in this ecoregion is woody cover. Although not the only factor involved in woody cover maintenance, topographic relief (and its effect on fire intensity and frequency) is a key influence. Draws, escarpments, and rocky outcroppings often serve as barriers to fire because of light amounts and patchy distribution of fine fuels. Infrequent fire in these areas allowed woody seedlings to develop and mature, in contrast to flat or rolling terrain that burned more frequently and prevented encroachment of woody plants. Riparian areas also burned infrequently because moist soil, higher humidity, and green vegetation, seldom allowed a fire to carry. Even when these wooded areas occasionally burned, many of the woody species were fire-tolerant and had the ability to sprout from roots and quickly recover.

Fire, along with the normally dry climate of the GPE, protected integrity of grasslands from woody encroachment. However, local moisture conditions and topographic features served to promote habitat diversity in the form of trees and



Figure 2. Long-term fire suppression and subsequent encroachment of woody vegetation results in decreased use by mule deer in the Canadian Breaks of Texas. (Photograph by Duane Lucia/TPWD).



Figure 3. Managers must implement large-scale burning to enhance mule deer habitat at the landscape level. (Photograph by Jeff Bonner/TPWD).

shrubs. These localized concentrations of woody plants are extremely valuable to mule deer (Severson 1981) and numerous other wildlife species in the Great Plains. Mule deer can be found in grassland habitats with little woody cover, especially in areas with undulating terrain. However, woody plants can benefit deer habitat by improving cover and increasing forage diversity and availability throughout the year.

Historical fire intervals in this ecoregion, combined with animal-related influences and other environmental factors, served to maintain grasslands with tremendous structural and compositional diversity, including coverts and corridors of woody cover. A gradual shift in vegetation composition in favor of woody and fire-intolerant species has since occurred as a result of several factors: 1) lengthening fire intervals, 2) shifting the predominant fire season from

summer to early spring, and 3) reduced fire intensity. In some instances, the result has been improved conditions for mule deer. For example, big sagebrush (*Artemisia tridentata*) increased in the northwestern Great Plains; and sand shinnery oak (*Quercus havardii*) and sand sagebrush (*Artemisia filifolia*) increased in the southern extreme. In other instances, the shift in plant species composition is threatening the integrity of grasslands (Fig. 2). In the northern GPE, Rocky Mountain juniper (*Juniperus scopulorum*) has proliferated with fire suppression.

Common issues related to suppression of fire and altered fire regimes in the GPE can be summarized in 3 main categories (Heffelfinger et al. 2006).

Plant Species Composition

- Decreased diversity of plant communities.
- Reduction or loss of herbaceous plants.
- Decreased reproduction and prevalence of desired plant species.
- Replacement of important perennial forbs and grasses by annuals.
- Replacement of deep-rooted perennial bunchgrasses with less desirable species.
- Encouragement of non-native plant species.
- Increased plant susceptibility to disease and insect infestation.

Vegetative Structure

- Elimination of early and mid-successional plant communities.
- Reduction of herbaceous understory.
- Encroachment or dominance of woody plants.
- Rapid expansion of shade-tolerant tree and shrub populations.
- Increased age of important browse species.
- Monotypic communities of similar age and structure.
- Increased height, changing insects and pathogens.
- Increased erosion.
- Loss of water.

Nutritional quality

- Absence of abundant and diverse high quality forage.
- Decrease in nutrient value of plant species.
- Reduction or elimination of nutrient cycling.
- Decreased browse nutrient content.
- Decreased palatability of forages.

GUIDELINES

Plant communities of the GPE were shaped and sustained through landscape-level, natural-disturbance processes and they are well adapted to fire. While fire is an effective and cost-efficient tool for restoring and maintaining mule deer habitat, managers must have a clear understanding of historic fire regimes to achieve success. In addition,



Table 1. Benefits of fire on important habitat requirements (food, cover, water) of mule deer in fire adapted plant communities (Severson and Medina 1983, Richardson et al. 2001, Heffelfinger et al. 2006).

FOOD	<ul style="list-style-type: none"> ➤ Reduces undecomposed organic materials and litter that inhibit growth of grasses and forbs ➤ Improves nutrient cycling ➤ Increases nutrient value of plant species ➤ Increases palatability of forage ➤ Removes dense, rank, or over-mature growth ➤ Stimulates crown or root sprouting ➤ Provides for early successional species and communities ➤ Creates a mosaic of different successional stages ➤ Encourages early spring green-up ➤ Elimination of undesirable plant species ➤ Stimulates seed germination
COVER	<ul style="list-style-type: none"> ➤ Creates or maintains appropriate cover levels ➤ Produces temporary openings ➤ Creates edge ➤ Modifies utilization patterns ➤ Provides control of young invading woody plants ➤ Improves fawning cover through promotion of seed germination and growth of perennial bunchgrasses (fawning cover) ➤ Improves ability to detect predators
WATER	<ul style="list-style-type: none"> ➤ Improves water yield ➤ Improves water infiltration, retention, and deep percolation (through increased ground cover) ➤ Spring recharging

Table 2. Effects of fire and season on vegetation (Severson and Medina 1983, Richardson 2003, Heffelfinger et al. 2006).

EFFECTS OF FIRE		
TIMING	FORBS	WOODY PLANTS
COOL SEASON (EARLY-MID WINTER)	<ul style="list-style-type: none"> ➤ Improved germination ➤ Improved growth and vigor of desirable grasses and forbs ➤ Promotes cool-season annuals and perennials ➤ Maximum forb growth 	<ul style="list-style-type: none"> ➤ Temporary suppression ➤ Reinvigoration of desirable browse
COOL SEASON (LATE WINTER)	<ul style="list-style-type: none"> ➤ Reduces abundance of annual forbs ➤ Promotes perennial grasses ➤ Improved grass quality and species composition 	<ul style="list-style-type: none"> ➤ Temporary suppression ➤ Reinvigoration of desirable browse
WARM SEASON	<ul style="list-style-type: none"> ➤ Reduces abundance of annual forbs ➤ Promotes perennial grasses ➤ Improved grass quality and species composition 	<ul style="list-style-type: none"> ➤ Maximum mortality



Figure 4. Planning and execution of a prescribed burn are critical to outcome. Firebreaks need to be prepared (top photo). Wind and moisture conditions are important factors to evaluate before the fire is set and personnel need to be trained and equipped properly (middle photo). The outcome of a prescribed fire is a rejuvenated and diverse plant community (bottom photo). (Photographs by Tom Norman/KDWP).

understanding impacts of fire on key habitat components (Table 1) of mule deer is critical (Cantu and Richardson 1997). Strategies for using fire must carefully consider timing (Table 2), frequency, and intensity. Prescribed burning follows specific guidelines that establish conditions and manner under which fire is applied to an area in order to achieve well-defined goals and objectives (Fig. 3).

A. Plan

The first step to a successful prescribed burn is thorough planning. A written plan should be prepared by a knowledgeable person who understands fire behavior, suppression techniques, and effects of fire on natural communities (Fig. 4). Elements of the plan should include:

1. Site description (topography, vegetation, and structures);
2. Management objectives;
3. Preparations (site, personnel, and equipment);
4. Desired prescription (weather conditions and timing);
5. Special considerations (endangered species, erosion potential, archaeological concerns, and other potential adverse impacts);
6. Execution (ignition, suppression measures, and smoke management);
7. Notification procedures (regulatory agencies, local fire departments, law enforcement, and adjoining landowners);
8. Post burn management activities; and
9. Burn evaluation and monitoring strategies.

B. Effects of Fire on Critical Habitat Components

1. Food

Great Plains habitats used by mule deer are highly diverse, as are their food sources and the factors that affect them. In general, mule deer prefer early successional forage species that are promoted by periodic fire or other disturbances. Early successional habitats provide an abundance and diversity of forbs and young shrubs that are high in protein and other nutrients (Heffelfinger et al. 2006). However, a diverse forage composition across the landscape ensures availability of year-round nutritional requirements (Short 1981, Wakeling and Bender 2003). For plant communities that are fire-adapted, such as those in the Great Plains, fire is an effective tool for returning or maintaining those communities in early successional stages. Burning converts mature plants to a rapid-growth stage and releases nutrients immobilized in mature woody tissue, thereby enhancing accessibility, palatability, and nutritional value (Figs. 4-5).

2. Cover

Mule deer require cover for 2 primary purposes: protection and hiding cover. For protection, mule deer are very adept at using slope, aspect, terrain (draws, drainages, canyons), and woody cover. During hot weather, shade provided by vegetation and terrain helps deer to conserve moisture and

energy. Germaine et al. (2004) noted that the site temperature and canopy closure were the most influential variables affecting bed site selection by mule deer. During winter, the leeward side of hills combined with draws, escarpments, and woody cover help to reduce snow depth, which affects movement and thus, use of habitat. Obviously, deer do not rely exclusively on shrubs for protection during weather extremes and use of woody cover is controversial relative to its importance as an integral component of protection for mule deer in the Great Plains (Fig. 6). Nevertheless, shrubs and woody cover likely provide benefits to mule deer during winter. Fire serves a critical role in preventing woody plant encroachment into grasslands, particularly when combined with frequent drought. However, most areas preferred by mule deer include topographic features that serve as barriers to fire or limit fire intensity. Consequently, natural protection from frequent fire in rougher terrain helps to perpetuate a critical cover component (shrubs and trees) within habitats most important to mule deer. Infrequent fire can help to rejuvenate mature stands of woody vegetation by stimulating new sprouts in most woody species (e.g., skunkbush sumac [*Rhus trilobata*], chokecherry [*Prunus virginiana*], western snowberry [*Symphoricarpos occidentalis*], serviceberry [*Amelanchier* spp.], buffaloberry [*Shepherdia* spp.], Chickasaw plum [*Prunus angustifolia*], Havard or sand shinnery oak, saltbush [*Atriplex* spp.], Woods' rose [*Rosa woodsii*], and others) and even promoting seedling development in some woody species.

Broken, undulating terrain that allows mule deer to escape predators, quickly disappear from view, or avoid detection altogether is a key feature in quality mule deer habitat. As quantity of broken terrain declines, vegetation increases in importance for satisfying certain cover requirements (screening or security). In flat to rolling terrain, mule deer often use fairly dense shrubs and succulents (e.g., yucca [*Yucca* spp.] and cholla [*Cylindropuntia* spp.]) as screening cover when moving between feeding and bedding areas. In the GPE, tall, herbaceous vegetation can be an important cover type for screening, loafing, and fawning cover. However, mule deer evolved using long-range vision to detect and avoid predators. Woody cover can become so dense that mule deer predator avoidance and escape mechanisms become ineffective, ultimately reducing survival and production (Geist 1981). Fire can be an important tool in maintaining woody plant densities at suitable levels for mule deer ($\leq 30\text{-}40\%$).

C. Additional Tools to Consider

A number of other management options are available for enhancing mule deer habitat. These options fall within 2 primary categories: mechanical and chemical treatments. Like prescribed burning, proper planning and execution is critical for achieving success. Managers must carefully



Figure 5. Diverse forage composition across the landscape ensures the availability of year-round nutritional requirements. The series begin at the top in March 2006 and show recovery after one year. (Photographs by Jeff Bonner/TPWD).

Table 3. Advantages and disadvantages of mechanical and chemical treatments (Richardson et al. 2001, Heffelfinger et al. 2006).

TREATMENT	ADVANTAGES	DISADVANTAGES
MECHANICAL	<ul style="list-style-type: none"> ➤ Selective ➤ Promotes a variety of herbaceous plants through soil disturbances and decreased competition ➤ Produces immediate forb response ➤ Encourages sprouting of palatable and nutritional browse plants 	<ul style="list-style-type: none"> ➤ Cost ➤ Most methods only provide temporary control of woody plants ➤ High erosion potential
CHEMICAL	<ul style="list-style-type: none"> ➤ Provides for treatment of large areas in a short time period (aerial) ➤ Low erosion potential (no ground disturbances) ➤ Not limited by topography (aerial) ➤ Selective (individual plant treatment) ➤ Useful as a preparatory treatment before prescribed burning 	<ul style="list-style-type: none"> ➤ Cost ➤ Short-term suppression of desirable plants (1-2 years after treatment) ➤ Non-selective (non-target damage or mortality to desirable plants) ➤ Some woody plants are resistant to herbicides ➤ Woody plants not totally consumed (standing dead woody plants) ➤ Litter and debris not consumed ➤ Herbicide applicator's license required



Figure 6. Concentrations of woody vegetation within riparian areas provide critical mule deer habitat requirements. (Photograph by Jeff Bonner/TPWD).

consider advantages and disadvantages of each method (Table 3). Combining > 1 method may assist in achieving management objectives. Consideration must be given to cover requirements of mule deer and other wildlife, soil types, slope angle and direction, soil loss and erosion factors, and post-treatment measures to achieve success and minimize adverse impacts to both target and non-target species (Richardson et al. 2001).

1. Mechanical Treatment

Mechanical treatments or tools include: rootplows, chaining, roto-beating, grubbers, dozing, hydraulic shears, aerators, roller-choppers, and others. Mechanical treatments are among the most selective tools available, but also the

most expensive. Richardson et al. (2001) suggested mechanical treatment be used for removing brush canopy and promoting a variety of forbs and grasses through soil disturbances and decreased competition.


2. Chemical Treatment

Chemical treatment involves use of herbicides to control (reduce or eliminate) undesirable plants or vegetation patterns. Methods and rates of application vary considerably depending on desired results. Herbicides may be applied in pellet or liquid form, on foliage or in soils, and aerially or through ground treatment methods (Richardson et al. 2001). Method and rate of application must be carefully selected to maximize success and minimize adverse impacts.

EXCESSIVE HERBIVORY

BACKGROUND

Large herds of grazing mammals have been a major feature of the unglaciated Great Plains for > 40,000 years. Dominant large herbivores during the last 10,000-14,000 years were bison, elk, and pronghorn (*Antilocapra americana*). Fossil and archaeological records suggest mule deer numbers were highest in the dry, sagebrush-steppe and shortgrass communities (Graham and Lundelius 1994). This is particularly true where rougher terrain, such as badlands and buttes, are associated with grasslands (Severson 1981). Large numbers of domestic livestock, primarily cattle, essentially replaced bison as a primary herbivore during the mid-late 1800s, first as free-ranging herds and later under fenced ranch operations. As was the



case throughout the West, excessive livestock numbers led to significant overgrazing in many areas (Roosevelt 1888, Bahre 1991, Knue 1991).

Settlement of the GPE set into motion a series of environmental changes to the landscape. Initial vegetative changes involved cutting of the limited number of trees for fuel and construction of buildings, corrals, and fences (Butler and Goetz 1984). Long-term changes primarily revolve around intensive management for livestock grazing and long-term fire suppression. In areas with chronic livestock overgrazing, grassland communities remain at an early seral stage, dominated by less palatable species of plants (e.g., blue grama [*Bouteloua gracilis*], prickly pear cactus [*Opuntia* spp.], fringed sagebrush [*Artemisia frigida*], and buckbrush [*Ceanothus cuneatus*]). Wooded, deciduous draws lack an understory of saplings to replace canopy trees (Duxbury 2003). Rangeland that has been overgrazed by sheep (*Ovis aries*) tends to lack forbs and woody shrubs.

Definitions

Any discussion of effects of livestock grazing on vegetation must be based on a consistent use of terminology. The following definitions have been applied to each of the ecoregional habitat guidelines for mule deer. Grazing is neither good, nor bad; it is simply the consumption of available forage by an herbivore. Grazing annual production of herbage at inappropriately high intensities is termed “overuse.” “Overgrazing” describes a condition where the range is chronically overused for a multi-year period, resulting in degeneration in plant species composition and soil quality (Severson and Urness 1994:240). There are different levels of overgrazing: range can be slightly overgrazed or severely overgrazed (Severson and Medina 1983).

ISSUES AND CONCERNS

Grazing and Mule Deer Habitat

Livestock grazing has potential to change both food and cover available to deer. Dietary overlap is an important consideration, but if shared forage plants are not used heavily there may be no competition for food. Proper levels of grazing allow different types of ungulates to assume their natural dietary niche. Under appropriate grazing regimes, cattle primarily eat grass (if available), have a lesser impact on forbs and browse, and can facilitate forb growth (Jenks et al. 1996). However, many forbs are highly palatable to cattle and, given their larger size, cattle can remove a large volume of forbs (Lyons and Wright 2003). During drought or when annual growth of herbaceous material is overused, cattle may increase use of woody plants, potentially increasing competition with deer (Severson and Medina 1983).

Domestic sheep and goats (*Capra hircus*) have diets very

similar to deer (forbs and browse), and as such, have the potential to seriously reduce forage available to deer (Smith and Julander 1953). Cattle are the most important class of livestock to consider in these guidelines because of their abundance and widespread distribution across rangelands of the GPE.

In the Great Plains, dietary overlap between cattle and deer is usually low because of the predominance of grass in cattle diets and browse and forbs in deer diets (Mackie 1970, Knowles 1975, Komberec 1976, Mackie et al. 1998). The effect of any dietary overlap not only depends on abundance of commonly used forage species (Godwin and Thorpe 1994), but also on relative numbers of cattle, deer, and other large herbivores present. Impacts on deer are minor when cattle stocking rates are controlled such that cattle use primarily grass species and limited browse. But if higher cattle stocking rates result in greater browsing by cattle, forage competition can reduce nutrient intake of mule deer or displace them from preferred habitat (Austin and Urness 1986, Godwin and Thorpe 1994).

Deer tend to avoid cattle and areas heavily grazed by cattle (McIntosh and Krausman 1982, Wallace and Krausman 1987, Kie et al. 1991, Loft et al. 1991, Yeo et al. 1993). This observation appears to be most pronounced during the rearing season (Loft et al. 1987, Loft et al. 1991). Within a general region, areas that have been ungrazed or lightly grazed by cattle tend to have the highest mule deer densities. Gallizioli (1976) suggested that those areas had higher vegetative productivity and better habitat conditions than areas intensively used by cattle.

Light to moderate grazing by cattle utilizes the grass component of rangeland but leaves adequate forbs and woody vegetation for deer (Fig. 7). The effects of overgrazing may include shifts in the plant community, soil compaction, and loss of mulch, which may result in increased runoff and erosion, and a declining trend in plant vigor (Severson and Medina 1983, Jones 2000). These trends may occur rapidly, but frequently take years to occur and therefore be poorly appreciated by local managers who do not detect these slow shifts among the normal and sometimes erratic annual changes (Peek and Krausman 1996, Bleich et al. 2005). Enclosures, time-lapse-photo sequences (Klement et al. 2001) and fence line observations (Fig. 8) are important aids to appreciate the long-term effects of grazing. The Great Plains is an important region for cattle grazing with over 40% of the cattle in the USA. Therefore, practices and policies that address grazing management will have high potential to improve mule deer populations (Longhurst et al. 1976).

Ungulate Competition

Competition between 2 species can occur for any resource that is in short supply and used by both. Concerns of



Figure 7. Appropriate livestock grazing in the GPE leaves adequate forbs and woody vegetation to meet the nutritional and cover requirement of mule deer. (Photo by Lloyd Fox/KDWP).



