HABITAT GUIDELINES FOR MULE DEER

SOUTHWEST DESERTS ECOREGION

A Product of the
Mule Deer Working Group

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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. 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 in 2001 showed 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 Boreal 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 boreal forests. Winterkill is not a problem in the Southwest Deserts, but overgrazing and drought detrimentally impact populations.

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 the 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 provided for growth of important deer browse plants. 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.

Because of the vast blocks of public land in the West, habitat management throughout most of the geographic range of mule deer is primarily the responsibility of federal land management agencies. Mule deer habitats are facing unprecedented threats from a wide variety of human-related developments. If mule deer habitats are to be conserved, it is imperative that state and federal agencies and private conservation organizations are aware of key habitat needs and participate fully in habitat management for mule deer. Decades of habitat protection and enhancement under the nomer of "game" management benefited countless other unhunted 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 amelioration 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/twigs of woody shrubs). Deer digestive tracts differ from cattle (Bos taurus) and elk (*Cervus canadensis*) in that they have a smaller rumen in relation to their body size and so they must be more selective in their feeding. Instead of eating large quantities of low quality feed like grass, deer must select the most nutritious plants and parts of plants. Because of this, deer have more specific forage requirements than larger ruminants.

The presence and condition of the shrub component is an underlying issue found throughout different ecoregions and is important to many factors affecting mule deer populations. 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.

Mule deer are known as a "K-selected" species. This means that populations will increase until the biological carrying capacity is reached. If deer populations remain at or beyond carrying capacity they begin to impact their habitats in a negative manner. The manager must also be aware that long-term impacts like drought conditions and vegetation succession can significantly lower the carrying capacity for deer and even when a droughty period ends the overall capacity may be lower than it might have been 20 years earlier. This may well be the situation in many mule deer habitats in the west and the manager 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 being mobile will move in and out of the treatments and thus a larger area of habitat will benefit. In general, a number of smaller treatments in a mosaic or patchy pattern are more beneficial than one 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 (NAMDCP) provides a broad framework for managing mule deer and their habitat. 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.

THE SOUTHWEST DESERTS ECOREGION

Description

The Southwest Deserts include southern portions of California, Arizona, New Mexico, and west Texas, extending south into the Mexican states of Baja, Sonora, Chihuahua, Coahuila, and Durango (Fig. 1). Mule deer in this ecoregion inhabit areas primarily classified as Sonoran, Mohave, and Chihuahuan desert vegetation associations. Climate is arid to semi-arid with extreme temperature variations and high evaporation rates. Annual rainfall in these desert areas is low (< 4 - 20 in) and highly variable. In the southeastern portion of this region, violent summer storms produce most of the annual moisture, but rainfall is more evenly balanced between winter and summer periods in the northwestern extent of these desert regions. Southwest soils are generally low in organic material and high in calcium carbonate.

Ecoregion-specific deer ecology

Fawn recruitment is highly variable depending on amount and timing of rainfall. Population fluctuations rely largely on abundance of spring forbs produced as a result of winter rainfall. Smith and LeCount (1979) analyzed 9 years of fawn:doe ratios, winter rainfall totals, and deer forage abundance in Arizona and found there was an extremely high correlation between October-April rainfall and forage (forbs and browse species) available to deer in mid-gestation (April). Further analysis showed that January fawn:doe ratios for mule deer are also highly correlated with amount of forbs produced the previous spring. Snow is uncommon in mule deer habitat in this region, which means these non-migratory deer benefit from abundant winter precipitation rather than suffer high winter mortality.

Browse plants that deer rely on most for nutrition appear to have inadequate levels of protein and phosphorus except during the active winter growing season (Urness et al. 1971). After annual growth stops in early spring, protein and phosphorus drop below levels recommended for satisfactory growth for the remainder of pregnancy. To compensate for this, deer supplement their diet with forbs, which are extremely important because they are highly digestible and supply a disproportionate amount of nutrients like protein and phosphorus.