Figure 8. Overgrazing may cause degradation of plant communities and increased soil erosion resulting in long-term declines in both plant species diversity and plant vigor, the foundations for animal communities. (Photo by Adam Schmidt/Saskatchewan Ministry of Environment).


ungulate competition are usually focused on forage resources. The degree of forage competition between 2 species depends primarily on amount of dietary overlap (similarity in diet) and whether plants used by both species are in short supply (Holechek et al. 1998). Competition of mule deer with other ruminants for food and space is a function of inter-relationships of range-overlap, diet similarity, consumption rates and amounts, forage availability, relative size, species distribution patterns, timing, and social interactions (Nelson 1982). A high degree of

dietary overlap does not infer competition; it only indicates the potential exists. Resource partitioning mechanisms facilitate coexistence of sympatric cervids in the form of spatial or temporal segregation, species-specific preferences for forage plants and plant parts, and different feeding heights (Hudson 1976).

Elk, moose (*Alces alces*), pronghorn, and white-tailed deer coexist with mule deer to varying degrees throughout the Great Plains. Mule deer diets contain predominantly forbs in spring and summer and browse in winter (Mackie 1970, Singer and Norland 1994, Miller 2002). Mule deer are competitively subordinate to elk under poor range conditions because elk have a greater diet adaptability, greater digestive capacity (Collins and Urness 1983), and larger size and reach in browse habitats (Leslie et al. 1984). Additionally, crude protein

maintenance requirements for elk are lower than for mule deer (Nelson and Leege 1982). Mackie (1976) reported significant dietary overlap of elk with mule deer; however, little interspecific aggression was observed. This observation suggested range separation between the 2 species was a consequence of individual ecological requirements rather than overt avoidance. Although moose and pronghorn eat forages used by mule deer, limited range overlap occurs with moose, and the spatial and temporal segregation with pronghorn results in minimal competition with mule deer (Deschamp et al. 1979, Boer 1997, Yoakum 2004).

White-tailed deer and mule deer have considerable dietary overlap. Both species possess small rumens and gut length relative to body size, which requires them to be more selective and eat smaller volumes of easily digestible food compared to larger ruminants. Competition for food between the deer species is limited because mule deer evolved in drier, more variable environments, and are adapted to handling larger amounts of coarser forage, whereas white-tailed deer are restricted to more succulent, higher quality foods (Mackie et al. 1998). The adaptation of white-tailed deer to acquire nutrition from highly nutritious and easily digestible plants has resulted in a close association with agriculture (Mackie et al. 1998), and is probably one reason why this species surpassed mule deer as the dominant deer in the early and mid 1900s in the northern Great Plains. White-tailed deer have more finely structured incisors, which reflect their more selective foraging behavior compared to mule deer, as well as differences in pattern and timing



of tooth replacement (Gordon and Illius 1988). Potential competition for space seems to be limited because mule deer are adapted to more open environments with greater extremes in temperature and wind-chill compared to white-tailed deer, resulting in winter habitat segregation (Mackie et al. 1998, Dubreuil 2003). Mule deer that occupy open, dry environments have cooling and water conservation adaptations (lack sweat glands, dense blood vessels in larger ears to dissipate heat, panting to cool), which may serve as mechanisms for summer habitat segregation from white-tailed deer, which are less heat tolerant and select moister, cooler habitats with overhead cover in summer (Mackie et al. 1998). During winter in the southern Black Hills, mule deer selected ponderosa pine (*Pinus ponderosa*)-mountain mahogany (*Cercocarpus montanus*)-Rocky Mountain juniper habitats with > 70% canopy cover and a grass-forb and shrub understory (Dubreuil 2003); deer also selected burned ponderosa pine dominated habitats. In the summer, mule deer selected ponderosa pine habitats, but avoided burned pine, pine-aspen (*Populus tremuloides*), and meadow habitats. Selected habitat characteristics differed between mule deer and white-tailed deer, which could have occurred due to competitive interactions. There are no studies providing evidence of social dominance of 1 deer species over the other as a factor leading to habitat segregation. Anthony and Smith (1977) demonstrated that interaction between the 2 species due to their similar diets but, observed that they were spatially separated in an elevation zone. Brunjes et al. (2006) documented the importance of open space for mule deer and areas with concealment features as important for white-tailed deer in areas where the species were sympatric in Texas.

A potential problem in the future is the spread of feral swine (*Sus scrofa*). In 1982 feral swine had only been reported on a widespread basis within the range of mule deer in California, New Mexico, and Texas. By 2004, feral swine had been reported within the range of mule deer in Arizona, California, Kansas, Nebraska, Nevada, New Mexico, Oklahoma, Oregon, and Texas (Hutton et al. 2006). In July 2007 a small herd of feral swine was reported within North Dakota's primary mule deer range, the Badlands of Little Missouri National Grasslands. Feral swine (wild boar phenotype) have also established self-sustaining populations in Saskatchewan.

Some of the spread of feral swine is due to the prolific nature of this animal, while other disjunct populations probably resulted from escapes from domestic herds and game farms, and unauthorized releases of animals into the wild. Feral swine not only contribute to habitat destruction by excessive rooting and grazing; they can also influence wildlife populations by competing directly for food, spreading diseases, behaviorally displacing wildlife from usable habitat, and eating young (Wood and Barrett 1979, Seward et al. 2004). Potential influence of feral swine on mule deer is unknown, but may be substantial, particularly where

mule deer habitat interfaces with agricultural cropland and riparian habitat.


Ungulates are not the only group of animals that can affect vegetation and potentially compete with mule deer for forage. Historically, grasshoppers have periodically been severe competitors for forage on the northern GPE (Severson and Sieg 2006). In some cases, rodents can impact grass and forb density through seed predation and herbivory (Brown and Heske 1990, Howe and Brown 1999). As a result, managers should consider all grazers and how they are using vegetation.

Interference competition can occur between rangeland cattle that carry Bovine Viral Diarrhea Virus (BVDV) and mule deer, which can have negative consequences for mule deer populations (Hibler 1981). BVDV can cause blindness in adults and fawns (Hibler 1981), still born fawns, and congenital hypotrichosis in fawns (Zimmerman et al. 2004); and mule deer populations in close proximity to cattle or their feces can be affected. For example, Zimmerman (2004) documented that 27% of mule deer sampled in the southern Black Hills were exposed to the disease. Moreover, Van Campen et al. (2001) determined that 60% of mule deer sampled near Pinedale, Wyoming had positive titers for the disease. Consequently, diseases, such as BVDV, that affect mule deer can limit populations despite the presence of quality habitats.

Stocking Rates

Stocking rate is usually defined as "the amount of land allocated to each animal unit for the grazable period of the year" (SRM 1989). There are a variety of units used to express stocking rates, however, throughout most of the ecoregion, Animal Unit Months (AUMs) per square mile is the basic unit of grazing capacity and is defined as potential forage intake (animal demand) of 1 animal unit for 1 month or 30 days (Vallentine 1990). A qualitative measure of carrying capacity, the "animal unit month" is further described as 750 pounds of air-dry forage (2.5% of body weight \times 1,000 pounds \times 30 days). An "animal unit" (AU) is considered to be a cow-calf pair. Thirty days of grazing by a cow-calf pair constitutes 1 animal month (AM). The U.S. Forest Service (USFS) gives the following estimates: 1 yearling AM = 1 AUM, 1 cow-calf pair AM = 1.32 AUM, and 1 bull = 1.5 AUM (Svedarsky and VanAmburg 1996). The standard for AU is based upon a 1,000 pound animal, but over time livestock weights have been increasing because of changes in breeds, genetic development, and improved nutrition. In North Dakota, average cow weight at weaning is 1,231 pounds, and average calf weaning weight (heifers, steers, and bulls) is 557 pounds (Ringwall and Helmuth 1998).

Stocking intensity is the most important factor affecting rangeland productivity and stability (Wilson 1986).



Van Poolen and Lacey (1979) reviewed numerous studies and concluded that adjustment in animal numbers has a greater effect on herbage production than type of grazing system.

Maximum utilization rate recommended for rangelands in good condition grazed in dormant season is 35-40% (Holechek et al. 1998). Precipitation rates are the leading indicator of annual forage production. Jensen (1990) reviewed published tree-ring data for North Dakota from Will (1946) from 1406 to 1891, and annual precipitation data for the years 1981 to 1990 (U.S. Department of Commerce 1981-90). Based upon this review of 585 years of weather information he found: 1) mean length of dry and wet periods were 8.8 and 8.3 years, respectively; 2) the longest dry period was 16 years (1633 to 1646), the longest wet period was 39 years (1663 to 1702), and annual precipitation rates, between 1892 and 1990, were in drought status for 35% of years (USFS standard defines <85% of average precipitation as drought); 3) drought conditions existed during 40% of summer growing seasons and 53% of early fall periods; and 4) precipitation rates were totally independent of previous year precipitation. Jensen (1990) found no detectable patterns of wet and dry periods. In short, no one should be surprised by a periodic lack of precipitation in the GPE. When stocking rates are being set and grazing systems developed; producers and land managers should plan for drought conditions rather than stock at maximum capacity.

The effects of climate change on rangeland livestock production have long been under consideration (Baker et al. 1993). Researchers have suggested a major increase in future drought conditions for the northern (Sorenson et al. 1998), and central Great Plains (Gu et al. 2007). Precipitation rates and the predictability of long-term drought for the Great Plains appear closely tied to sea surface temperatures, particularly El Nino events in the southern Pacific (Schubert et al. 2008). The potential impacts of climate change include reduced forage production, reduced nutritional quality of forage, reduced animal productivity due to increased climate variability and environmental stress, and an increase in the spread of parasites and diseases from low to mid-latitude areas resulting in new threats and reduced livestock health (National Science and Technology Council 2008). In the future, climate change will likely affect stocking rates and livestock herd health issues on the Great Plains, and will be a growing concern for producers. These same climatic stress factors will likely impact mule deer and other wildlife populations on the Great Plains.

Rotational Grazing

Savory and Parsons (1980) advocated grazing pastures intensively and moving livestock frequently to improve range conditions while simultaneously increasing stocking rates. Some even claimed that on some ranches, stocking rates

could be doubled or tripled and still improve range and livestock productivity (Holechek et al. 2000). A synthesis of grazing studies world-wide showed that short-duration grazing systems were not superior to continuous grazing when stocking rates are held constant (Holechek et al. 2000, Briske et al. 2008). Additionally, Savory and Parsons (1980) claimed increased “hoof action” of large herds of cattle during intensive grazing would increase water infiltration, but research has shown this to not be the case. Despite these facts, some range managers continue to allow and promote Savory’s original ideas. Again, the importance of accurate stocking rate data cannot be overstated.


Rice and Carter (1982) found height and density of forage left ungrazed was influenced by both grazing system and stocking rate. Rice and Carter (1982) compared 4 grazing systems and found that a rest-rotation system resulted in a highest amount of forage ungrazed. Notably, acres/AUM for the entire rest rotation were lowest for all grazing systems tested (Rice and Carter 1982). The impetus for this research was improving residual nesting cover for prairie chickens (*Tympanuchus cupido*).

Another consideration of livestock grazing is the effect of timing. Deferred rest-rotation grazing systems may not only provide increased residual bedding cover for fawns, but limit displacement by cattle from resting pastures, particularly in June and early July, when very young fawns are vulnerable.

Riparian and Xeroriparian

Riparian (land next to wetlands, lakes, and streams) and xeroriparian (dry washes or arroyos) habitats make up a relatively small portion of the ecoregion, but are extremely important to mule deer and other wildlife. Xeroriparian areas are highly important mule deer habitats in both the Southwest Deserts and the northern Great Plains (Jensen 1988). In North Dakota during summer, adult deer were associated with secondary arroyos (those arroyos having a flat bottom 3-16 ft. wide) more frequently than expected. This use was likely associated with cooler habitats, as much as 17°F cooler than surrounding ambient temperatures (Jensen 1988). Large primary arroyos (flat bottoms > 16 ft. wide) with steep, sheer-walled sides 16-33 feet high and tertiary arroyos with their “V” shaped bottoms were avoided. Jensen (1988) thought this avoidance was due to limitations on escape options, poor visual surveillance of surroundings, and unstable footing. In contrast, secondary arroyos were avoided as bedding sites in late October. Germaine et al. (2004) found that mule deer fawn bedding site selection was most influenced by temperature and canopy closure. Fawn foraging sites likely were chosen within concealment and thermoregulation constraints (Germaine et al. 2004).

Cold air drainage into bottoms of secondary arroyos was as much as 13°F cooler than nearby juniper stands 33 feet



above the arroyo bottom (Jensen 1992). Use of warmer micro-climates has been documented for mule deer (Wood 1988) and other cervids (Robinson 1960, Henshaw 1968, Staines 1976). Additionally, home ranges of adult does were significantly smaller in drainages that were highly dissected with arroyos when compared to flatter and more gently rolling drainages (Jensen 1988).

Fawns also used bedding sites closer to secondary arroyos more frequently than expected. However, when coyote (*Canis latrans*) dens were present in the drainage this pattern was not supported. Apparently coyotes also used these arroyos as travel corridors, and either mule deer avoided these areas or coyotes preyed more on fawns using these arroyos than in surrounding areas (Jensen 1988).

Water and distribution of riparian and xeroriparian habitat also influences cattle distribution. This is most easily seen around water developments where several studies have documented the influence of concentrating cattle on vegetation around water developments out to ≤ 0.25 miles and perhaps as much as 0.5 miles (Jensen 1991, Belsky et al. 1999, Maxwell 2001). In summary, both riparian and xeroriparian areas provide cover, secure bedding sites, and a diversity of forbs and shrubs for feeding, as well as a source of pooled water. These areas must be provided protection from overuse when developing grazing strategies.

Improving Habitat with Livestock

Some work has investigated use of livestock as a mule deer habitat improvement tool (Severson 1990). This approach should not simply reduce grazing pressure to improve conditions, but actually alter condition or structure of forage to increase deer carrying capacity above that in the absence of livestock. Livestock grazing has resulted in improvements to mule deer habitat in the past, but these improvements have not always been planned actions (Connolly and Wallmo 1981). Managers must be wary of blanket claims that heavy grazing improves mule deer habitat and guard against this being used as an excuse for overgrazing. In reality, improvements can only be made through strictly manipulated timing of grazing specifically for this purpose (Severson and Medina 1983), based upon a carefully crafted management plan.

Timing and location of treatments needed to improve mule deer habitat may not be in the best interest of livestock operators from a financial standpoint (Longhurst et al. 1976). There are 4 basic principles for effective range management that collectively facilitate increased livestock production, improved watershed condition, and ecosystem stability:

- Design grazing system with appropriate grazing timing and intensity (avoids loss of forage plant species or ground cover, or risk of soil erosion);

- Leave adequate leaf area to ensure re-growth (ensures plant vigor and drought resistance);
- Allow a period of non-grazing during the active growth season (improves range productivity); and
- Control livestock distribution and access to minimize selective grazing behavior and re-grazing of plants (ensures plant vigor and promotes root growth and drought resistance).

GUIDELINES

A. Grazing Plan

Grazing should always be done under the direction of a grazing management plan that provides for adaptive management and considers provisions outlined in The Wildlife Society's (2003) position statement regarding livestock grazing on federal rangelands. The overall goal of a grazing plan should be based upon maintaining appropriate ecosystem functions. Healthy land benefits wildlife, cattle, and man.

1. In the Great Plains, goals of a grazing system will likely include:
 - Maintain or increase density, vigor, cover, and diversity of vegetation, particularly native perennial grass species
 - Decrease exotic (e.g., leafy spurge [*Euphorbia esula*]) and increaser species (e.g., prickly pear cactus, while increasing native palatable species; and
 - Increase health of riparian areas (see below).
2. Managers should develop grazing plans in full cooperation with rangeland management specialists familiar with local vegetation associations. Guidelines developed in one habitat type may not be completely applicable in another. Remember that stocking rate of cattle on the range usually has more of an effect than various management plans.
3. If the plan covers a ranch that includes several administrative agencies, include the entire ranch in a coordinated ranch management plan. A coordinated plan might allow greater flexibility to rotate seasonally between pastures and season of use of pastures annually.
4. The plan and any associated rotational system should be flexible enough for the landowner, permittee, and land management agency to adapt to changing environmental conditions.
5. Develop a contingency plan for reaching maximum utilization level, particularly in drought conditions. Drought is defined as "prolonged dry weather, generally when precipitation is less than 75 % of average annual amount" (SRM 1989). Periodic drought on the Great Plains should be expected and anticipated when developing a grazing plan. The plan should include specific recommendations for responding to drought conditions in a timely manner.
6. Management of riparian areas must be carefully planned (Elmore and Kauffman 1994). In these environments, timing of grazing is important.

Table 4. Qualitative characteristics of grazing intensity categories used to characterize New Mexico rangelands (from Holechek and Galt 2000).

QUALITATIVE GRAZING INTENSITY CATEGORY	USE OF FORAGE (% BY WEIGHT)	QUALITATIVE INDICATORS OF GRAZING INTENSITY
LIGHT TO NON-USE	0-30	Only choice plants and areas show use; there is no use of poor forage plants.
CONSERVATIVE	31-40	Choice forage plants have abundant seed stalks; areas > 1 mi. from water show little use; approx. $\frac{1}{3}$ - $\frac{1}{2}$ of primary forage plants show grazing on key areas.
MODERATE	41-50	Most accessible range shows use; key areas show patchy appearance with $\frac{1}{2}$ - $\frac{2}{3}$ of primary forage plants showing use; grazing is noticeable in zone 1-1.5 mi. from water.
HEAVY	51-60	Nearly all primary forage plants show grazing on key areas; palatable shrubs show hedging; key areas show lack of seed stalks; grazing is noticeable in areas > 1.5 mi. from water.
SEVERE	> 60	Key areas show clipped or mowed appearance (no stubble height); shrubs are severely hedged; there is evidence of livestock trailing to forage; areas > 1.5 mi. from water lack stubble height.

Table 5. Recommended grazing utilization standards for Great Plains Ecoregion (based in part on modifications of Holechek et al. 1998:207 derived for the Southwest Deserts).

REPRESENTATIVE VEGETATION TYPES AND GEOGRAPHIC REGIONS	ANNUAL PRECIPITATION (IN.)	UTILIZATION MAXIMUM ON POOR RANGES OR RANGES GRAZED IN GROWING SEASON* (%)	UTILIZATION MAXIMUM ON GOOD RANGES GRAZED IN DORMANT SEASON (%)
Chihuahuan Desertscrub and Semidesert Grasslands (Trans-Pecos and Panhandle of TX and OK)	< 12	25	35
Short and Mixed Grasslands (Central and Northern GPE)	10-21	30	40
Pine, Mixed Conifer, Spruce-Fir Forest	16-50	30	40

* If a pasture is used during the growing season, no use is allowed during other times of that year (i.e., livestock cannot be returned to the pasture later that same year).

Table 6. Grazing intensity guide for key shrubs for southern Great Plains (common winterfat [*Krascheninnikovia lanata*], fourwing saltbush [*Atriplex canescens*], mountain mahogany [*Cercocarpus spp.*]), based on New Mexico rangelands (from Holechek and Galt 2000).