In Southwest Deserts, female fawns rarely breed. High body weight and good physical condition are prerequisites for breeding as fawns. Deer in this region are born much later than northern deer and normally do not have the nutrition necessary to attain breeding condition as fawns. The yearling cohort is most susceptible to nutritionally induced variations in fertility (Lawrence et al. 2004). This variation is important because there are many more yearling does in the population than any other age cohort. Impact of nutrition on yearling does is precisely why consecutive years of above-average rainfall are important to building deer populations in the Southwest Deserts. Effect of nutrition on total herd productivity then, is largely manifested in proportion of yearlings breeding and average number of fawns they recruit into the population.

In a study involving white-tailed deer (*Odocoileus virginianus*), 92% of fawns born to malnourished does died within 2 days (Verme 1962), while does receiving good nutrition throughout the last half of pregnancy gave birth to fawns that weighed twice as much and only 5% died within a few days. A similar relationship exists in mule deer (Salwasser et al. 1978), which is important in the Southwest because the late-gestation period corresponds to the low point in the annual nutritional cycle. If winter rains are sparse and forb production low, pregnant does enter the summer nutritional bottleneck in poor condition with summer rains not arriving until the last few weeks of pregnancy.

Precipitation is the main factor affecting deer nutrition in the Southwest Deserts, but the condition of the habitat plays a large role in determining how much of that nutrition is available to each deer. Other ungulates (cattle, elk, other deer, burros, sheep, etc.) can reduce amount of forage available to deer and negatively affect reproduction. Moderate to heavy grazing on desert vegetation can quickly reduce herbaceous cover crucial for fawning cover and doe nutrition (Horejsi 1982). Excessive livestock stocking rates in desert areas can result in livestock removing the current (and previous) year's annual growth of browse twigs, which might cause them to further impact the herbaceous forbs.

In Mexico, the climate/habitat effects on deer populations are overshadowed by ineffective restrictions on harvest. Leopold (1959) observed that subsistence hunting was depressing deer populations in many areas of Mexico. This situation still exists and may limit the distribution of mule deer on the southern periphery of their range.

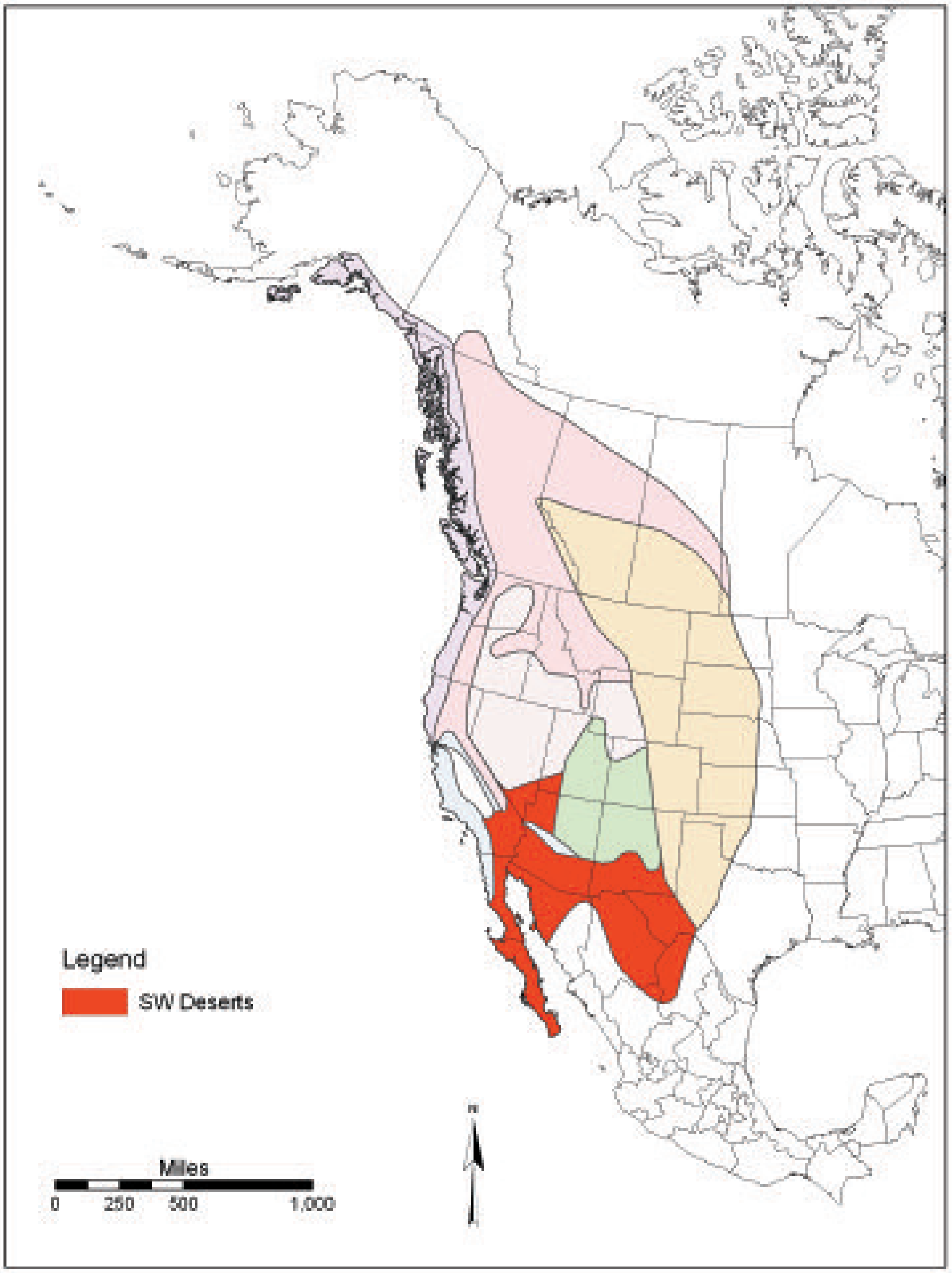

Figure 1. The Southwest Deserts Ecoregion (Sue Boe/AGFD)

Plant species composition has been modified. In some cases noxious or invasive species have proliferated in native plant communities, frequently reducing species richness by replacing native flora with near-monocultures. More subtlety, less desirable species have become more abundant at the expense of more desirable species (e.g., blue grama replacing higher quality grama grasses).

Vegetation structure has been modified. Both increases and decreases in woody species can decrease mule deer habitat quality. Increasing woody cover in some cases decreases the amount and diversity of herbaceous species. Conversely, decreases in some woody species often results in less nutrition and hiding or thermal cover.

Nutritional quality has decreased. Increasing age of woody shrubs can result in forage of lower nutritional quality and the plant growing out of reach of mule deer. Many browse plants eventually become senescent and die if not disturbed. Some factors can also result in the death of woody plants or in a growth form where much of the nutrition is beyond the reach of deer.

Loss and fragmentation of usable habitat due to human encroachment and associated activities. Mule deer habitat is lost completely due to the expansion of urban/suburban areas and other associated activities such as energy and mineral development, road building, and motorized recreation. Related human activity can also displace mule deer from otherwise suitable habitat.

Long-term Fire Suppression

Background

The importance of fire in shaping and maintaining southwestern landscapes is well documented (Stewart 1956, Wright and Bailey 1982, McPherson 1995, and Frost 1998). Pase and Granfelt (1977) suggested that many biotic communities of the Southwest co-evolved with fire in the last 10,000 to 12,000 years. Wright and Bailey (1982) reported that only deserts with less than 7 inches of annual precipitation escaped the influence of fire.

Wildfire remained a principal force in natural community development and maintenance until the arrival of Anglo-Americans during the 19th century. Settlement brought about significant landscape level changes including the alteration and/or removal of natural processes such as fire. Considered non-compatible with human land-use practices, fire suppression continued in the Southwest throughout much of the twentieth century.

Figure 2. Dense monocultures that exceed maximum canopy coverage of 40% and lack diverse understories with adequate amounts of quality forage are of little value to mule deer (Photograph by Clay Brewer/TPWD).

Issues and Concerns

Ecological succession is the directional, predictable, and orderly process of community change involving replacement of one plant community by another. More recently, ecologists are starting to realize that plant communities can remain stable at a lower successional state than originally occurred there (Laycock 1991, Briske et al. 2003). The pattern and rate of change in plant communities are controlled by the physical environment, which has significant implications for mule deer populations. The arid to semi-arid climate of the Southwest is characterized by extreme temperatures and unpredictable precipitation. As a result, mule deer and other wildlife are particularly sensitive to many human-caused landscape changes.