QUALITATIVE GRAZING INTENSITY CATEGORY	USE OF CURRENT YEAR BROWSE PRODUCTION (% BY WEIGHT)	LEADERS BROWSED (%)
LIGHT TO NON-USE	< 30	< 15
CONSERVATIVE	31-50	16-50
MODERATE	51-75	51-80
HEAVY	75-90	81-100
SEVERE	> 90	100, plus old growth used

B. Stocking Rate

1. Stocking rates should be maintained at a level below long-term capacity of the land. Because of dramatic environmental fluctuations and likelihood of drought, stocking at full capacity results in overuse in approximately 50% of years and may necessitate supplemental feeding or liquidation of livestock. Stocking somewhere below capacity leaves forage in wet years, which will help plants recover and build some energy reserves (Holechek et al. 1999). Martin (1975) concluded the best approach would be stocking at $\leq 90\%$ of average proper stocking, but with some reductions during prolonged severe drought.
2. Make use of sources such as the Natural Resources Conservation Service (NRCS) Ecological Site Descriptions that give production estimates and aid in determining appropriate stocking levels.
3. Steep slopes, areas of extremely dense brush, and lands distant from water sources will not be used by cattle and should be deleted from grazable land area (Fulbright and Ortega-Santos 2006). Holechek et al. (1998) recommend that lands with slopes between 11% and 30% be reduced in grazing capacity by 30%, lands with slopes between 31% and 60% be reduced in grazing capacity by 60%, and lands with slopes $> 60\%$ be deleted from the grazable land area. Also, they suggested that lands 1-2 miles from water be reduced in grazing capacity by 50% and lands > 2 miles from water be deleted from the grazable land area.
4. To facilitate comparison of stocking levels between ranches in similar areas, stocking levels should be clearly stated in uniform terms. Stocking levels should be in terms of AUMs or "head/mile² year-long," using only capable and suitable acres for calculation of square miles in the allotment.
5. Use classes of livestock that are least apt to impact preferred deer dietary items. Weight of the breed of cattle being stocked should also be taken into account.

C. Use Rates and Stubble Heights

1. Utilization rate is closely related to stocking rate. Reduction in utilization, if needed, can usually be accomplished by simply reducing stocking rate accordingly.
2. Consider timing of grazing; even light stocking rates in some vegetation associations (e.g., riparian) can be detrimental if grazing occurs at the wrong time of year, such as too early in the season.
3. Annual monitoring of grazing intensity is essential for proper management of rangeland resources. Although most monitoring programs are labor intensive, rangeland can be evaluated with more qualitative guidelines such as those outlined by Holechek and Galt (2000, Table 4).
4. Manage for utilization rates of 25-35% of annual forage production in desert and desert scrub and 30-40%

use in semi-desert and plains grassland (Table 5).

These utilization rates were developed for optimal livestock management; cattle utilization rates to optimize mule deer habitat quality would be at the lower end of these ranges (Lyons and Wright 2003). Robel-pole measurements (Robel et al. 1970) provide a quick and useful measure of residual cover.

5. Avoid heavy grazing ($> 50\%$) averaged over the whole area (Table 4). Depending on topography, there might be some tolerance for heavy use on $\leq 30\%$ of the grazable land, but immediate reduction in livestock numbers is needed anytime use of $> 33\%$ of the area is classified as severe (Holechek and Galt 2000).
6. Avoid heavy use of the same areas year after year (Table 4, Holechek and Galt 2000).
7. Consider residual vegetation height when evaluating intensity of grazing, rather than simply percentage of annual herbage removed (Holechek et al. 1982, Hanselka et al. 2001).
8. Holechek and Galt (2000) provided useful stubble height guidelines that are applicable to most rangelands in Southwest Deserts and may provide useful insight for Great Plains rangeland. These guides correlate stubble height measured to overall intensity of grazing.
9. Livestock should not be allowed to browse $> 50\%$ of annual leader growth (by weight) of woody shrubs, which equates to approximately 50% of leaders browsed (Holechek and Galt 2000, Table 6).

D. Other Considerations

1. Emphasize winter grazing. Grazing rangelands in winter has less impact on forage production and range condition than grazing during the growing season,

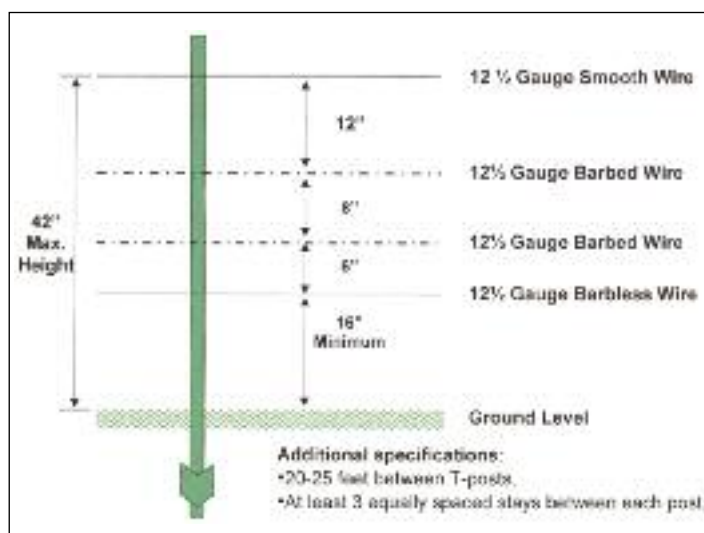


Figure 9. Specifications for a four-strand wildlife-friendly fence. Modification to existing fences can be made easiest by either removal of the bottom wire of an existing four-strand fence, or replacement of the bottom wire with a smooth wire that is at least 16 inches off the ground, 18 inches or more on range shared by pronghorn.

especially for small allotments with limited rotational opportunities. However, even moderate use of forbs by cattle in winter may impact mule deer nutrition (Lyons and Wright 2003).

2. Improve riparian habitats by controlling timing of grazing, reducing utilization, or eliminating grazing in some sections that are very important to mule deer. No grazing in some important riparian zones may be the preferred method to improve these crucial habitat components (Elmore and Kauffman 1994). Grazing by livestock may be a means to stress invasive grass species such as smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) on some sites and prevent them from dominating the area. Timing and duration of the cattle grazing may be critical in those situations and consultation with local range management and invasive species managers is recommended before this approach is applied.
3. Establish wildlife passage standards for all fences (Fig. 9). We believe a unified message should consider fencing requirements of both mule deer and pronghorn (Autenrieth et al. 2006), so that wildlife managers are sending a consistent message to landowners and the public. Five-strand barbed wire fences and net-wire

fences are not acceptable. New fences should be built to wildlife specifications and existing fences that differ from wildlife specifications (e.g., net-wire, 5-strand barbed wire) should be altered. A wildlife-friendly fence should include:

- Smooth (barbless) top wire;
- Minimum of 12 inches between the top 2 wires. Deer prefer to jump over fences and if the top 2 wires are too close they can catch their feet between these wires and become entangled;
- Smooth bottom wire ≥ 18 inches from the ground; and
- Maximum height of 42 inches.
- Interior pasture fences may include 3-wire fences where livestock pressure is normal.

WATER AVAILABILITY AND HYDROLOGICAL CHANGES

BACKGROUND

The GPE area has a middle-latitude, dry, continental climate with abundant sunshine, moderate precipitation, frequent winds, low humidity, and a high rate of evaporation.

Mean annual temperature ranges from approximately 43° F in the north to 63° F in the south. Mean annual precipitation ranges from 4 inches in the west to 20 inches in the east. During most years in much of the area, irrigation is required for economically viable yields of typical crops like alfalfa (*Medicago sativa*), corn (*Zea mays*), cotton, soybeans (*Glycine max*), and peanuts (*Arachis* spp.). Water developments for crop production, such as irrigation reservoirs, channel diversions, and irrigation wells, are common practices on private property. Dryland farming techniques are used in the production of much of the wheat and sorghum that is grown in the region; however, a variety of other crops are also grown commercially.

Water developments for livestock production, such as ponds and wells (powered by windmills), are common practices on private property in the GPE. Water development projects are also an economic force occurring in the region. Indeed, water development projects, big and small, are attractions to tourists and influence use of the land and conditions for mule deer.

Streams and rivers in the Great Plains change as a result of flood events, annual precipitation, prolonged droughts, and human removal of water (directly from streams or from ground water resources). Recovery of streams and riparian vegetation frequently takes long periods of time and may be influenced by events far from stream courses. Baker (1977) stated that stream channel adjustments and vegetation recovery of the

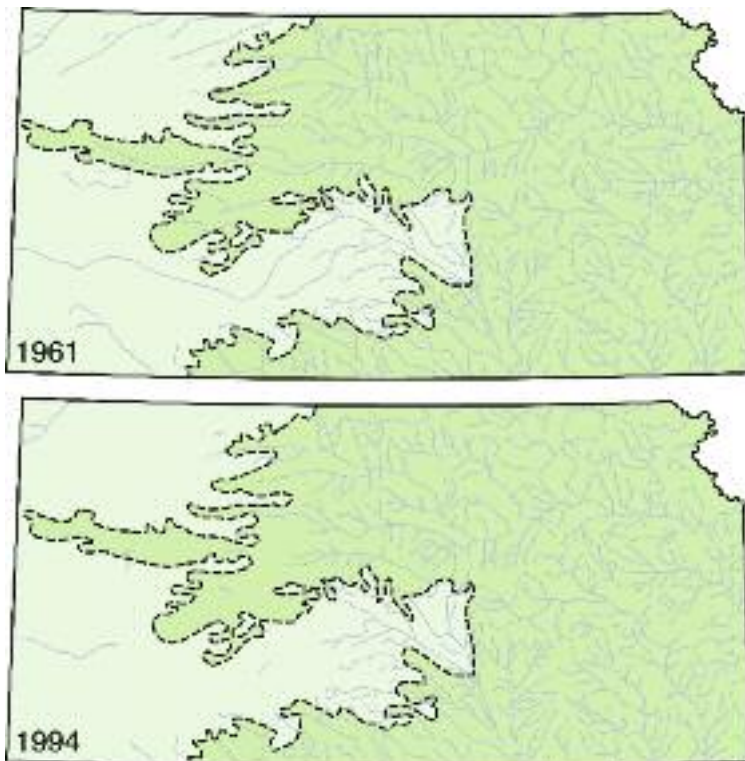


Figure 10. Changes in the distribution of major perennial streams in Kansas have been associated with changes in agricultural use of water. Top illustration is adapted from United States Geological Survey 1:500,000 scale base map compiled in 1961. Bottom illustration summarizes stream flow observations made by the Kansas Department of Health and Environment from October 1989 through January 1994.

Cimarron River in southwestern Kansas continued for decades after a single event (VanLooy and Martin 2005).

ISSUES AND CONCERNS

Habitat use and deer movements

A fundamental goal of many mule deer management programs is to have mule deer scattered throughout broad areas with few unoccupied sites. Habitat improvements are then initiated to fill voids of habitat deficiencies. Water development projects are seen as one means of accomplishing that task. Few studies have been completed on mule deer habitat relationships in the Great Plains, especially on private property in the region. We therefore rely heavily on studies conducted elsewhere and assume similar conditions (Heffelfinger et al. 2006).

Water Exploitation and Use

The efficiency with which water is retained and used in the GPE has changed through time. Soil and water conservation practices are designed to maximize use of available water (e.g., field terraces, mulch and stubble management practices). These practices reduce runoff, and thus influence stream flow intensity and frequency. Further, use of ground water for irrigation has had a large influence on stream flows as it depleted sources of water for above-ground stream flow (Fig. 10). Various state and county programs provide assistance for landowners to manage water resources, and state and local agencies, such as ground water management districts, regulate development. However, federal programs provide the bulk of funding for water projects. As a result, much of the funds used in water development projects and programs in this region are gathered through taxes levied on people living in other regions.

Exploitation of water resources has changed the face of habitat in this ecoregion. Development of techniques to pump large volumes of water resulted in widespread use of center-pivot irrigation (Fig. 11). That innovation resulted in conversion of dryland farming to irrigated farming and to conversion of thousands of acres of native habitat to crops like corn on sites prone to wind and water erosion.

Water in the High Plains (Ogallala) aquifer is occasionally referred to as “fossil water” as much of the vast quantity of water in that aquifer was the result of water stored during the last ice age. It is not being recharged at a significant rate compared to the current demands for water. Life expectancy of this resource is limited (Fig. 12) which means major land-use changes will need to occur in the

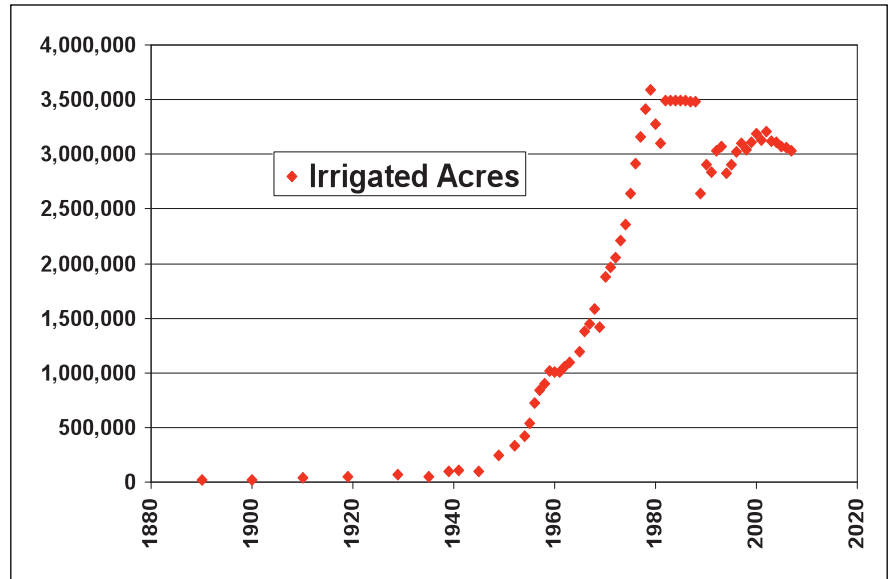


Figure 11. Development of the center pivot irrigation in the High Plains of western Kansas occurred rapidly during the 1960s and 1970s, as can be seen in the graph of irrigated acres by year shown above (source of data from <http://www.kgs.ku.edu/HighPlains/atlas/atistct.htm>). Sand sage habitat, like that south of the Arkansas River near Garden City, KS were quickly and intensively converted to irrigated cropland, as can be seen in these near infrared Landsat satellite image taken in 2002 (bottom). (Images courtesy of Mike Houts/Kansas Applied Remote Sensing Program).

near future. Exploitation of ground-water resources has allowed agricultural activity to occur at intensities otherwise not possible (Fig. 13). Hopefully, consideration of future uses of these areas will incorporate mule deer habitat.

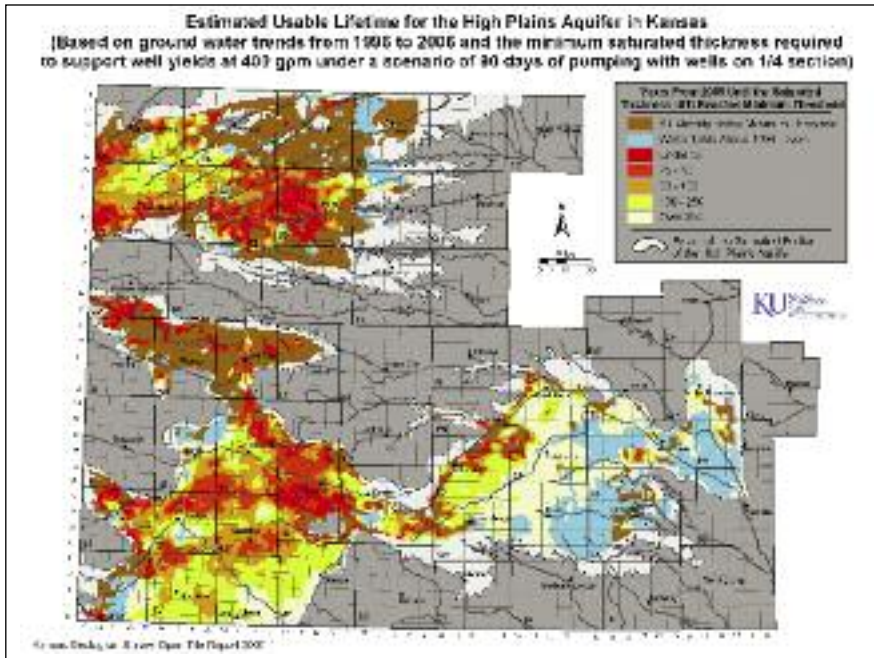


Figure 12. Center pivot irrigation systems using ground water from the Ogallala Aquifer in the High Plains of Kansas have a limited life expectancy, which will result in future land-use changes. (Diagram courtesy of Kansas Geologic Survey).



Figure 13. Center pivot irrigation systems have allowed arid areas of the Great Plains to be converted to crop production. This may provide improved nutrition for mule deer but frequently results in increased conflicts between people and deer. Irrigation allows livestock populations to be maintained at higher levels in new regions (note cattle feedlot in foreground) with chances for overgrazing becoming more prevalent, thus affecting native habitats beyond the area of crop production. (Photo by Lloyd Fox/KDWP).

Water Quality and Disease Potential from Anthropogenic Water Sources

Water quality has changed as a result of irrigation. As an aquifer is lowered there is a tendency for highly mineralized ground waters to be brought to the surface. Irrigation systems inject herbicides, pesticides, and fertilizers into irrigation waters. Perennial streams have ceased to exist and have been replaced by ephemeral streams, frequently with

small, stagnant pools of water with high evaporation rates that create potential for water quality problems (Kubly 1990).

Water quality has been raised as a potential health concern for ungulates (Sundstrom 1968, deVos and Clarkson 1990, Broyles 1995, Krausman et al. 2006). Both natural and artificial water sources can become contaminated with the bodies of dead animals. Botulism (*Clostridium botulinum*) was documented in bighorn sheep (*Ovis canadensis*) at 2 artificial watering sites in California (Swift et al. 2000). Deer that died after consuming water during droughts in western South Dakota were documented with polio lesions in brain tissue; lesions were presumably related to cause of death (J. A. Jenks, SD State University, unpublished data). In general, however, quality of water from natural and developed water sources in the southwestern U.S. was not considered a wildlife health issue (deVos and Clarkson 1990, Rosenstock et al. 2004, Bleich et al. 2006).

The Great Plains mark the limits of range distribution for some parasites and diseases, and some might argue that periodic scarcity of water provides evolutionary advantages for some species over others. Midges (*Culicoides* spp.) that increase in stagnant water are involved in transmission of hemorrhagic diseases in deer. However, midges can travel > 12 miles from water sources, and the relationship between low precipitation, higher midge populations and increases in hemorrhagic disease have not been established (Rosenstock et al. 2004). In contrast, during years with high levels of precipitation, intermediate hosts for meningeal worm may increase, which could affect prevalence levels in mule deer (Jacques and Jenks 2004).

Feeding and baiting are implicated in the spread of some diseases, including tuberculosis and chronic wasting disease. Similar arguments could be raised about artificial concentrations of mule deer at water sources. However, further research is needed to investigate this issue.

Benefits of water

A primary habitat function of water for mule deer in the GPE is the benefit it provides for plant growth, especially along riparian corridors. Free standing water for consumption by mule deer may be important in determining daily or seasonal movement patterns, especially in the western and drier portions of the ecoregion. Development of additional water sources intended primarily for mule deer may aid in distributing mule deer through a larger area and thus reduce deer

impacts on vegetative cover at traditional watering areas (Rosenstock et al. 1999). Decisions to develop artificial water sources are best addressed at the local or site-specific level rather than ecoregion level.

GUIDELINES

A. Need

Drought conditions are not as common in the GPE as they are in Southwest Desert and Intermountain West Ecoregions; however, they may be long and severe. Planning water developments specifically intended to improve conditions for mule deer should be initiated only after a critical review of need and consideration of potential negative impacts. Some items to consider before initiation of new projects include:

1. Is lack of available free water limiting current distribution or abundance of mule deer?
2. Will developments cause detrimental additional exploitation of forage resources? This may include either year-round forage utilization or exploitation of forage that is critical during another season.
3. Will developments increase competition between mule deer and other species?
4. Will developments concentrate mule deer in a manner that could increase predation, poaching, or disease or parasite transmission?
5. Will developments increase movement or exposure of mule deer through high risk areas (e.g., across highways)?
6. Will developments increase conflicts between people and mule deer (e.g., increase crop depredation)?
7. Will water developments be matched with forage availability and other habitat features and mule deer population management goals?