Before the fire suppression era, frequent, low-severity wildfires maintained landscape and habitat diversity by providing opportunities for the establishment and maintenance of early successional species and communities (Schmidly 2002). These successional patterns were changed through the alteration of natural fire frequencies and intensities (Fig. 2). The results of these alterations can be found throughout the Southwest. Examples include: the deterioration of desert grasslands through woody plant encroachment and loss of important plant species and the increase of large-scale, intense, and detrimental catastrophic fires that result from the buildup of abnormal fuel loads.

Figure 3. Mule deer benefit from lower tree canopy (<40%), increased ground cover and diversity, and stimulation of important forage species following a prescribed burn in a Ponderosa pine community (Davis Mountain Preserve - Photograph by Clay Brewer/TPWD).

Figure 4. Fire is also important in regenerating desirable woody plants, such as this New Mexican locust re-sprouting following the "Rodeo-Chediski Fire" in Arizona (Photograph by Jim Heffelfinger/AGFD).

The combined forces of drought, overgrazing, and fire suppression resulted in significant changes to plant community composition, structure, nutritional values, and disturbance processes (Lutz et al. 2003, Richardson 2003). This landscape-level deterioration of habitat towards stable and low-diversity plant communities is a key factor responsible for diminishing mule deer populations in many areas of the Southwest. Reintroducing ecologically appropriate fire regimes holds the most potential for sustaining and creating mule deer habitat in this Ecoregion (Figs. 3-6).

The specific issues related to the suppression of fire in some portions of the Southwest Deserts can be summarized in 3 main categories.

Plant Species Composition

- Decreased diversity of plant communities as woody and invasive species proliferate.
- Reduction or loss of herbaceous plants as canopy cover increases.
- Decreased reproduction and prevalence of desired plant species as canopy structure changes.
- Replacement of important perennial forbs and grasses by invasive species.
- Replacement of deep-rooted perennial bunchgrasses with less desirable annual species.
- Encouragement of non-native plant species.
- Increased plant susceptibility to disease and insect infestation as woody plants become decadent.

Vegetation Structure

- Elimination of disturbances that maintain early and mid-successional woody plant communities.
- Reduction of herbaceous understory due to increased canopy cover.
- Encroachment or dominance of woody plants.
- Rapid expansion of shade tolerant tree and shrub populations.
- Increased age and senescence of important browse species.
- Monotypic communities of similar age and structure.
- Increased height of community, changing insects and pathogens.
- Increased erosion due to less ground cover.
- Local hydrologic changes.

Nutritional Quality

- Absence of abundant and diverse high quality forage.
- Decrease in nutrient value of plant species as plants mature.
- Reduction and/or elimination of nutrient cycling through lack of disturbance.
- Decreased palatability of maturing forages.

Guidelines

Some vegetation communities are adapted to, and reliant on, frequent fire, but some are not. Managers need to strive to restore historic fire regimes where ecologically appropriate, yet protect some plant communities from harmful fires. The restoration of fire in some southwestern ecosystems serves as a highly effective and cost efficient tool for enhancing mule deer habitat (Table 1). In areas where fire naturally helped maintain the plant community, prescribed burning is one of several tools available to habitat managers. Fire creates a natural mosaic of diverse

Figure 5. Long-term fire suppression and subsequent encroachment of woody vegetation, results in decreased use by mule deer in the Guadalupe Mountains of New Mexico (Photograph by Barry Hale/NMDGF).

Figure 6. In heavily vegetated mountainous areas of the Southwest, managers can use large-scale burning to enhance mule deer habitat at the landscape level (Photograph by Jim Heffelfinger/AGFD).

plant communities that provides for important habitat needs at any given time (Fig. 7). Prescribed burning must follow specific guidelines that establish the conditions and manner under which fire is applied to an area in order to achieve well-defined short and long-term management objectives. Considerations for the size, timing, frequency, and intensity of fire are critical for achieving burn objectives (Table 2). Successful managers understand the essential habitat requirements of mule deer and understand how management practices such as prescribed burning impact these requirements (Cantu and Richardson 1997).

A. Fire Management 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 the effects of fire on various natural communities. Elements of the plan should include:

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

B. Effects of Fire on Important Habitat Components

1. Food: One of the most important factors influencing the health, productivity, and survival of mule deer in the Southwest is the quantity, quality, and variety of food plants (Richardson et al. 2001). The absence of abundant and diverse high quality forage in late seral communities fails to provide the diet quality and nutrition that is required for most aspects of deer production and survival (Fig. 8; Short 1981, Wakeling and Bender 2003). According to Cantu and Richardson (1997), mule deer require a diet of approximately 16% protein along with carbohydrates, fats, vitamins, and a variety of trace minerals and no single forage provides adequate levels of all these requirements. A wide variety of browse and forbs allows mule deer to take advantage of plant availability and those with higher nutritive value (Krausman et al. 1997). Early successional habitats provide an abundance and diversity of young forbs and shrubs that are high in protein and nutritious. Fire is an effective tool available for returning natural communities to early successional stages in plant communities that are fire adapted (Fig. 9). In communities that did not evolve with periodic fires, an increase in the frequency of fire can be devastating.

2. Cover: The importance of woody plants in providing security cover, shelter from weather extremes, and escape from predators has been documented extensively (Severson and Medina 1983). In the Southwest, many woody plants are also an important source of food. However, late seral plant communities that are dominated by woody vegetation can become too dense and unsuitable for mule deer. Use of fire in managing woody plants can be beneficial or detrimental to mule deer, depending on how it influences cover and food (Cantu and Richardson 1997). Wiggers and Beasom (1986) found that mule deer numbers in west Texas tended to decrease as woody plant cover increased and that mule deer populations could be enhanced by limiting woody plant cover to about 40%. Avey et al. (2003) found a mean shrub cover of 37.3% for mule deer in west-central Texas and suggested that managers maintain a lower percent woody cover and encourage native forb growth to enhance mule deer populations. Managers should consider a canopy cover of $<40\%$ as the general rule of thumb.

Figure 7. Appropriate cover and availability of quality browse and forbs following a prescribed burn in the Davis Mountains of West Texas (Davis Mountain Preserve–Photograph by Clay Brewer/TPWD).

C. Additional Tools to Consider

Two other options are available for enhancing mule deer habitat, mechanical and chemical treatments. These may be useful options for plant communities that are not fire adapted. Like prescribed burning, proper planning and execution is critical for achieving success. Managers must carefully consider the advantages and disadvantages of each method (Table 3). Combining more than one 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).

Figure 8. Degraded desert grasslands, like this area of Chihuahuan Desert in Texas, fail to provide important habitat requirements of mule deer, such as quality forage and adequate cover (Photograph by Clay Brewer/TPWD).

1. Mechanical Vegetation Treatment

Mechanical treatments include: rootplows, chaining, ripping, rotobeating, grubbers, bulldozing, 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 that mechanical treatment be used for removing brush canopy, and promoting a variety of forbs and grasses through soil disturbances and decreased competition.

Figure 9. Fire is the most efficient tool available for rejuvenating important browse species such as mountain mahogany (foreground) and reducing the density of undesirable woody plants such as manzanita (background). Photo by Tom Deecken.

2. Chemical Vegetation Treatment

Chemical treatment involves the use of herbicides to control undesirable plants or vegetation patterns (Figs. 10-11). Methods and rates of application vary considerably depending on the desired results. Herbicides may be applied: in pellet or liquid form, foliar or in soils, and aerially or through ground treatment methods (Richardson et al. 2001). The method and rate of application must be carefully selected to maximize success and minimize adverse impacts.

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

Food	➤ Improves nutrient cycling ➤ Increases palatability of forages ➤ Stimulates crown or root sprouting ➤ Creates a mosaic of different successional stages ➤ Elimination of undesirable plant species ➤ Increases nutrient value of plant species ➤ Removes dense, rank, and/or over mature growth ➤ Provides for early successional species and communities ➤ Encourages early spring green-up ➤ Stimulates seed germination ➤ Reduces undecomposed organic materials and litter that inhibit growth of grasses and forbs
Cover	➤ Creates/maintains appropriate cover levels ➤ Creates edge ➤ Controls young invading undesirable woody plants ➤ Produces temporary openings ➤ Modifies utilization patterns ➤ Improves detectability of predators ➤ Improves fawning cover through the promotion of seed germination and growth of perennial bunchgrasses (fawning cover)
Water	➤ Improves water yield ➤ Spring recharging ➤ Improves water infiltration, retention, and deep percolation (through increased ground cover)

Table 2. Effects of fire and season on vegetation (Severson and Medina 1983, Richardson et al. 2001).