B. Water quality

Water quality has generally not been identified as an immediate health issue for mule deer. Therefore, water quality seldom receives high priority in deer habitat management plans. However, issues and trends in water quality throughout the Great Plains suggest that natural resource managers may need to periodically review water quality. Some common-sense management to improve water quality includes:

1. Design catchment-type water sources so they will be periodically flushed during high rainfall events.
2. Avoid areas where water may be contaminated or contain high levels of minerals, herbicides, pesticides, fertilizers, livestock waste, etc.
3. Periodically examine sites and remove organic debris.
4. Provide shade for surface water catchments.
5. Use materials and designs that reduce moist, muddy substrates and habitat conditions favorable for midge populations.
6. Periodically test water quality.



Figure 14. Water development projects in the Great Plains include diversion canals that may become hazards to deer and impede their movements. (Photo courtesy of Nebraskaland Magazine).



Figure 15. Artificial water collection and holding facilities may allow for a better distribution of mule deer through the available habitats. (Photo by Brandon Mason/Mule Deer Foundation).

C. Design

Water developments that benefit mule deer may take many forms in the Great Plains. The natural drainage features may be modified with dams, creating ponds and even reservoirs. Water-diversion systems transport water from 1 location to another (Fig. 14). Ground-water sources may be brought to the surface with windmills or solar pumps. Natural springs and seeps may be modified to gather and maintain water in storage tanks or reservoirs, and thus provide water for an extended period of time. These developments are frequently initiated for another primary purpose. Artificial collection systems specifically designed to provide water for wildlife have been employed

throughout western North America (AGFD 2004, Krausman et al. 2006; Fig. 15).

D. Storage Capacity

Storage capacity is a critical part of design in water-catchment devices and pond construction. A 1-inch rainfall will produce approximately 100 gallons/160 ft² of area in the watershed. Topography, vegetation, and soil will modify yield, and professional advice is frequently necessary to match construction design to water storage needs (Fig. 16). Evaporation rates and number of animals using a water source also impact water storage needs.

E. Other considerations

Water management for mule deer habitat in the GPE should focus on protection of water in streams and ground-water sources feeding those streams:

1. Prevent over-allocation of ground-water resources.
2. Establish and maintain minimum stream flow



Figure 16. Professional assistance is frequently needed to design water structure systems to match storage capacity to estimated watershed yield. (Photo Mike Blair/KDWP).



Figure 17. Diversion canal built with concrete ramp to provide escape for trapped animals. (Photo by Bruce Trindle/NGPC).

requirements.

3. Construct water developments in manners that will minimize the possibility of animal entrapment and drowning (Fig. 17).
4. Water troughs should not exceed 20 inches in height to allow use by mule deer fawns.

Development of water sources to augment distribution and reliability of natural sources should include consideration of the following:


1. Must meet biological needs for improved mule deer management.
2. Should provide year-round water of adequate quality for wildlife.
3. Should meet design standards that will provide years of service with minimal maintenance.
4. Must be cost effective and provide drinking water for game and non-game species.

An opportunity for cooperation on water issues in the Great Plains exists through the Conservation Reserve Enhancement Program (CREP). The program allows partnerships between the U.S. Department of Agriculture (USDA,) states, and landowners via incentives and cost sharing for eligible conservation practices, such as establishment of native vegetation. Current project development in the Upper Arkansas River in Kansas, encompassing > 1.5 million acres in a 10-county area, is designed to conserve water resources and reduce amounts of agricultural chemicals and sediments entering the river. An objective of the project is to reduce ground water irrigation on 17,000 acres by 29,750 acre-feet annually. The project will also apply conservation practices on approximately 7,000 acres of highly erodible soils not suited for dryland farming. The combination of these activities will ensure a minimum stream flow and permanent habitat that will be beneficial to wildlife, including mule deer.

INVASIVE SPECIES

NON-NATIVE SPECIES BACKGROUND

Habitat alteration is a critical issue for native fauna in the Great Plains rangelands. This alteration has occurred in the form of land-use and vegetation changes. Much mule deer habitat has been developed, used for pasture by livestock, or converted to domestic crops, thereby creating a discontinuity of potential habitat. Land converted from native rangeland to cropland has been planted to introduced forage species to improve livestock production in spring and fall. In addition, forage and woody species have escaped ornamental, conservation, and pasture planting locations, only to invade native rangeland areas.



Effects of overgrazing are exacerbated by drought conditions, making native vegetation less capable of preventing non-native and native species invasion. The most significant non-native plant species that have invaded the GPE are: smooth brome; leafy spurge; tamarisk or saltcedar (*Tamarix ramosissima*); annual bromes, such as field brome (*Bromus arvensis*) and Japanese brome (*B. japonicus*); crested wheatgrass (*Agropyron cristatum*); Kentucky bluegrass; Timothy (*Phleum pratense*); and Russian olive (*Elaeagnus angustifolia*).

Kentucky Bluegrass

Kentucky bluegrass is a long-lived, sod-forming, cool-season perennial grass which reproduces by seed and spreads vegetatively by underground stems (Nicholson 2006). The species was reportedly introduced from Europe as a pasture grass before 1700 and its spread was so rapid, and its naturalization was so complete, that it commonly preceded settlers into new areas (Stubbendieck et al. 1985).

Kentucky bluegrass is found throughout the Great Plains, but is most abundant on range sites that have favorable soil moisture conditions, such as lowland or overflow sites. In many situations, it becomes problematic due to its ability to replace more productive and desirable grass species. Kentucky bluegrass is still very commonly planted for lawns and is commonly listed as a contaminant in cool-season grass mixtures.

When green and growing, Kentucky bluegrass is highly palatable and nutritious to all classes of livestock. Few grasses are able to withstand continued heavy grazing as well as this grass, so it increases rapidly on overgrazed pastures and meadows (Stubbendieck et al. 1985).

Timothy

Timothy, a cool-season, perennial bunch grass, was introduced from Eurasia by early colonists. Timothy reproduces by seed, with smooth stems reaching heights of 2-3 feet (Stubbendieck et al. 1985). Timothy has been seeded primarily for hay in meadows in eastern areas of the GPE. Timothy is famed for its production of leafy, palatable hay but has been proven capable of invading overflow and lowland range sites. Due to this invasion, many beneficial forbs and shrubs commonly desired by mule deer have been crowded out or replaced by both Kentucky bluegrass and Timothy.

Field Brome and Japanese Brome

Both field brome and Japanese brome are considered annual, introduced, cool-season grasses. They are widespread on disturbed areas and poor condition range sites in this ecoregion. They commonly occur on all range

sites except wetlands, sands, and choppy sands range sites (Stubbendieck et al. 1985). Most annual bromes have a very short life span, in which they are desirable for only a short period before they produce seed and die. However, in that time period they can use a considerable amount of valuable soil moisture prior to emergence of more desirable native grass species. On overgrazed sites, these annual bromes can form a dense thatch, making it very difficult for desirable species to persist.

Smooth Brome

Smooth brome was introduced from eastern Europe in 1884 (Stubbendieck et al. 1985). It is a perennial, cool-season species considered to be a good sod-forming species and palatable for all classes of livestock. Smooth brome is seeded as a cultivated pasture grass for hay and grazing, producing abundant herbage in spring and late summer. In certain situations, where smooth brome hay is produced after the plant has made viable seed, feeding hay facilitates distribution of seed into native grass areas used as feed sites. If surface disturbance occurs in the feeding areas, smooth brome seed can germinate and even become established.

Overgrazing that occurs in summer months, while smooth brome is normally dormant, further weakens native plants and allows the cool-season grass to survive. Over time, many native pastures will change from a site dominated by native, warm-season grass species to one dominated by smooth brome and other cool-season species compatible with the style of management that promotes its existence.

Crested Wheatgrass

Crested wheatgrass, a cool-season, perennial bunch grass, is native to eastern Europe and Asia. Although introduced to the U.S. in 1898, it was not commonly seeded until the 1930s, when it was used to stabilize old fields in more arid environments (Stubbendieck et al. 1985). Crested wheatgrass withstands drought and cold, has moderate salt tolerance, and establishes a stand rather rapidly. It recovers well from intense grazing, competes with weeds and forbs, and volunteers from scattered seed. Crested wheatgrass performs best on clayey and silty soils.

Leafy Spurge

Leafy spurge is a long-lived, perennial forb with a long tap root and is a widely established noxious weed and serious economic pest, especially in the northern Great Plains. Wallace et al. (1992) estimated that the acreage infested by this plant in North Dakota had doubled every 10 years for the previous 30 years. All parts of the plant contain a milky latex juice that can poison livestock. An aggressive competitor, spurge has successfully invaded native plant communities and dominated sites, thus reducing beneficial forage for mule deer (Fig. 18).



Figure 18. Leafy spurge, the yellow flowering plant in this photo, is an aggressive noxious weed capable of invading native plant communities, replacing native species and dominating sites. Toxin produced by this plant can poison livestock and probably many species of wildlife. (Photo by Adam Schmidt/Saskatchewan Ministry of Environment).



Figure 19. Tamarisk invades native riparian sites and dominates the stand, like this site along the Cimarron River in Kansas. The tap roots of tamarisk draw salt from ground water and its leaves deposit the salt on the soil surface where it reaches concentrations that prohibit the grow of many native species such as willow and cottonwood. (Photo courtesy of NRCS).

Tamarisk (Saltcedar)

Saltcedar is a deciduous shrub or small tree that grows most successfully in riparian zones (Brock 1994; Fig. 19). A facultative phraeophyte (roots grow deeply into the soil and depend on ground water), tamarisk was introduced to the U.S. in the 1800s and planted for wind breaks, creating shade, stabilizing eroding stream beds, or as ornamental shrubs (Fig. 20). Saltcedar was first reported outside of cultivation in the 1870s (Di Tomaso 1998), and the greatest degree of invasion occurred between 1935 and 1955 (Christensen 1962).

In the GPE, saltcedar is found in Colorado, Kansas, Oklahoma, Texas, Montana, New Mexico, North Dakota,

and Wyoming. Saltcedar tends to increase salinity of the soil and thus prevent the presence of many native species. Salt cedar readily takes up solutes from the soil and then deposits them above the ground from salt glands or by dropping its leaves. Salt deposition creates an allelopathic effect because surrounding plants are unable to grow in areas with these high salt concentrations (Di Tomaso 1996). For example, saltcedar can tolerate salinity $\leq 36,000$ ppm, whereas native floodplain species such as willow (*Salix* spp.) and cottonwood (*Populus deltoides*) can only tolerate $\leq 1,500$ ppm (Wiesenborn 1996).

Russian Olive

Russian olive is a deciduous tree or shrub growing to 35 feet in height, easily recognized by the scaly underside of the leaves and slightly thorny stems. Russian olive invades various wetland habitats, old fields, woodland edges, saline lowlands, riparian, and disturbed sites where it can form a dense shrub layer which displaces native species and closes open areas (Fig. 21). Russian olive is native to Europe and western Asia and was introduced into America in the late 1800s. Since then it has been widely planted for wildlife habitat, mine reclamation, and shelterbelts, leading to widespread escapes and invasion of rangeland throughout the Great Plains. Russian olive has been deemed a noxious plant in Colorado and New Mexico.

NATIVE SPECIES BACKGROUND

Two native, woody species (eastern redcedar and Rocky Mountain juniper) commonly associated with conservation plantings throughout the GPE combine to provide some of the most challenging habitat management choices. These choices differ depending upon whether you focus on benefits provided (wildlife cover) or their ability to invade and totally dominate sites occupied by more desirable native species.

Eastern Redcedar

Eastern redcedar, native to North America and found in all of the lower 48 states, is commonly found in rangeland, pastureland, road-side ditches, or almost anywhere distribution of seed occurs. Many infestations result from a lack of prescribed burning practices. When preventative measures are not taken, redcedar can form closed stands and reduce desirable plant communities. Seeds develop and mature between July and November, facilitating spread of seed by animals, such as birds, that consume and spread seed considerable distances.

Eastern redcedar has long been used in conservation plantings, such as windbreaks and shelterbelts, leading to invasion of adjacent rangeland. At a stocking rate of 250 trees/acre on shallow prairie soils in Oklahoma, redcedar can reduce forage production by 50% (Engle et al. 1987).

Loss of forage production is just one area of concern with this particular species. Due to high canopy density, rain and snow is captured in the canopy, where it evaporates back into the atmosphere. When total rainfall exceeds holding capacity of the canopy, it can then be captured in litter underneath trees. In Texas, Thurow and Hester (1997) noted that as much as 66-80% of moisture falling within the canopy of junipers was intercepted by both canopy and litter. Certainly, less intense rainfall events are more easily captured and retained by both canopy and litter. As stands of eastern redcedar become denser, potential for rainfall loss due to canopy and litter interception increases. Natural springs become less reliable sources of year-round water flow as a result of reduced rainfall reaching and entering the soil. Changing the hydrology of watersheds eventually has an impact on plant communities, leading to habitat change for targeted wildlife species.

In 1950, the NRCS in Oklahoma estimated that 300,000 acres were occupied by ≥ 50 redcedar trees/acre. That number had increased to 3.5 million acres by 1985 and 8 million acres in 2004 (Snook 1985). The rate of occupation by eastern redcedar is increasing at 762 acres/day or 300,000 acres/year (Snook 1985). Similar increases in eastern redcedar are found throughout many of the Great Plains states.

Rocky Mountain Juniper

Rocky Mountain juniper is native to the U.S. and commonly found on rocky, shallow, or eroded soils in many western states. In many situations, Rocky Mountain juniper is comparable to eastern redcedar and has even been found to hybridize with its relative. Like its relative, Rocky Mountain juniper can provide shelter and protection for wildlife, but because it rapidly spreads by seed, it can quickly invade areas where it is not desirable. A lack of prescribed burning has benefited Rocky Mountain juniper. As with redcedar, well-planned prescribed burns are very effective in controlling movement and establishment of Rocky Mountain juniper.

ISSUES AND CONCERNS

General Impacts of Invasive Species

Due to extensive grazing pressure by large herbivores, many of the herbaceous, cool-season species of concern (Kentucky bluegrass, Timothy, field brome, Japanese brome, smooth brome and crested wheatgrass) have become widely established in Great Plains mule deer range. Some believe healthy native plant communities are immune to the advancement of these non-native plant species. However, once seed is made available through some dispersal mechanism and an acceptable soil surface or vegetation disturbance has occurred, these non-native species can become established. Spread of some invasive species was aided by seeding croplands for livestock



Figure 20. Tamarisk (often called saltcedar) is an attractive plant originally planted for shade and stream bank stabilization but also used in wind breaks and as an ornamental. People select species like this instead of native species for conservation plantings. (Photo by Shane Hesting/KDWP).



Figure 21. Russian olive is another exotic species that was widely used in conservation plantings that is now invading into prairie habitats, like along this stream in Stafford County, Kansas. The initial benefits from this plant may be negated over time as it displaces native species and forms a dense single species stand. (Photo by Chris Techlenburg/NRCS).

grazing operations. Once established, their distribution has been enhanced by feeding hay produced from these pastures in other locations. Seed dispersal may also be facilitated directly by grazing animals.

Once invasive species become established in a native plant community, it becomes difficult to apply methods of management to these complex plant communities. Depending upon the targeted season of use, grazing systems, and management practices, invasive species may be relatively innocuous or rapidly alter plant composition of plant communities, thereby impacting desirable mule deer habitat. Degree of impact heavily depends upon management decisions one makes. Actions that weaken



Figure 22. Few techniques have proven effective or long-lasting in the effort to control invasive species. People often consider dense cover, like this stand of saltcedar, as beneficial for deer management and oppose techniques like prescribed burning, thus making control of exotic and invasive species time consuming and expensive, which diverts available manpower and funds from other areas. (Photo courtesy of NRCS).

health and vigor of native species will most likely strengthen the hold of invasive plants or make these plant communities unsuited for mule deer. Due to typically drier climate in the western GPE, complete recovery from a major disturbance may require several years. Livestock producers may often be limited in their approach to control invasive species due to concerns with management options. In many instances, prescribed fire is very effective in controlling both non-native and native invasive species. However, risks associated with using this management tool often limit its use.

As pointed out in the Southwest Deserts habitat guidelines (Heffelfinger et al. 2006), non-native species such as those listed above can provide direct or indirect improvement to localized mule deer habitat where native plant communities have either been overgrazed or deteriorated. However, potential for escape or invasion of these species throughout an entire range or habitat area remains a threat to long-term vegetation management for a species such as mule deer.

Management needs, opinions and perceptions regarding native and non-native woody species differ greatly throughout the ecoregion. Some people associate dense cover, such as provided by these invasive woody species, with the best possible deer habitat, while many wildlife managers view the need for more native, open areas as critical to the existence of species such as mule deer. Because of these differing viewpoints, some management practices (e.g., prescribed burning or brush management) are difficult to implement (Fig. 22).

GUIDELINES

A. The Management Plan

The first step in the process of habitat management is to evaluate current condition of the habitat. Thus, evaluation of habitat condition in a specific area with invasive species should start with assessment of the extent of invasive species distribution. Habitat managers should start with a map identifying characteristics of the area of interest. In some cases, habitat management units can be defined using differences in topography (elevation, slope, aspect, etc.), vegetation association, and availability of water or cover.

Once distribution of invasive species is assessed and habitat management units are determined, a practical and efficient monitoring system should be established. The monitoring system should include tracking direction and speed of invasion, as well as changes in vegetative composition.

Magnitude of negative or positive effects of non-native species on a specific area should be identified based on quantitative data related to mule deer population performance and specific management goals. Habitat managers should consider previous land use and potential scenarios if invasive species were absent. Outcomes of evaluations must be data driven and verifiable. On a small scale, managers may want to use maps of vegetation associations to record and track mule deer sightings or other locations. Trend data from changes in deer occurrence or abundance may help to identify habitat use and preferences to guide future habitat manipulations.

Managers must always consider all other social demands for management of the land. In areas of predominantly private land, habitat management plans will not be successful without full cooperation and coordination with landowners. Sometimes alterations by non-native species would be preferable to complete habitat destruction or fragmentation by urban development.

B. Specific Guidelines

1. Mitigate negative effects of past pasture plantings by allowing natural successional processes of shrubs and tree encroachment to create cover for mule deer.
2. Promote native species production with focus on plants used or preferred by mule deer (see Appendix A).
3. Use proper livestock grazing practices, such as appropriate stocking rates and rotations, to favor native browse establishment to benefit mule deer. Also, use grazing systems that provide intensive grazing pressure on areas where invasive species (see Appendix B) exist and are desired by grazing animals, with the intention of reducing seed production, plant vigor, and storage of nutrients.
4. Identify management and structural practices that

either remove or mitigate effects of invasive species. These practices can range from prescribed fire to grazing systems which promote health and vigor of desirable native species and discourage persistence of undesirable species.