Timing	Effects of Fire	
	Forbs	Woody Plants
Cool Season (early-mid winter)	➤ Improved germination ➤ Improved growth and vigor of desirable grasses and forbs ➤ Promotes cool-season annuals and perennials ➤ Maximum forb growth	➤ Temporary suppression ➤ Reinvigoration of desirable browse
Cool Season (late winter)	➤ Reduces abundance of annual forbs ➤ Promotes perennial grasses ➤ Improved grass quality and species composition	➤ Temporary suppression ➤ Reinvigoration of desirable browse
Warm Season	➤ Reduces abundance of annual forbs ➤ Promotes perennial grasses ➤ Improved grass quality and species composition	➤ Maximum mortality

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

Treatment	Advantages	Disadvantages
Mechanical	➤ Selective ➤ Produces immediate forb response ➤ Promotes a variety of herbaceous plants through soil disturbances and decreased competition ➤ Encourages sprouting of palatable and nutritional browse plants	➤ Cost ➤ High erosion potential ➤ Limited by topography ➤ Archaeological concerns ➤ Most methods only provide temporary control of woody plants
Chemical	➤ Provides for treatment of large areas in a short time period (aerial) ➤ Erosion potential is less (no ground disturbances) ➤ Not limited by topography (aerial) ➤ Selective (individual plant treatment) ➤ Useful as a preparatory treatment before prescribed burning	➤ Cost ➤ Some woody plants are resistant to herbicides ➤ Short-term suppression of desirable plants (1-2 years after treatment) ➤ Non-selective (non-target damage or mortality to desirable plants) ➤ Woody plants and litter not totally consumed (standing dead woody plants)

Figure 10. Chemical treatment using herbicides to control undesirable plants or vegetation patterns can be an effective way to improve mule deer habitat. (Photo by Chris Casaday/Natural Resource Conservation Service)

Figure 11. Herbicides can be used to reduce undesirable amounts or types of woody plants, as depicted here following the application of the herbicide Spike®. (Photo by Chris Casaday/Natural Resource Conservation Service)

Excessive Herbivory

Background

Large herds of grazers have been absent from the deserts of the Southwest since the mass extinctions at end of the Pleistocene Epoch about 10,000 years ago (Martin and Klein 1984). The fossil record indicates mule deer were extremely limited in number and distribution during the Pleistocene and expanded throughout the Southwest only after the disappearance of these large grazers.

The first livestock were brought into Mexico by Hernando Cortez in 1515 (Holechek et al. 1998:49). In 1540, Coronado brought cattle, sheep, and horses into the United States with his first expedition into the Southwest. Many of these livestock escaped and proliferated in feral herds throughout New Mexico, Arizona, Texas, and northern Mexico. As human settlement progressed, the numbers of domestic sheep, goats, cattle, and horses increased on most available rangelands by the late 1800s. New Mexico averaged over 100 sheep per square mile in much of the northeastern part of the state (Carson 1969). By the time a multiyear drought hit the Southwest in the 1890s it was obvious the arid southwestern ranges could not be stocked as heavily as more mesic grasslands to the east and north (Bahre 1991). The chronic overuse of vegetation by an inappropriately high number of livestock set in motion landscape-scale changes to southwestern rangelands (Fig. 12). In more recent years (1980-94) the number of cattle have decreased by 9% in the U.S., but increased (11%) in Mexico (Holechek et al. 1998:13). During that same period, the number of sheep decreased by 24% in the U.S. and 9% in Mexico.