5. Identify negative and positive effects of habitat alterations such as non-native plantings and use this information for adaptive management in future land-use decisions.
6. Never introduce non-native plant species in an attempt to “improve” habitat conditions.
7. Seed native species and practice proper range management to expedite rehabilitation of deteriorated areas. Identify deteriorated, but uncolonized, areas and make these a high priority for proactively seeding native species.
8. Consider potential for non-native plant invasion when deciding whether to build, improve, or maintain roads (Gelbard and Belnap 2003).
9. Take every opportunity to educate the public on habitat needs of mule deer and diffuse misconceptions about the need for certain vegetative types or quantities of vegetation types (e.g., juniper and other invasive woody species).
10. Eradication of invasive species is unlikely; the primary management goal should be to change vegetation composition to reduce invasive species dominance and spread and promote higher plant diversity.

HUMAN ENCROACHMENT

BACKGROUND

The GPE comprises the largest grassland ecosystem in North America, and it has been heavily influenced by the activities of man. The land is relatively flat and is broken by drainages and dotted with buttes and escarpments (Severson 1981). The rough topography is interspersed with grasslands, trees, and shrubs, which provide critical forage and cover habitat for mule deer (deVos et al. 2003). Hardwood draws and woody drainages cutting through the country also complement important cover (Mackie et al. 1998). Mule deer in prairie habitats appear to be more vulnerable to hunting than mule deer in forested habitats (Swenson 1982). Management of deer hunting in prairie habitats where both mule deer and white-tailed deer occur may need to be intensified and shifted to favor mule deer survival compared to hunting programs in other habitats that provide additional escape cover.

Vast areas of grassland have been converted to cropland in this ecoregion as the country became settled and on into the modern day agricultural period. Conversion of native grassland vegetation to small grain crops is generally seen as negatively affecting mule deer habitat. However, mule

deer may supplement consumption of native forages with cultivated crops where the crops dominate (deVos et al. 2003). Mule deer in this ecoregion are generally non-migratory, but move throughout the habitat based on localized moisture and vegetation conditions. Use of plains habitats by mule deer often appears to center on cover requirements rather than food (Severson 1981).

Human encroachment may impact mule deer habitat in a variety of ways and to varied degrees. The most obvious and negative impact of human encroachment on mule deer habitat occurs when human activities alter the physical characteristics of mule deer habitat to the extent that mule deer are no longer able to adapt to those changes and can no longer occupy that site (e.g., construction of buildings, roads, and urban centers). Human activity in the area may disturb mule deer and result in spatial or temporal displacement (e.g., noise and activities of hikers or off-road vehicle users may cause mule deer to avoid certain areas). Human activities may change habitat suitability and carrying capacity for mule deer (e.g., conversion of native habitats like sand sagebrush habitat to anthropogenic habitats like irrigated cropland).

Modern human occupation of the Great Plains has been characterized by repeated waves of settlement and expansion to dominate the land through exploitation of natural resources (primarily through agricultural practices), followed by periods of environmental extremes and resulting economic and social collapse. The Homestead Act of 1862 in the United States and the Dominion Lands Act of 1872 in Canada encouraged the settlement of the prairies (Helms 1981). Periodic droughts like those during the Dust Bowl days of the Great Depression of the 1930s



Figure 23. Wind erosion continues to shape the Great Plains as seen in this photo from 2007 in Stanley County, South Dakota. Effects of erosion will accelerate as land is taken from programs like CRP and placed into production for food, livestock, and now biofuels. (Photo by Boyd Schulz/USFWS).



Figure 24. Mule deer may be stressed when housing developments are placed in or near critical habitats. Low density developments, like these ranchettes around Wilson Reservoir, Kansas, cover large areas and benefit few people, whereas high density developments have an overall smaller footprint for the same number of people. Housing developments result in a complex of roads, people, traffic, pets, and companion livestock. (Photo by Shane Hesting/KDWP).



Figure 25. Off highway vehicle traffic can damage vegetation and cause disturbance in areas important to mule deer. The Arkansas River was designated as a navigable stream, but is now dry much of the time and accessible to OHVs. (Photo by Mark Sexson/KDWP).

have been a common recurring event during the Holocene (Grimm 2001). This pattern continues (Fig. 23) and was, in part, responsible for development of various farm programs, such as the Conservation Reserve Program (CRP) in the United States and Prairie Farm Rehabilitation Administration (PFRA) in Canada. These programs were designed to provide economic support to farmers and ranchers, promote more sustainable farming practices, and conserve natural resources by retiring cropland from production (Osborn 1997). The pattern of human demographics and farm program implementation are important components of the human encroachment issue in the GPE because these factors provide the greatest

opportunity to manage habitat for mule deer and other wildlife species.

ISSUES AND CONCERNS

Permanent Displacement by Human Occupancy

Human occupation of the landscape in the Great Plains contributes to long-term loss of mule deer habitat. Nearly all aspects of the human occupancy section in the habitat guidelines developed for the Southwest Deserts Ecoregion (Heffelfinger et al. 2006) apply to the GPE. People prefer sites with habitat components valuable to mule deer because they have attractive landscape features for human occupancy of an area. However, as people occupy these sites and modify them with their structures such as, homes, fencing, roadways, agriculture, and supporting infrastructures, such as communities, stores, and health facilities, the area loses its esthetic appeal to people and much of its habitat value for mule deer (Vogel 1989, Fig. 24). People who occupy these areas frequently bring domestic dogs and livestock that may jeopardize wildlife through direct mortality or disease transmission. These communities are often located in critical habitats needed by mule deer in times of environmental stress. The human population is increasing and expanding in some critical areas for mule deer. Lutz et al. (2003) estimated that during the mid 1990s alone, development occupied 5.4 million acres of open space in the West.

The GPE has a history of human occupancy that includes periods when large portions of the human population left the area. The U.S. Census Bureau estimated that most of the Great Plains states except Colorado, Oklahoma, and Texas had a net emigration from 1995 through 2000 (Franklin 2003). The region has both a sparse human population, and a population with a relatively high portion of people over the age of 65 (G. M. Hayden, KDWP, personal communication). These periods of emigration in the past have provided opportunities for habitat protection, such as the acquisition of areas that were developed for national grasslands.

Human occupancy of the land may lead to improved forage conditions, readily available water, and decreased predation. However, it may also lead to artificial feeding, unnatural concentration of animals, and introduction of diseases and parasites. The majority of mule deer populations in this ecoregion are not believed to have migratory movement patterns. Mule deer population densities are also relatively low compared to other ecoregions.

Spatial and Temporal Displacement

Activities of people can influence use of areas by mule deer regardless of habitat quality. Noise, livestock, and pets may influence mule deer behavior. Disturbances during hunting

seasons can cause mule deer to shift their habitat selection to areas with more woody cover, or in treeless habitats, to areas with more topographic relief (Swenson 1982). Information regarding response of deer to roads and vehicular traffic is scarce and imprecise (Mackie et al. 2003). Some studies suggest that mule deer may habituate to some disturbances, such as low-flying aircraft (Krausman et al. 1986). Volume of traffic may influence mule deer response. For example, behavior may be more affected near main roads but less so near primitive roads (Perry and Overly 1977). People on foot appeared to create a greater disturbance than people on snowmobiles (Freddy et al. 1986). However, elk behavior was influenced to a greater extent by off highway vehicle (OHV) activity than by hiking or horseback riding (Wisdom et al. 2004).

Mule deer have increased size of their home range in response to disturbance during military training operations (Stephenson et al. 1996). Proximity to roads and trails has a greater correlation with deer distribution than does crude calculations of mean road densities (Johnson et al. 2000). Off-road recreation is increasing rapidly on public lands. Several rivers, such as the Arkansas River in Kansas, designated as navigable, have subsequently dried due to over-appropriation of irrigation water. These streambeds have now become OHV travel lanes (Fig. 25). Activities such as OHV use have negative effects on habitat and create disturbance. However, assigning specific causes to changes in mule deer behavior is difficult. Human activity may result in different behavior of mule deer depending upon the environmental setting. For example, roads through open meadow habitat resulted in reduced use of the area by deer, whereas roads through forested habitats did not (Perry and Overly 1977). The USFS estimated that OHV use has increased 7-fold during the past 20 years (Wisdom et al. 2004).

Reduction of Habitat Suitability

Human activity has the ability to alter habitat suitability through the direct alteration of habitat characteristics, thereby influencing habitat quality. At times when agricultural commodities are of high value there are pressures on landowners to farm all possible acreages leading to road-ditch-to-road-ditch planting (Fig. 26). Improper use of OHVs can alter habitat characteristics through destruction of vegetation, compacting soil, and increasing erosion. Trails through the prairies that allow ranchers to maintain windmills and mineral blocks also provide access for people (Fig. 27).

The most obvious negative impact on habitat suitability is the elimination of linkage corridors between important habitats. Loss of linkages may be the result of actual development or road proliferation and improvement.

Recognition and understanding of the impact of highways on wildlife populations have increased dramatically in the past decade (Forman et al. 2003). In fact, highway-associated impact has been characterized as one of the most prevalent and widespread forces affecting natural ecosystems and habitats in the United States (Noss and Cooperrider 1994, Trombulak and Frissell 2000, Farrell et al. 2002). These impacts are especially severe in western states where rapid human population growth and development are occurring at a time when deer populations are depressed. Human population growth has resulted in increased traffic volume on highways, upgrading of existing highways, and construction of new highways, all serving to further exacerbate highway impacts to mule deer and other wildlife.



Figure 26. Road-ditch-to-road-ditch cropping in some areas results in human disturbance of mule deer and loss of habitat even in remote areas with few people. (Photo by Lloyd Fox/KDWP).



Figure 27. Networks of private trails through Great Plains prairies allow increased and frequently unauthorized access and may lead to erosion, soil compaction, habitat damage, and disturbance of mule deer. This system is being developed to install wind generators. (Photo by Matt Smith/KDWP).

Direct loss of deer and other wildlife due to collisions with motor vehicles is a substantial source of mortality affecting populations. Romin and Bissonette (1996) conservatively estimated that > 500,000 deer of all species are killed each year in the U.S. Schwabe and Schuhmann (2002) estimated this loss at 700,000 deer/year, whereas Conover et al. (1995) estimated > 1.5 million deer-vehicle collisions occur annually. Many human injuries and loss of life occur with deer-wildlife collisions annually, and the damage to

property from collisions is tremendous (Reed et al. 1982, Romin and Bissonette 1996, Bissonette et al. 2008). Deer-vehicle collisions are a particularly severe problem on winter ranges to which deer populations historically have migrated in concentrated densities (e.g., Gordon and Anderson 2003). Conover et al. (1995) estimated collisions involved 29,000 human injuries and 200 deaths annually. Additionally, roadways fragment habitat and impede movements for migratory herds (Lutz et al. 2003). Some highway transportation departments have used overpasses and underpasses for wildlife to mitigate highways as impediments. Recently, temporary warning signs have been demonstrated to be effective in reducing collisions during short duration migration events (Sullivan et al. 2004). Hotspots for deer-vehicle collisions tend to be less predictable or concentrated in this ecoregion (Bissonette and Kassar 2008). Therefore, justification for highway modifications, such as underpasses and exclusionary fencing, may be more difficult in this ecoregion compared to some others.

Of all the impacts associated with highways, the most important to mule deer and other wildlife species are barriers and fragmentation effects (Noss and Cooperrider 1994, Forman and Alexander 1998, Forman 2000, Forman et al. 2003). Highways alone act as barriers to animals moving freely between seasonal ranges and to critical habitat areas. Barriers fragment habitats and populations, reduce genetic interchange among populations or herds, and limit dispersal of young; all serve to ultimately disrupt processes that maintain viable mule deer herds and populations. Furthermore, effects of long-term fragmentation and isolation render populations more vulnerable to the

influences of random events, and may lead to extirpations of localized or restricted populations of mule deer. Other human activity impacts directly tied to increased travelways include increased poaching of mule deer, unregulated off-highway travel, and ignition of wildfires. Highways also serve as corridors for dispersal of invasive plants that degrade habitats (White and Ernst 2003).

In the past, efforts to address highway impacts were typically approached as single-species mitigation measures (Reed et al. 1975). Today, the focus is more on preserving ecosystem integrity and landscape connectivity, which benefits multiple species (Clevenger and Waltho 2000). Farrell et al. (2002) provide an excellent synopsis of strategies to address ungulate-highway conflicts.

One of the greatest impacts to habitat suitability in the Great Plains has been

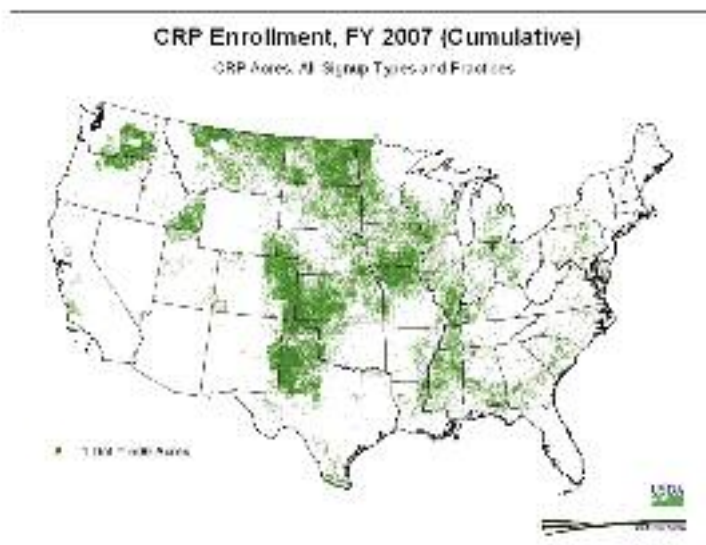



Figure 28. CRP projects attempt to restore grasslands. The distribution and extent of these plantings have influenced vast areas of the Great Plains Ecoregion. Figure provided by USDA-FSA Conservation and Environmental Program Division. The full text is available at: http://www.fsa.usda.gov/Internet/FSA_File/annual_consv_2007.pdf.



Figure 29. Mule deer habitats in the Great Plains Ecoregion benefited from grass plantings established as a result of CRP. (Photo by Bob Grier/courtesy of Nebraskaland Magazine).



conversion of habitats back and forth between grasslands and domestic crops. Implementation of CRP practices returned large acreages of tilled land to native vegetation and appeared to be a positive force for mule deer populations (Fig. 28). There has been little specific research on the relationship between CRP acres and mule deer populations. However, Kamler et al. (2001) reported that the mule deer population nearly doubled and expanded to occupy 88% of Texas Panhandle counties from 1985 to 2000. The authors thought the expansion was due to enrollment of crop fields into CRP. Program fields provided taller vegetative cover and greater distribution of suitable cover across relatively flat terrain otherwise dominated by cropland and short-grass prairie. These fields provide permanent cover of relatively tall and dense grasses (Fig. 29). Because most CRP fields lie adjacent to croplands, mule deer have adequate cover adjacent to feeding areas. Kamler et al. (2001) believed availability and distribution of cover was limiting mule deer distribution until the advent of CRP. Mule deer in Montana utilized CRP fields at all times of year (Selting and Irby 1997). Biologists in South Dakota observed mule deer taking advantage of CRP grass fields that would be tilled during normal agricultural practices (T. Benzon; SD Game, Fish and Parks; personal communication).

Native ungulates, including mule deer, have evolved in a grassland ecosystem subject to a variety of natural disturbances. Fire, grazing, and drought have all contributed to the mosaic of plant species composition and distribution across the ecoregion. Left undisturbed, CRP fields over time tend to lose some of the benefits for mule deer. Therefore, managers may want to modify plans for CRP fields to include some form of disturbance to make them more attractive for deer (Hobbs and Huenneke 1992, Millenbah et al. 1996, Allen et al. 2001). Controlled burning or managed cattle grazing may provide tools to accomplish this disturbance. Both forms of disturbance can increase plant vigor and species diversity. Inter-seeding forbs and legumes will provide an additional forage source for wintering deer. Beneficial disturbance regimes will vary according to soil type and weather conditions over such a large ecoregion (Campa and Winterstein 1992, Ford and McPherson 1996). Consultation with biologists having local expertise has helped in developing appropriate plans for individual CRP fields.

Some intensive deer management practices on private lands can lead to an overall reduction in habitat suitability for free ranging mule deer populations. Practices such as high-fence confinement, and artificial feeding and baiting of free ranging herds may result in abnormal and unhealthy concentrations of animals that can damage native plant communities. These practices may also result in disease transmission at levels not seen under normal densities.

Species that seldom would come into contact with free ranging mule deer, including exotic deer and other ungulates, may be placed together behind high fences. High-fence operations may disrupt movement patterns of free ranging herds. Few high-fence areas are not completely secure when viewed over a long time period. Therefore, diseases occurring outside the fence may find a way into these pens and then be transported to other locations through the commerce in privately owned deer. An even greater concern is the development of disease or genetic problems that becomes magnified behind the fence but eventually escapes into the wild population where the potential for control or eradication is unlikely.

GUIDELINES

A. Planning and Coordination

1. Initiate new research studies on mule deer habitat relationships on private lands in the GPE.
2. Encourage land and wildlife management agencies to play a proactive role in city and county planning, zoning, and development.
3. Develop and maintain interagency coordination in land planning activities to protect important habitats.
4. Identify important habitats, seasonal use areas, and important populations of mule deer.
5. Coordinate with agricultural producers to consider wildlife needs in the selection of crops, locations, and rotations. Identify acceptable wildlife use.
6. Analyze linkages and connectivity of habitats to identify likely areas for impact hazards as new roads are developed or altered for higher speed and greater volume traffic.
7. Monitor activities that artificially concentrate mule deer, or that could increase the potential for disease transmission.

B. Minimizing Negative Effects of Human Encroachment

1. Develop consistent regulations for OHV use.
2. Maintain interagency coordination in the enforcement of OHV regulations.
3. Designate areas where vehicles may be legally operated off road.
4. Encourage use of native vegetation in landscaping human developments to minimize loss of usable habitat.
5. Examine records of deer-vehicle collisions to determine where major impact areas exist and evaluate the need for wildlife passage structures.
6. Construct overpasses and underpasses along wildlife corridors known to be mule deer travel routes.
7. Monitor activities that may unduly stress deer at important times of the year. Reduce or regulate disturbance if deemed detrimental.
8. Enhance alternate habitats to mitigate for habitat loss, including components like water availability.
9. Provide ungulate-proof fencing to direct wildlife to



Figure 30. Conservation easements such as this one in North Dakota can be an effective tool for conserving vulnerable open space for all wildlife. (Photo by Brandon Mason/ Mule Deer Foundation).



Figure 31. Establishing shrubs can be expensive and prone to failure in the Great Plains. A fabric weed barrier can be a cost effective method to increase survival and planting success of shrubs. The row of chokecherry on the left was protected with a fabric weed barrier and had high survival and strong growth while the row in the center that was not protected with a weed barrier had a lower survival and poorer growth rate. (Photo by Shane Hesting/KDWP).

right-of-way passage structures or away from areas of frequent deer-vehicle collisions.

10. Encourage the use of wildlife-friendly fence (permeable) in appropriate areas to minimize habitat fragmentation.
11. Coordinate with agencies to provide private landowner incentives, such as conservation easements, for protecting habitat.

C. Wildlife Passage Structures

1. Locate passage structures to maximize use by deer and other wildlife; passage structures should be located away from areas of high human activity and disturbance. For established passage structures in place > 10 years, Clevenger and Waltho (2000) found that structural design characteristics were of secondary influence to

ungulate use as compared to human activity.

2. Verify that passage structures are located in proximity to existing or traditional travel corridors or routes (Singer and Doherty 1985, Bruinderink and Hazebroek 1996), and in proximity to natural habitat (Foster and Humphrey 1995, Servheen et al. 2003, Ng et al. 2004).
3. Verify spacing between structures is based on local factors (e.g., known deer crossing locations, deer-vehicle collision “hotspots,” deer densities adjacent to highways, proximity to important habitats).
4. Use models and other tools where appropriate and available, to assist in location of passage structures (Clevenger et al. 2002, Barnum 2003, Claar et al. 2003).
5. Design passage structures to maximize structural openness (Reed 1981, Foster and Humphrey 1995, Ruediger 2001, Clevenger and Waltho 2003, Ng et al. 2004). The openness ratio (width × height/length) should be > 0.6 (Reed et al. 1979), and preferably > 0.8 (Gordon and Anderson 2003). Reductions in underpass width influence mule deer passage more than height (Clevenger and Waltho 2000, Gordon and Anderson 2003).
6. Design underpasses specifically for mule deer with widths ≥ 20 feet and heights ≥ 8 feet (Forman et al. 2003, Gordon and Anderson 2003). Gordon and Anderson (2003) and Foster and Humphrey (1995) stressed the importance of animals being able to see the horizon as they negotiate underpasses. Mule deer make minimal use of small passage structures such as livestock and machinery box-culverts (Gordon and Anderson 2003, Ng et al. 2004).
7. Incorporate more natural conditions within underpasses (e.g., earthen sides and naturally vegetated) to promote use by ungulates (Dodd et al. 2007). In Banff National Park, Alberta, deer strongly preferred (10 times more use) vegetated overpasses compared to open-span bridged underpasses (Forman et al. 2003).
8. Use ungulate-proof fencing in conjunction with passage structures to reduce deer-vehicle collisions (Clevenger et al. 2001, Farrell et al. 2002). Caution should be exercised when applying extensive ungulate-proof fencing without sufficient passage structures to avoid creating barriers to deer movement.
9. Design fences into existing natural passage barriers (e.g., large cut slopes, canyons; Puglisi et al. 1974).
10. When fencing is not appropriate, incorporate enhanced signage to alert motorists to reduce deer-vehicle collisions (Farrell et al. 2002), Swareflex reflectors (with generally inconclusive results [Farrell et al. 2002]), deer crosswalks (Lehnert and Bissonette 1997), or electronic roadway animal detection systems (RADS, Huijser and McGowen 2003).

D. Reclamation of Cropland to Mule Deer Habitat

1. Prioritize sites where habitat will be created to make

the most cost-effective use of funds.

- Select areas where permanent easements have been granted (Fig. 30).
 - Select areas where landowner has entered long-term contract.
 - Avoid areas near roads, communities, or energy development sites.
 - Select highly erodible sites, as they will be less likely to be converted back to cropland.
2. Prepare site with nurse crop and irrigate to establish seeding where possible.
 3. Select seed source that emphasizes native species and locally adapted sources. Avoid exotic species such as old world bluestem (*Bothriochloa ischaemum*).
 4. Include forb and shrub component into the planting mix.
 - Use weed barrier to increase survival of rooted stock plantings (Fig. 31). Technical notes, such as available from NRCS for establishing trees and shrubs, describe care and precautions needed to reduce rodent damage, and minimize damage to stems by the fabric.
 5. Limit vehicle access to the area.
 6. Use disturbance to maintain vegetation in vigorous and diverse condition.
 - Use prescribed burning.
 - Strip-disk areas within large blocks of grassland to create species and structure diversity.
 - Food plots may be incorporated into fire breaks.

ENERGY AND MINERAL DEVELOPMENT

BACKGROUND

Energy consumption and production continues to be a major part of our nation's overall energy policy. According to the National Energy Policy (2001), "...if energy production increases at the same rate as during the last decade our projected energy needs will far outstrip expected levels of production. This imbalance, if allowed to continue, will inevitably undermine our economy, our standard of living, and our national security." Even as recent as 2006, President Bush stated, "America is addicted to oil..." He has set a new national goal of replacing > 75 % of the United States' oil imports from the Middle East by 2025. As pressure mounts to explore new energy initiatives, alternatives, and develop more areas (e.g., Arctic National Wildlife Refuge, Raton Basin, San Juan Basin, Uinta-Piceance Basin, Green River Basin, Powder River Basin etc.,

(Fig. 32)), careful attention must be given to how industry can expand to satisfy increasing energy demands without damaging the environment. A national debate must focus on identifying practical means of moving forward with energy independence while at the same time recognizing the importance of a healthy environment in terms of the diversity of economies, recreation, and inherent aesthetics it supports and provides.



Figure 32. Coal bed natural gas production activities in the Powder River Basin and associated "breaks," illustrating effects of development on mule deer, their habitats, and hunter recreation opportunities. (Photo by Bert Jellison/WGFD).

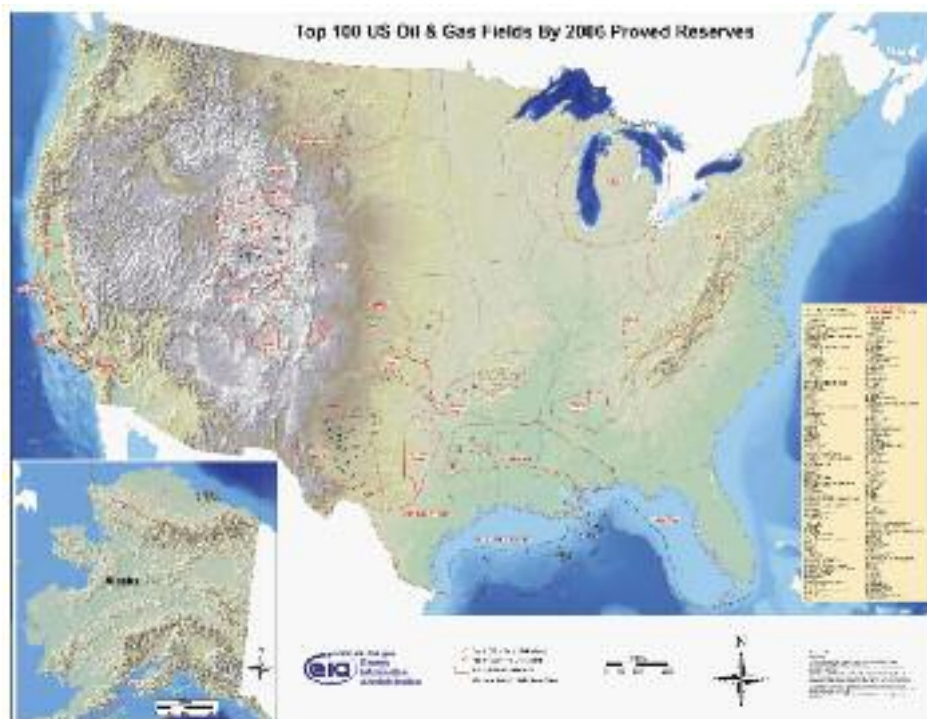


Figure 33. Proven reserves is an energy industry method of estimating the future product potential of sites. The Great Plains is a region where future oil and gas production will be high, as seen in this map of top U.S. oil and gas fields by 2005. (Map courtesy of Energy Information Administration, U.S. Department of Energy [DOE]). The full map can be viewed at http://www.eia.doe.gov/oil_gas/rpd/topfields.pdf.

Much of the GPE is comprised of mountain-foothill, timbered breaks, prairie-badlands, and adjacent prairie-agricultural and plains river bottoms that are predominantly held in private ownership. Public and private surface ownerships are more disjointed than in most mule deer ranges due to relatively small ownerships. In addition, private surface ownership is commonly underlain by federal or second-party minerals ownership. This split-estate issue creates a significant challenge for effective implementation of habitat guidelines across a landscape involving energy and mineral development activities. A significant portion

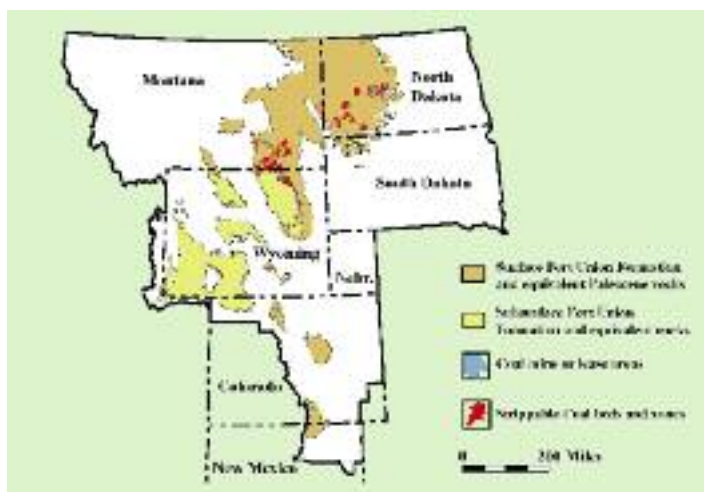


Figure 34. Paleocene coal-bearing basins, the lateral extent of the Fort Union and equivalent formation, mine lease areas, and targeted coal beds or zones (Map courtesy of U.S. Geological Survey).

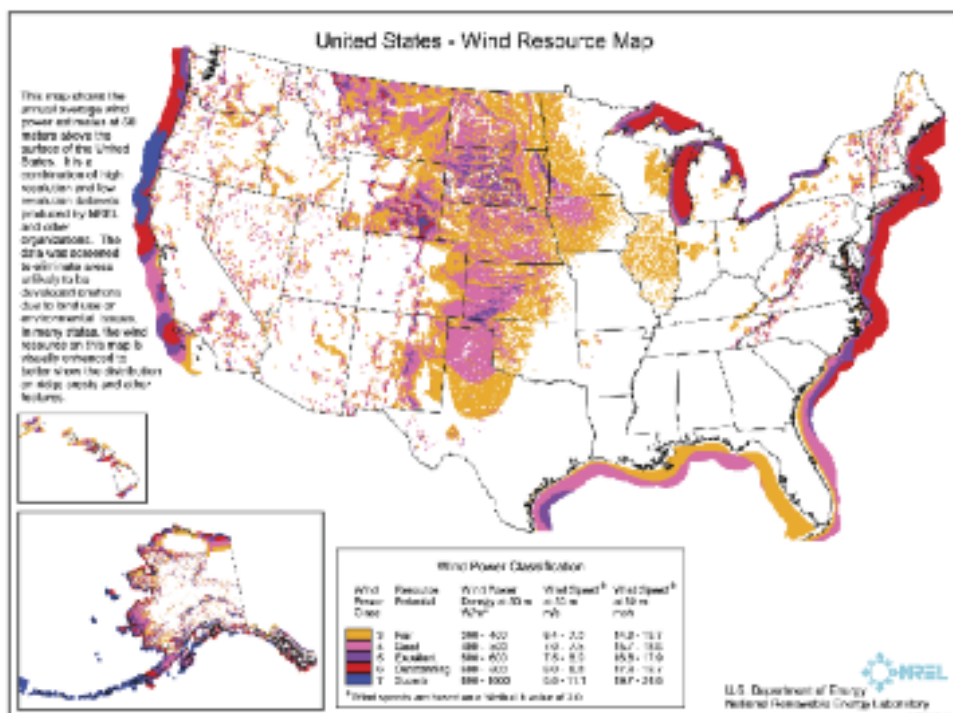


Figure 35. Wind energy potential. (Map courtesy of Wind and Hydro Power Technologies Program, U.S. DOE, http://www1.eere.energy.gov/windandhydro/wind_potential.html).

of the GPE contains accumulations of natural gas (Fig. 33) and coal deposits (Fig. 34). A relatively new area of significant interest has been development of natural gas from coal beds. Depending on depth of the coal seam, coal bed natural gas (CBNG) production and coal mining activities can occur in the same general area, thus raising concerns about possible cumulative effects on mule deer and other wildlife.

In the Wyoming portion of the Powder River Basin, a Record of Decision was signed 30 April 2003 to amend the Resource Management Plan for the Powder River Basin Oil and Gas Project. The BLM analyzed the effects of drilling $\leq 51,000$ CBNG wells (both federal and non-federal) over a 10-year period, along with continued drilling of an estimated 3,200 "conventional" oil or gas wells. The planning area encompasses almost 8 million acres of federal, state, and private lands. Overall, implementation could disturb as much as 212,000 acres. As witnessed in the Powder River Basin, development and extraction activities associated with CBNG, coal, and deep-well natural gas tend to be aggressive and therefore have potential for more profound and long-term impacts on the environment.

The Paleocene Fort Union Formation of Wyoming, Montana, and North Dakota contain vast amounts of strippable coal (Fig. 34). Those coal beds currently being mined are as much as 140 feet thick. That region includes the 14 largest coal mines in the U.S. Coal from this ecoregion is relatively clean, as it contains less sulfur and ash than coals from other regions in the conterminous U.S.

Exploiting alternative and renewable forms of energy production such as wind electric generation and biofuels is quickly becoming more prevalent in this ecoregion. The U.S. Department of Energy (DOE 2007) estimated approximately 31 billion kilowatt-hours will be generated by wind energy in the U.S. in 2007, enough to power nearly 3 million average homes. Potential wind-energy development in the GPE is significant. Combined, the Great Plains states (excluding the provinces of Alberta and Saskatchewan) could potentially generate 4,688 megawatts of power (DOE 2007 Fig. 35).

Tessmann et al. (2004) reported that exploration and extraction of non-renewable resources has and continues to cause a range of adverse

effects. All disturbances to the landscape constitute an impact at some level. Severity of impact to mule deer depends upon the amount and intensity of disturbance, specific locations and arrangements of disturbance, and ecological importance of habitats affected. Small, isolated disturbances within non-limiting habitats are of minor consequence within most ecosystems. However, larger-scale developments within habitats limiting the abundance and productivity of mule deer are of significant concern to managers because such impacts cannot be relieved or absorbed by surrounding, unaltered habitats. Impacts, both direct and indirect, associated with energy and mineral developments have potential to affect ungulate population dynamics, especially when impacts are concentrated on winter ranges (Sawyer et al. 2002). However, Walter et al. (2006) evaluated construction and maintenance of a wind power facility on elk in Oklahoma and found minimal impacts.

For the purpose of this discussion, oil and gas development includes those activities used to extract all hydro-carbon compounds such as natural gas, crude oil, CBNG, and oil shale. Many industries depend upon other materials (e.g., copper, uranium, vanadium, etc.) for their products or services, and extracting these raw materials can have the very same effect on wildlife and the environment as oil and gas development. Therefore, although issues and concerns as well as guidelines discussed in this section focus predominantly upon oil, gas, and coal development, in most circumstances they are relevant and applicable to other mineral extraction and alternative energy development activities.

Impact Thresholds

Impact thresholds, as defined by Tessman et al. (2004), are levels of development or disturbance that impair key habitat functions by directly eliminating habitat, by disrupting access to habitat, or by causing avoidance and stress. For this discussion, impact thresholds are based upon 2 quantitative measures: density of well locations (pads) and cumulative disturbance per section (legal section of 640 acres or an area equivalent to 640 acres). Density of well locations has bearing on the intensity of disturbances associated with oil and gas field operations while cumulative area of disturbance measures direct loss of habitat.

In addition to well pads, a typical oil and gas field includes many other facilities and associated activities that affect wildlife: roads, tanks, equipment staging areas, compressor stations, shops, pipelines, power supplies, traffic, human activity, etc. (Figs. 36-37). Densities of well pads can be viewed as a general index to well-field development and activities. However, thresholds based upon well pad densities and cumulative acreage alone may under represent the actual level of disturbance.



Figure 36. A typical coal bed natural gas drilling operation creates disturbances for mule deer both on the site and within an area around it. (Photo by Bert Jellison/WGFD).



Figure 37. Other facilities such as compressor stations, shops, pipelines, roads, equipment staging areas, and power supplies, as well as the traffic and human activities around those facilities makes habitat less suitable for mule deer. (Photo by Olin Oedekoven/WGFD).

Measures to reduce impacts should be considered when well densities exceed 4 wells/section or when road density exceeds 3 miles of road/section (USDI 1999). The following describe and define relative degrees of impact (Table 7).

Moderate Impact: Habitat effectiveness is reduced within a zone surrounding each well, facility, and road corridor through human presence, vehicle traffic, and equipment activity.

High Impact: At this range of development, impact zones surrounding each well pad, facility, and road corridor begin to overlap, thereby reducing habitat effectiveness over much larger, contiguous areas. Human, equipment, and vehicular activity; noise; and dust are also more frequent and intensive. This amount of development will impair the ability of animals to use critical areas (winter

Table 7. Categories of impact on mule deer from energy and mineral extraction activities (Tessman et al. 2004).

MODERATE	HIGH	EXTREME
Impacts can be minimized or avoided through effective management practices and habitat treatments	Impacts are increasingly difficult to mitigate and may not be completely offset by management and habitat treatments	Habitat function is substantially impaired and cannot generally be recovered through management or habitat treatments
1-4 wells and < 20 acres disturbed/section	5-16 wells and 20-80 acres disturbed/section	> 16 wells or > 80 acres disturbed/section



Figure 38. Color infrared aerial photo of coal bed natural gas production near Gillette, Wyoming shows the network of disturbances that occur with this type of energy production. (Image courtesy of the USGS EROS Data Center).



Figure 39. Pipeline construction activities, such as this one in the Powder River Basin, WY, destroy existing habitat, provide sites for invasive species to establish, and temporarily disrupt mule deer movements and use of adjacent areas. (Photo by Bert Jellison/WGFD).

range, fawning grounds, etc.) and impacts will be much more difficult to mitigate. It may not be possible to fully mitigate impacts caused by higher well densities, particularly by developing habitat treatments on site. Habitat treatments will then generally be located in areas near, rather than within, well fields to maintain function and effectiveness of critical areas.

Extreme Impact: Function and effectiveness of habitat would be severely compromised (Fig. 38). With CBNG, a single well may only be capable of removing a small amount of the gas contained within the coal bed. Consequently, many hundreds to thousands of wells may be required to recover available gas (USDI 2005). Long-term consequences are continued fragmentation and disintegration of habitat leading to decreased survival, productivity, and ultimately, loss of carrying capacity for the herd. This will result in a loss of ecological functions, recreation, opportunity, and income to the economy. An additional consequence may include permanent loss of migration memory from large segments of unique, migratory mule deer herds.

Impacts to mule deer from energy and mineral development can be divided into the following general categories:

- 1) direct loss of habitat;
- 2) physiological stresses;
- 3) disturbance and displacement;
- 4) habitat fragmentation and isolation; and
- 5) other secondary effects (Tessman et al. 2004).

Each of these, alone or in conjunction with others, has potential to significantly influence whether deer can maintain some reasonable existence in the developed area or will abandon it altogether.

ISSUES AND CONCERNS

Direct Loss of Habitat

Direct loss of habitat results primarily from construction and production phases of development. Presence of well pads, open pits, roads, pipelines, compressor stations, wind turbines, and outbuildings directly removes habitat from use (Figs. 37-38). Within the Powder River Basin Oil and Gas Project area, short-term disturbances are projected to encompass approximately 3% (212,000 acres) of the project area, and most would be associated with construction of pipelines and roads. Long-term disturbance

is projected to involve 109,000 acres, approximately 51 % of the total area disturbed (Fig. 39).

Reclamation attempts of these sites appear to be varied. For instance, Kniola and Gil (2005) estimated 84% of operators in the Powder River Basin were out of compliance with CBNG reclamation conditions of approval and best management practices. Most non-compliance issues were related to a lack of seeding and excessive weeds.

Physiological Stress

Physiological stresses occur when energy expenditures by an animal are increased due to alarm or avoidance movements. These are generally attributed to interactions with humans or activities associated with human presence (traffic, noise, pets, etc.; Fig. 40).

During winter months, stress can be particularly important because mule deer are already operating at an energy balance deficit. In addition, diversion of energy reserves can be detrimental for other critical periods during the life cycle, such as gestation and lactation. Based on a simulated mine disturbance experiment, Kuck et al. (1985) suggested increased energy costs of movement, escape, and stress caused by frequent and unpredictable disturbance may have been detrimental to elk calf growth. An Environmental Impact Statement on oil and gas development in the Glenwood Springs (NM) Resource Area determined these impacts could ultimately have population effects through reduced production, survival, and recruitment (USDI 1999).

Disturbance and Displacement

Increased travel by humans within the area, equipment operation, vehicle traffic, and noise related to wells and compressor stations, etc. are primary factors leading to avoidance of developed areas by wildlife (Fig. 41). These avoidance responses by mule deer (indirect habitat loss) extend the influence of each well pad, road, and facility to surrounding areas. Zones of negative response can reach a 0.25-mile radius for mule deer (Freddy et al. 1986).


Significant differences in elk distribution between construction and non-construction periods were observed by Johnson et al. (1990) in the Snider Basin calving area of western Wyoming. Elk moved away from construction activities during calving season, but returned the following year when no construction activities occurred. Furthermore, these elk not only avoided areas near drill sites but also areas visible from access routes. Walter et al. (2006) noted that during construction of wind power facilities in Oklahoma, nutrition (based on isotope analysis and fecal nitrogen concentrations) and movement (based on home range analysis) of elk were not affected. However, elk were disturbed and loss of grassland habitat was documented.



Figure 40. Mule deer are under increased physiological stress and expend greater energy to maintain alert status and to avoid contact with people in areas where energy production occurs compared to undisturbed sites. This stress has been determined to result in mule deer avoiding some winter areas. It may also result in reduced survival and reproductive success. (Photo by Mark Gocke/WGFD).



Figure 41. Traffic and dust associated with coal bed natural gas development, as seen in this photo from the Powder River Basin, WY, is an obvious symptom of the increased human activities near development sites. (Photo by Olin Oedekoven/WGFD).



During all phases, roads tend to be of significant concern because they often remain open to unregulated use. This contributes to noise and increased human presence within the development area. Rost and Bailey (1979) found an inverse relationship to habitat use by deer and elk with distance to roads. This displacement can result in under use of habitat near disturbances while overuse may occur in nearby locations. This has the added potential for creating depredation problems with nearby agricultural properties. Added consequences from human presence include, but are not limited to, mortality and injury due to vehicle collisions, illegal hunting, and harassment from a variety of increasing recreational activities.

Habitat Fragmentation and Isolation

Associated with displacement is the greater impact of fragmentation. Meffe and Carroll (1997) suggested the largest single threat to biological diversity is outright destruction of habitat along with habitat alteration and fragmentation of large habitats into smaller patches. As stated earlier, road networks have a cumulative effect when considering total amount of habitat lost. This is especially evident in their contribution to habitat fragmentation. A report by USDI (1997) stated: “As road density increases, the influence on habitat effectiveness increases exponentially, such that at road densities of 3 miles per square mile, habitat effectiveness is reduced by about 30 percent.”

Based on their research on the Pinedale Anticline, Sawyer et al. (2006) suggested mule deer were less likely to occupy areas in close proximity to well pads than those farther away. They noted that changes in habitat selection appeared during the first year of development and that there was no evidence of acclimation to the well pads during the course of their study.

Habitat fragmentation creates landscapes made of altered habitats or developed areas fundamentally different from those shaped by natural disturbances that species have adapted to over evolutionary time (Noss and Cooperrider 1994). These changes likely manifest themselves as changes in vegetative composition, often to weedy and invasive species. This, in turn, changes the type and quality of the food base as well as habitat structure. Increased edge effect between developed and undeveloped areas often results in reduced forage quality and security cover, potentially increasing deer susceptibility to predation.

Use of migration corridors is influenced by factors such as aspect, slope, and weather. Therefore, when planning developments, it is critical to consider impacts to these corridors and how to mitigate them to facilitate migration of mule deer (Merrill et al. 1994). Flexibility in movement across ranges can improve survival and productivity of the

deer population and enhance their ability to recover from population declines.

Secondary Effects

Secondary effects may be as significant as those direct effects described above. Activities associated with support or service industries can aggravate adverse impacts. These impacts are similar to those that occur during construction and operations, only intensified. Vehicular traffic to support operations would likely increase significantly, which may result in increased deer-vehicle collisions. Additional human presence from increased support industries, as well as community expansion, will contribute to human-wildlife interactions and declines in mule deer habitat availability and quality.

Roads, pipelines, and transmission corridors not only directly remove habitat but also have potential to contaminate ground and surface water supplies. Noxious weeds can infiltrate roadside impact zones and bring negative impacts such as non-native bacteria, viruses, insect pests, or chemical defense compounds with toxic or allergenic properties (NMDGF 2007). Surface disturbance associated with CBNG development may facilitate establishment of non-native plants, such as Russian thistle (*Salsola* spp.), Canada thistle (*Cirsium arvense*), cheatgrass, and kochia (*Bassia scoparia*) (Bergquist et al. 2007).

Activities occurring at the development site (drilling, pumping, etc.) or associated with product transportation to other destinations via pipeline or vehicle, may lead to release of a variety of toxic compounds. These compounds are common by-products and pose serious health risks to not only employees, but also the environment and wildlife inhabiting the locality.

All of these events can increase the amount of area unavailable to mule deer and other wildlife. Finally, potential exists for rendering an area useless to wildlife for an indeterminable amount of time unless careful consideration is given to planning and implementing quality mitigation and reclamation programs.

GUIDELINES

To minimize impacts of energy and mineral development activities on mule deer and their habitat, several recommendations are provided for consideration and implementation. These recommendations are compiled from a number of sources and support principles for prudent and responsible development as stated in the National Energy Policy (2001). When energy development is proposed, the federal government has the dual responsibilities of facilitating such energy development and conserving our natural resource legacy.

A. Pre-planning and Scoping

1. Consult appropriate state and federal wildlife agencies during pre-planning exercises.
2. Design configurations of oil and gas development, coal mining, and wind energy to avoid or reduce unnecessary disturbances, wildlife conflicts, and habitat impacts. Where possible, coordinate planning among companies operating in the field.
3. Identify important, sensitive, or unique habitats and wildlife in the area. To the extent feasible, incorporate mitigation practices that minimize impacts to these habitats and resources.
4. Where practical, implement timing limitation stipulations that minimize or prohibit activities during certain, critical portions of the year (when deer are on winter range, fawning periods, etc.).
5. Prepare a water management plan in those regions and for those operations that generate surplus quantities of water of questionable quality (e.g., CBNG).
6. Plan the pattern and rate of development to avoid the most important habitats and generally reduce the extent and severity of impacts. To the extent practicable, implement phased development in smaller increments.
7. Cluster drill pads, roads, and facilities in specific, “low-impact” areas.
8. Locate drill pads, roads, and facilities below ridgelines or behind topographic features, where possible, to minimize visual and auditory effects, but away from streams, drainages, and riparian areas, as well as important sources of forage, cover, and habitats important to different life cycle events (reproduction, winter, parturition, and rearing).
9. Encourage directional drilling to minimize surface disturbances, including well pads, roads, pipelines, etc.

B. Roads

1. Use existing roads and 2-tracks if they are sufficient and not within environmentally sensitive areas.
2. If new roads are needed, close existing roads that provide access to the same area but impact important mule deer habitat (Fig. 42).
3. Construct the minimum number and length of roads necessary.
4. Use common roads to the extent practical.
5. Coordinate road construction and use among companies operating in the same oil and gas field.
6. Design roads to an appropriate standard no higher than necessary to accommodate their intended purpose.
7. Design roads with adequate structures or features to prohibit or discourage vehicles from leaving roads.

C. Wells

1. Drill multiple wells from the same pad using directional (horizontal) drilling technologies.
2. Disturb the minimum area (footprint) necessary



Figure 42. Roads can be closed to public access to reduce unnecessary disturbance of mule deer. (Photo by Olin Oedekoven/WGFD).



Figure 43. Remotely sensed coal bed natural gas wells in the Powder River Basin, WY have reduced maintenance traffic, which may have beneficial effects for wildlife. (Photo by Olin Oedekoven/WGFD).



Figure 44. The quality and quantity of water released during coal bed natural gas extraction can degrade riparian habitats that are important for mule deer and other wildlife. (Photo by Bert Jellison/WGFD).

- to efficiently drill and operate a well.
3. Utilize “mat” drilling to eliminate top-soil removal.

D. Ancillary Facilities

1. Use existing utilities, road, and pipeline corridors to the extent feasible.
2. Bury all power lines in or adjacent to roads.

E. Noise

1. Minimize noise to the extent possible. All compressors, vehicles, and other sources of noise should be equipped with effective mufflers or noise suppression systems (e.g., “hospital mufflers”).
2. Whenever possible, use electric power instead of diesel to power compression equipment.
3. Use topography to conceal or hide facilities from areas of known importance.

F. Traffic

1. Develop a travel plan that minimizes the amount of vehicular traffic needed to monitor and maintain wells and other facilities.
2. Limit traffic to the extent possible during high wildlife use hours (within 3 hours of sunrise and sunset).
3. Use pipelines to transport condensates off site.
4. Transmit instrumentation readings from remote monitoring stations to reduce maintenance traffic (Fig. 43).
5. Post speed limits on all access and maintenance roads to reduce wildlife collisions and limit dust (30-40 mph is adequate in most cases).
6. Utilize “mass” transit or carpools to reduce overall traffic volume to and from sites.

G. Human Activity

1. Employees should be instructed to avoid walking away from vehicles or facilities into view of wildlife, especially during winter months.
2. Institute a corporate-funded reward program for information leading to conviction of poachers, especially on winter range.

H. Pollutants, Toxic Substances, Fugitive Dust, Erosion, and Sedimentation

1. Avoid exposing or dumping hydrocarbon products on the surface. Oil pits should not be used, but if absolutely necessary, they should be enclosed in netting and small-mesh fence. All netting and fence must be maintained and kept in serviceable condition.
2. Produced water should not be pumped onto the surface except when beneficial for wildlife, provided water quality standards for wildlife and livestock are met (Fig. 44).
3. Produced water should not be pumped onto the surface within big game crucial ranges. However, produced

water of suitable quality may be used for supplemental irrigation to improve reclamation success.

4. Re-injection of water into CBNG sites should be considered when water quality is of concern.
5. Hydrogen sulfide should not be released into the environment.
6. Use dust abatement procedures including reduced speed limits, and application of an environmentally compatible chemical retardant or suitable quality water.

I. Monitoring and Environmental Response

1. Monitor conditions or events that may indicate environmental problems (e.g., water quality in nearby rivers, streams, wells, etc.). Such conditions or events can include any significant chemical spill or leak, detection of multiple wildlife mortalities, sections of roads with frequent and recurrent wildlife collisions, poaching and harassment incidents, severe erosion into tributary drainages, migration impediments, wildlife entrapment, sick or injured wildlife, or other unusual observations.
2. Immediately report observations of potential wildlife problems to the state wildlife agency and, when applicable, federal agencies such as U.S. Fish and Wildlife Service or Environmental Protection Agency.
3. Apply GIS technologies to monitor the extent of disturbance annually and document the progression and footprint of disturbances. Release compilations of this information to state and federal resource agencies at least annually.

J. Research and Special Studies

1. Where questions or uncertainties exist about degree of impact to specific resources, or effectiveness of mitigation, industries and companies should fund studies to collect data for evaluation and documentation.

K. Noxious Weeds

1. Control noxious and invasive plants that appear along roads, on well pads, or adjacent to other facilities.
2. Clean and sanitize all equipment brought in from other regions. Seeds and propagules of noxious plants are commonly imported by equipment and mud clinging to equipment.
3. Request that employees clean mud from footwear before traveling to the work site to prevent importation of noxious weeds.

L. Interim Reclamation

1. Establish effective, interim reclamation on all surfaces disturbed throughout the operational phase of the well field.
2. Where practical, salvage topsoil from all construction and reapply during interim reclamation (Fig. 45). When strip mining, soil material should be direct

hauled whenever possible. This enhances vegetative establishment and diversity in reclaimed areas. Direct hauling provides increased viable propagules (any of various usually vegetative portions of a plant, such as a bud or other offshoot, that aid in dispersal of the species and from which a new individual may develop) and helps to maintain soil organics and structure (i.e., soil aggregation).

3. Approved mulch application should be used in sensitive areas (dry, sandy, steep slopes).
4. A variety of native grasses, shrubs, and forbs should be used. Non-native vegetation is unacceptable for any purpose, including surface stabilization. Continue to monitor and treat reclaimed surfaces until satisfactory plant cover is established.

M. Final Reclamation

1. Salvage topsoil during decommissioning operations and reapply to reclaimed surfaces.
2. Utilize “mat” drilling to eliminate top-soil removal.
3. Replant a mixture of forbs, grasses, and shrubs that are native to the area and suitable for the specific ecological site.
4. Restore vegetation cover, composition, and diversity to achieve numeric standards that are commensurate with the ecological site.
5. Do not allow grazing on re-vegetated sites until plants are established and can withstand herbivory (Fig. 46).
6. Continue to monitor and treat reclaimed areas until plant cover, composition, and diversity standards have been met.
7. Reevaluate the existing system of bonding. Bonds should be set at a level that is adequate to cover the company’s liability for reclamation of the entire well field.

8. Special-handle drainage bottom and wetland soils. Replacement of alluvial soils maintains moisture-holding capacity and desired seed bank in these areas. This promotes better establishment of desired vegetation.
9. Use rocky or coarse textured soil or spoil material to promote establishment and propagation of ponderosa pine, shrub, and other plant communities (permeable

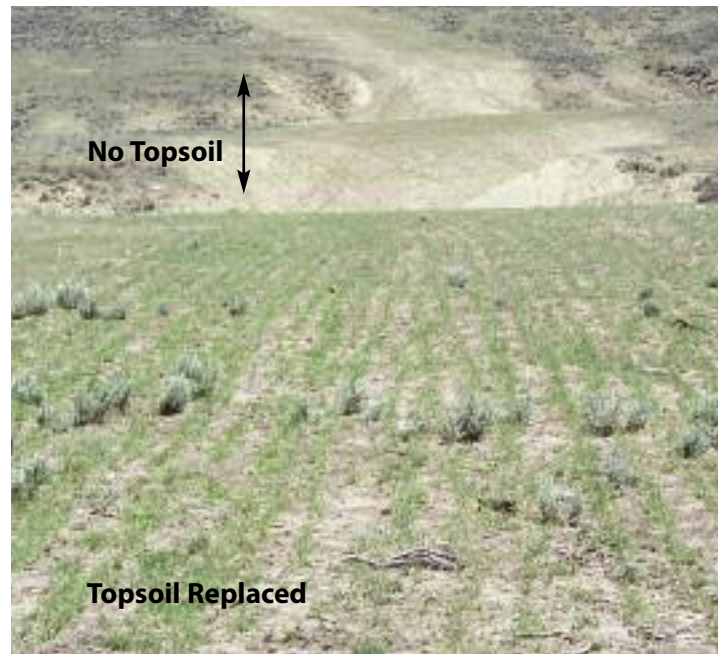


Figure 45. Reclamation efforts in the Powder River Basin, WY vary widely depending on surface and mineral ownerships. Two years after reclamation, the site in the foreground is doing well. In the background, the landowner did not require topsoil replacement, thus revegetation efforts have been mostly unsuccessful. Note the Wyoming big sagebrush establishment that occurred without being planted. (Photo courtesy of WGFD).



Figure 46. Cattle grazing on a pipeline reclamation site before the vegetation is successfully established, such as this one in the Powder River Basin, WY, may hinder the recovery process. (Photo by Larry Gerard/BLM, Buffalo Field Office).



Figure 47. Topography can be an important component that influences the quality of habitat for mule deer. Strip mine reclamation should attempt to restore the slope, aspect and micro-habitat features of the site to pre-mine conditions. (Photo by Bert Jellison/WGFD).



Figure 48. Mine facilities and transportation corridors should be positioned and designed to minimize disturbances and allow mule deer to access important habitats. (Photo by Bert Jellison/WGFD).

soil or spoil material reduces herbaceous competition by increasing surface infiltration).

10. Replace water sources such as seeps, springs, wells, ponds, and streams lost as a result of mining.

N. Topography (pertains to strip mine reclamation only)

1. Design final topography to approximate pre-mine conditions. Include varying aspects, slopes, and micro-topographic features: swales, rocky knobs, benches, ridge-tops, drainage bottoms, rubble zones, etc. Modern equipment can be used to create post-mine conditions that provide topographic features more beneficial to wildlife than open, level ground (Fig. 47).
2. Drainage bottoms should be designed to approximate the pre-mine pattern. This should promote a diversity of riparian vegetation. Sediment control structures can be used to create wetlands (temporary and permanent) and to provide sources of surface water.

O. Mine Facilities (pertains to strip mine reclamation only)

1. Design facilities, such as coal conveyers, to minimize disturbance or hindrance to movements (Fig. 48).
2. Design livestock fences to permit necessary movement and access. Fences around hazardous areas should be designed to exclude both livestock and wildlife.
3. Transportation corridors should be located in a manner to reduce impacts.
4. Design the size and location of mine facilities to minimize disturbance.
5. Enhance off-site areas to improve mule deer habitat. Enhancement of adjacent habitat can sustain animals displaced from disturbed areas or attract deer away from newly reclaimed areas.

The GPE is a vast area of mule deer habitat historically dominated by grasslands. Although deer are considered browsers, not grazers, native prairies have adequate forbs and shrubs to provide suitable habitat for mule deer. This region is the eastern limit to the historic distribution of the mule deer. In fact, a few mule deer are harvested each year in western Minnesota. However, the factor(s) limiting the eastward distribution of mule deer have not been quantified. Elk are frequent competitors with mule deer where they occur within the Great Plains; however, because of their similar body size and forage requirements, white-tailed deer compete with mule deer more intensely and over a larger area than elk in this ecoregion. Mule deer populations frequently occur at lower densities in this ecoregion than in some other areas, and much of the area is privately owned. These 2 factors contribute to difficulties in conducting research and management projects. Applicability of basic ecological and management studies conducted in other ecoregions is questionable in this ecoregion; therefore, we lack much of the site-specific information needed to provide management prescriptions.

Extreme and powerful environmental forces, such as acute drought and severe wind and water erosion, shaped the Great Plains. Although environmental gradients are generally mild and gradual, the extent of variation from north to south and east to west can be large. Effects of winter storms are a hazard in the north, whereas summer heat and drought, are more likely to be factors in the south.

Dynamic changes in the human population and implementation of new technologies have wrought significant changes to GPE environments. The recent history of human occupancy resulted in conversion of grasslands to agricultural uses. Although availability of high quality forage from agricultural crops and development of watering structures for livestock grazing have been beneficial for mule deer, the best remaining mule deer habitats are frequently areas too vulnerable to erosion to be converted to cropland.

Distribution of people in the Great Plains is a factor to be considered in mule deer habitat management. The trend is for people to leave this ecoregion following environmental and economic hardships. Sites such as the Front Range of the Rockies at the edge of the Great Plains and the Black Hills have undergone rapid development. Conversely, rural communities in dryland farming areas have undergone population declines in recent decades. When people concentrate and developments occur in or near critical mule deer habitat, adverse effects on mule deer populations are likely. As farm and ranch size

increase and fewer people inhabit areas, there may be improved prospects for habitat management of mule deer.

The Great Plains have sustained grazing animals in high numbers for thousands of years. During the last 150 years livestock grazing has been an integral part of human settlement. Grazing of livestock is generally conducted in areas unsuited for crop production. Intensity of livestock grazing can have dramatic effects on mule deer habitat. Therefore, livestock grazing should be kept to a moderate or conservative level to maximize habitat benefits to mule deer. Increasingly, private landowners are considering economic returns of managing grazing areas with mule deer habitat as a desired output. New economic forces and recreational opportunities are creating an atmosphere where wildlife can be managed on private lands.

Activities of humans, such as farming, ranching, energy development, roads, etc., provide ample opportunity for invasive species establishment. Human activities can also tip the scales and cause native species to become invasive under different circumstances. A variety of potential invasive species exist, and we expect new invasive species will become problematic for managers in the future. These guidelines encourage habitat managers to appreciate system complexity and critically examine the function of plant species, as well as their origins.

Water is frequently a critical factor in the ecology of the Great Plains. Development of water resources for irrigation, especially center-pivot irrigation systems using the Ogallal aquifer, has had dramatic effects on mule deer habitat. The extent of center-pivot irrigation since the 1960s has dramatically changed ground water levels and resulting stream flows. In some areas, these developments have resulted in conversion from dryland to irrigated farming, some with highly inefficient crops for an arid environment. In other areas, native habitat has been converted to irrigated cropland. As frequency and volume of stream flows have diminished, there have been reductions in riparian zones and changes in species composition. These changes likely have benefited white-tailed deer and increased potential for competition with mule deer. The final chapter in the impact of irrigation to produce crops in the GPE has not been written and it will undoubtedly involve reclamation of some areas into more energy- and water-sustainable systems.

Farm programs like Soil Bank and CRP offer great potential for improving fawn production sites and mule deer escape cover. These programs may be improved and targeted to produce better habitat conditions for wildlife. Cultural changes need to be incorporated into Farm Bill programs that recognize mule



deer habitat as a benefit for private landowners. In addition, use of grasslands for cellulosic ethanol production could have profound effects on mule deer habitat. Research should be conducted to determine how these resources can be utilized without negative effects on mule deer populations.

Development of energy resources in the ecoregion may have profound impacts on mule deer populations. Recent ecological studies have demonstrated the vulnerability of mule deer to human disturbances during energy development. Development of coal bed natural gas and other mining activities can negatively affect habitat for mule deer and other wildlife species. Impact of these activities on mule deer populations should be managed or mitigated to maintain habitat quality for the species.


Mule deer management on private property requires cooperation and coordination with private landowners. Habitat development projects will frequently be smaller in scope than on areas with large blocks of public land. Projects funded through the Farm Bill may have broad applications and benefits in this ecoregion. However, history has shown that lessons learned during one generation on the Great Plains are not always retained by the next generation. When economic pressures become intense, there has been a tendency for people to gamble during good environmental times and pay the price later. The future of wind energy and bio-fuels needs to be based on the fragility and volatility of the region. Sustainable development in the GPE must recognize that there will be future droughts and periods when crop production and energy output will be emphasized above the needs of conservation.

Fire has been a significant force in development of habitats in this ecoregion. Frequency and timing of fire can shape species composition and quality of forage available for mule deer. Mule deer are a selective feeder and depend on forbs and browse of relatively high digestibility and availability. In the Black Hills, mule deer using burned habitats displayed increased body weights and fat indices compared to mule deer using unburned habitat. This increased nutritional condition was directly attributed to the benefits of fire. Fire is the most cost effective means of changing grassland and shrubland communities. Prescribed fire is an important tool in the Great Plains; however, issues such as smoke management and containment complicate its use and acceptance, particularly among private landowners.

These guidelines for mule deer habitat are a start for administrators, land managers, and natural resource

specialists. Clearly, we do not know everything we need to know to maximize habitat management for this species, but we can improve upon conditions that occur over much of the area. Federal, provincial, and state agencies; universities; sportsmen and conservation organizations; and private landowners must work together in perfecting this effort. Habitat consequences for mule deer need to be considered during planning and development phases of projects. These guidelines were developed to aid managers in maintaining mule deer habitat as an important feature of the Great Plains landscape.

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APPENDIX

APPENDIX A.

Important forage plants [Common name (*Scientific name*)] for mule deer in the Great Plains Ecoregion. Adapted from Anderson (1949), Anderson et al. (1965), Boecker et al. (1972), Coop (1977), Dusek (1971), Jackson (1990), Kamps (1969), Keller (1975), Knowles (1975), Komberec (1976), Krysl et al. (1980), Sowell et al. (1985), Sullivan et al. (1988), Uzell (1958), Wood (1987), and Wood et al. (1989). Taxonomy based on USDA (2008) and Integrated Taxonomic Information System (2007).

FORBS

Alfalfa (*Medicago sativa*)
Alumroot, Roundleaf (*Heuchera cylindrica*)
Aster (*Aster* spp.)
Balsamroot, Arrowleaf (*Balsamorhiza sagittata*)
Bedstraw, Northern (*Galium boreale*)
Beebalm (*Monarda* spp.)
Beeblossom, Scarlet (*Gaura coccinea*)
Bellflower, Bluebell (*Campanula rotundifolia*)
Biscuitroot (*Lomatium* spp.)
Bladderpod (*Lesquerella* spp.)
Buckwheat, Fewflower (*Eriogonum pauciflorum*)
Bundleflower, Illinois (*Desmanthus illinoensis*)
Burdock, Common (*Arctium minus*)
Camphorweed (*Heterotheca subaxillaris*)
Coneflower, Upright Prairie (*Ratibida columnifera*)
Corn (*Zea mays*)
Croton (*Croton* spp.)
Daisy, Engelmann (*Erigeron engelmannii*)
Dandelion, Common (*Taraxacum officinale*)
Dayflower (*Commelina* spp.)
Flax (*Linum* spp.)
Filaree (*Erodium* spp.)
Geranium, Sticky (*Geranium viscosissimum*)
Globemallow, Scarlet (*Sphaeralcea coccinea*)
Knotweed (*Polygonum* spp.)
Krameria, Trailing (*Krameria lanceolata*)
Lettuce, Blue (*Lactuca tatarica*)
Licorice, American (*Glycyrrhiza lepidota*)
Milkwort, White (*Polygala alba*)
Milkvetch or Locoweed (*Astragalus* spp.)
Musineon, Leafy (*Musineon divaricatum*)
Nightshade, Silverleaf (*Solanum elaeagnifolium*)
Onion, Wild (*Allium* spp.)
Phlox, Hood's (*Phlox hoodii*)
Primrose (*Primula* spp.)
Pussytoes (*Antennaria* spp.)
Ragweed (*Ambrosia* spp.)
Rockcress, Holboell's (*Arabis holboellii*)
Sagebrush, Fringed (*Artemisia frigida*)
Salsify, Common (*Tragopogon dubius*)
Sandwort (*Arenaria* spp.)
Sorghum, Grain (*Sorghum bicolor*)

Stoneseed, Narrowleaf (*Lithospermum incisum*)
Sundrops, Yellow (*Calylophus serrulatus*)
Sweetclover (*Melilotus* spp.)
Thermopsis, Prairie (*Thermopsis rhombifolia*)
Toad-flax, Bastard (*Comandra umbellata*)
Violet (*Viola* spp.)
Wallflower, Sanddune (*Erysimum capitatum*)
Yarrow, Common (*Achillea millefolium*)

WOODY SPECIES

Ash, Green (*Fraxinus pennsylvanica*)
Barberry, Creeping (*Mahonia repens*)
Buffaloberry, Silver (*Shepherdia argentea*)
Clematis, Western White (*Clematis ligusticifolia*)
Chokecherry (*Prunus virginiana*)
Cottonwood, Eastern (*Populus deltoides*)
Dogwood, Redosier (*Cornus sericea*)
Douglas-fir (*Pseudotsuga menziesii*)
Ephedra (*Ephedra* spp.)
Gooseberry, Inland (*Ribes oxycanthoides*)
Grape (*Vitis* spp.)
Hackberry, Netleaf (*Celtis laevigata*)
Hawthorn, Black (*Crataegus douglasii*)
Juniper (*Juniperus* spp.)
Juniper, Creeping (*Juniperus horizontalis*)
Lotebush (*Ziziphus obtusifolia*)
Mahogany, Alderleaf Mountain (*Cercocarpus montanus*)
Mesquite (*Prosopis* spp.)
Oak, Sand Shinnery (*Quercus havardii*)
Pine, Ponderosa (*Pinus ponderosa*)
Plum, Chickasaw (*Prunus angustifolia*)
Plum, Creek (*Prunus rivularis*)
Rabbitbrush, Rubber (*Ericameria nauseosa*)
Raspberry, Red (*Rubus idaeus*)
Rose (*Rosa* spp.)
Sagebrush (*Artemisia* spp.)
Sagebrush, Big (*Artemisia tridentata*)
Sagebrush, Sand (*Artemisia filifolia*)
Sagebrush, Silver (*Artemisia cana*)
Sagewort, Gray (*Artemisia ludoviciana*)
Saltbush, Fourwing (*Atriplex canescens*)
Saltbush, Nuttall's (*Atriplex nuttallii*)
Saltbush, Shadscale (*Atriplex confertifolia*)
Serviceberry, Saskatoon (*Amelanchier alnifolia*)
Silverberry (*Elaeagnus commutata*)
Snakeweed, Broom (*Gutierrezia sarothrae*)
Snowberry, Western (*Symphoricarpos occidentalis*)
Soapberry, Western (*Sapindus saponaria*)
Sumac, Littleleaf (*Rhus microphylla*)
Sumac, Skunkbush (*Rhus trilobata*)
Willow (*Salix* spp.)
Winterfat (*Krascheninnikovia lanata*)



GRASSES

Barley (*Hordeum vulgare*)
Bluegrass (*Poa* spp.)
Bluestem, Little (*Schizachyrium scoparium*)
Bluestem, Silver (*Bothriochloa saccharoides*)
Grama, Blue (*Bouteloua gracilis*)
Muhly (*Muhlenbergia* spp.)
Needle and thread (*Hesperostipa comata*)
Needlegrass, Green (*Nassella viridula*)
Ricegrass, Littleseed (*Piptatherum micranthum*)
Rye, Cereal (*Secale cereale*)
Sedge (*Carex* spp.)
Sedge, Sprengel's (*Carex sprengei*)
Signalgrass, Plantain (*Urochloa plantaginea*)
Wheat, Common (*Triticum aestivum*)
Wheatgrass, Western (*Pascopyrum smithii*)
Wildrye, Virginia (*Elymus virginicus*)

SUCCULENTS

Cholla (*Cylindropuntia* spp.)
Pricklypear (*Opuntia* spp.)
Yucca, Soapweed (*Yucca glauca*)

APPENDIX B.

Alphabetical listing of Invasive plants [Common name (*Scientific name*)] of concern in the Great Plains Ecoregion. Taxonomy based on USDA (2008) and Integrated Taxonomic Information System (2007).


GRASSES

Bahiagrass (*Paspalum notatum*)
Bermudagrass (*Cynodon dactylon*)
Bluegrass, Kentucky (*Poa pratensis*)
Bluestem, Angleton (*Dichanthium aristatum*)
Bluestem, Caucasian (*Bothriochloa bladhii*)
Bluestem, King Ranch (*Bothriochloa ischaemum*)
Bluestem, Kleberg's (*Dichanthium annulatum*)
Brome, Field (*Bromus arvensis*)
Brome, Japanese (*Bromus japonicus*)
Brome, Smooth (*Bromus inermis*)
Buffelgrass (*Pennisetum ciliare*)
Cheatgrass (*Bromus tectorum*)
Cogongrass (*Imperata cylindrica*)
Grass, Annual Rabbit's-foot (*Polypogon monspeliensis*)
Guineagrass (*Urochloa maxima*)
Itchgrass (*Rottboellia cochinchinensis*)
Johnsongrass (*Sorghum halepense*)
Lovegrass, Lehmann (*Eragrostis lehmanniana*)
Millet, Pearl (*Pennisetum glaucum*)
Orchardgrass (*Dactylis glomerata*)
Plumegrass, Sugarcane (*Saccharum giganteum*)

Quackgrass (*Elymus repens*)
Reed, Giant (*Arundo donax*)
Ryegrass (*Lolium* spp.)
Ryegrass, Persian (*Lolium persicum*)
Timothy, Common (*Phleum pratense*)
Vaseygrass (*Paspalum urvillei*)
Wheatgrass, Crested (*Agropyron cristatum*)

FORBS

Absinthium (*Artemisia absinthium*)
Baby's Breath (*Gypsophila paniculata*)
Bartsia, Red (*Odontites vernus*)
Bedstraw, Marin County (*Galium spurium*)
Bindweed, Field (*Convolvulus arvensis*)
Bladderpod, Missouri (*Lesquerella filiformis*)
Bluebuttons (*Knautia arvensis*)
Bouncingbet (*Saponaria officinalis*)
Burdock, Common (*Arctium minus*)
Buttercup, Tall (*Ranunculus acris*)
Cleavers (*Galium aparine*)
Cress, Hoary (*Cardaria chalapensis*)
Crownvetch (*Coronilla varia*)
Daisy, Ox-eye (*Leucanthemum vulgare*)
Dandelion, Common (*Taraxacum officinale*)
Fern, Japanese Climbing (*Lygodium japonicum*)
Hemlock, Poison (*Conium maculatum*)
Hornpoppy, Blackspot (*Glaucium corniculatum*)
Hound's-tongue, Common (*Cynoglossum officinale*)
Knapweed, Diffuse (*Centaurea diffusa*)
Knapweed, Russian (*Acroptilon repens*)
Knapweed, Spotted (*Centaurea biebersteinii*)
Knapweed, Squarrose (*Centaurea triumfettii*)
Kochia, Prostrate (*Kochia prostrata*)
Lespedeza, Sericea (*Lespedeza cuneata*)
Loosestrife, Purple (*Lythrum salicaria*)
Mayweed, Scentless False (*Tripleurospermum perforatum*)
Milk-thistle, Blessed (*Silybum marianum*)
Mullein, Common (*Verbascum thapsus*)
Mustard, Garlic (*Alliaria petiolata*)
Mustard, Hare's-ear (*Conringia orientalis*)
Sowthistle, Perennial (*Sonchus arvensis*)
Stork's Bill, Redstem (*Erodium cicutarium*)
Spurge, Cypress (*Euphorbia cyparissias*)
Spurge, Leafy (*Euphorbia esula*)
Star-thistle, Yellow (*Centaurea solstitialis*)
Sweetclover, White (*Melilotus alba*)
Sweetclover, Yellow (*Melilotus officinalis*)
Tansy, Common (*Tanacetum vulgare*)
Thistle, Bull (*Cirsium vulgare*)
Thistle, Canada (*Cirsium arvense*)
Thistle, Musk (*Carduus nutans*)
Thistle, Scotch (*Onopordum acanthium*)
Toadflax, Dalmatian (*Linaria dalmatica*)
Toadflax, Yellow (*Linaria vulgaris*)
Tumblemustard, Tall (*Sisymbrium altissimum*)



Vervain, Brazilian (*Verbena brasiliensis*)
Whitetop (*Cardaria draba*)

WOODY SPECIES

Buckthorn, European (*Rhamnus cathartica*)
Currant, Cultivated Red (*Ribes rubrum*)
Elm, Siberian (*Ulmus pumila*)
Honeysuckle, Japanese (*Lonicera japonica*)
Lilac, Common (*Syringa vulgaris*)
Olive, Russian (*Elaeagnus angustifolia*)
Peashrub, Siberian (*Caragana arborescens*)
Privet, Chinese (*Ligustrum sinense*)
Rose, Macartney (*Rosa bracteata*)
Rose, Multiflora (*Rosa multiflora*)
Tallow, Chinese (*Triadica sebifera*)
Tamarisk (*Tamarix* spp.)

APPENDIX C.

Alphabetical listing by category [Common name (Scientific name)] of species cited in the text. Plant taxonomy based on USDA (2008) and Integrated Taxonomic Information System (2007).

FORBS AND GRASSES

Alfalfa (*Medicago sativa*)
Barley (*Hordeum vulgare*)
Bluegrass, Kentucky (*Poa pratensis*)
Bluestem, Yellow (*Bothriochloa ischaemum*)
Brome, Field (*Bromus arvensis*)
Brome, Japanese (*B. japonicus*)
Brome, Smooth (*B. inermis*)
Cheatgrass (*B. tectorum*)
Cholla (*Cylindropuntia* spp.)
Corn (*Zea mays*)
Cotton (*Gossypium* spp.)
Grama, Blue (*Bouteloua gracilis*)
Kochia (*Bassia scoparia*)
Peanut (*Arachis* spp.)
Pricklypear (*Opuntia* spp.)
Sorghum, Grain (*Sorghum bicolor*)
Soybean (*Glycine max*)
Spurge, Leafy (*Euphorbia esula*)
Thistle, Russian (*Salsola* spp.)
Thistle, Canada (*Cirsium arvense*)
Timothy (*Phleum pratense*)
Wheat (*Triticum aestivum*)
Wheatgrass, Crested (*Agropyron cristatum*)
Yucca (*Yucca* spp.)

TREES AND SHRUBS

Aspen (*Populus tremuloides*)
Buckbrush (*Ceanothus cuneatus*)
Buffaloberry (*Shepherdia* spp.)
Chokecherry (*Prunus virginiana*)
Cottonwood (*Populus deltoides*)
Juniper, Rocky Mountain (*Juniperus scopulorum*)
Mahogany, Mountain (*Cercoparpus montanus*)
Oak, Havard or Sand Shinnery (*Quercus havardii*)
Olive, Russian (*Elaeagnus angustifolia*)
Pine, Ponderosa (*Pinus ponderosa*)
Plum, Chickasaw (*Prunus angustifolia*)
Rabbitbrush, Rubber (*Ericameria nauseosa*)
Redcedar, Eastern (*Juniperus virginiana*)
Rose, Woods' (*Rosa woodsii*)
Sagebrush, Big (*Artemisia tridentata*)
Sagebrush, Fringed (*Artemisia frigida*)
Sagebrush, Sand (*Artemisia filifolia*)
Saltbush, Fourwing (*Atriplex canescens*)
Serviceberry (*Amelanchier* spp.)
Snowberry, Western (*Symphoricarpos occidentalis*)
Sumac, Skunkbush (*Rhus trilobata*)
Tamarisk or Saltcedar (*Tamarix ramosissima*)
Willow (*Salix* spp.)
Winterfat, Common (*Krascheninnikovia lanata*)

ANIMALS AND OTHERS

Bacteria, Botulinum (*Clostridium botulinum*)
Bison (*Bison bison*)
Cattle (*Bos taurus*)
Chicken, Prairie (*Tympanuchus cupido*)
Coyote (*Canis latrans*)
Deer, Mule (*Odocoileus hemionus*)
Deer, White-tailed (*Odocoileus virginianus*)
Dog, Prairie (*Cynomys* spp.)
Elk (*Cervus elaphus*)
Goat, Domestic (*Capra hircus*)
Midge (*Culicoides* spp.)
Moose (*Alces alces*)
Pronghorn (*Antilocapra americana*)
Sheep, Bighorn (*Ovis canadensis*)
Sheep, Domestic (*Ovis aries*)
Swine, Feral (*Sus scrofa*)
Worm, Meningeal (*Paraelaphostrongylus tenuis*)

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