There is much confusion about the interchangeability of terms such as grazing, over-grazing, and overuse. A discussion of the effects of livestock on vegetation must be based on a consistent use of terminology. "Grazing" is neither good nor bad, it is simply consumption of available forage by an herbivore. Grazing the 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 the potential to change both food and cover available to deer. Although precipitation is the most important factor affecting deer nutrition and fawn survival in the Southwest Deserts, habitat conditions as impacted by ungulate density determines how much of that nutrition

and cover remains available to deer.
Livestock grazing can cause both short- and long-term changes to mule deer habitat (Peek and Krausman 1996, Bleich et al. 2005). Grazing at light to moderate levels has little impact on deer, but overuse in arid environments removes much of the herbaceous cover that is crucial for doe nutrition and fawning cover (Loft et al. 1987,

Figure 12. Historic land use practices such as this 1940s goat camp in the Chihuahuan Desert of Texas significantly altered mule deer habitat (Photo courtesy of Michael Pittman/Texas Parks and Wildlife Department [TPWD]).

Figure 13. A biologist discusses mule deer habitat needs with a range manager following a precipitous decline in the local mule deer population.

Galindo-Leal et al. 1994). Long-term changes resulting from overgrazing include undesirable changes in the plant community, decreased mulch cover, decreased water infiltration, compacted soil, increased water runoff, decreased plant vigor and production, and a drier microclimate at ground level (Fig. 13, Severson and Medina 1983:24). Overgrazing also removes browse leaves and twigs important to mule deer, further exacerbating poor nutritional conditions created by removal of forbs (Hanson and McCulloch 1955). Livestock sometimes browse important deer shrubs excessively (Swank 1958, Knipe 1977). Jones (2000) reviewed the literature from arid rangelands in western North America and found that overuse and overgrazing had significant detrimental effects on 11 of 16 variables measured (mostly soil and vegetation characteristics).

Decades of experience and, more recently, research has shown that general rules and range management practices from more mesic ranges cannot be applied successfully to southwestern rangelands. The range manager's axiom of "take half and leave half" is excessive for arid desert ranges (Holechek et al. 1999, Lyons and Wright 2003). Reducing the intensity of grazing generally results in improvements in range condition, but there is a misconception that removing cattle will always result in the range recovering to a climax state or pristine condition (Pieper 1994:202, Briske et al. 2003). In reality, southwestern rangeland is not resilient to overgrazing. Long-term deferments from grazing in arid and semiarid regions may not result in any significant improvement in range condition (Laycock 1991, 1994:257; Holechek et al. 1998:191), or improvements may take 40-50 years (Valone et al. 2002, Guo 2004). Although overgrazing has impacted the Southwest Deserts more than other rangeland type (Pieper 1994), grazing is sustainable in this ecoregion if stocking rates are at appropriate levels and season of use is considered (Fig. 14, Holechek et al. 1999).

Ungulate Competition
Competition between 2 species can occur for any resource that is in short supply and used by both. Concerns of ungulate competition are usually focused on forage resources. The degree of forage competition between 2 species depends primarily on the amount of dietary overlap (similarity in diet) and whether the plants used by both are in short supply (Holechek et al. 1998:385). A high degree of dietary overlap alone does not infer competition, it only indicates the potential exists.

Mule deer in the Southwest have not co-existed with a large grazing competitor for thousands of years (Mead and Meltzer 1984). Competition for resources can occur between native ungulates in some cases, but generally competition is greater between 2 species that have not coevolved separate niches. White-tailed deer and mule deer have very similar diets in the Southwest (Anthony and Smith 1977), but generally stay separated spatially by occupying different elevation zones. High mule deer densities can create intense intraspecific competition, but this is less of an important issue in most desert areas because periodic drought generally keeps deer densities low. Deer carrying capacity fluctuates widely in the Southwest Deserts resulting in varying potential for competition. Periods of high deer densities and excessive browsing in the past have lowered the quality and condition of deer browse in some areas.

Elk were never common in the Southwest Deserts, existing only in high elevation mountains on the northern fringe of this ecoregion (Mearns 1907, Carrera and Ballard 2003). In the Southwest Deserts Ecoregion, bison (*Bison bison*) were only known to inhabit the grasslands of Chihuahua and southern New Mexico. As a result, historic competition with a large grazer was not an issue throughout most of the ecoregion. In recent years, however, elk have benefited from landscape changes such as the development of surface water for cattle production and have expanded into the low deserts in some areas. Elk are primarily grazers, but are more flexible in forage use and can seriously impact forbs and browse. The ecological relationships between elk and mule deer in these arid desert grasslands have not been studied, but there exists a greater possibility of competition in this less productive ecoregion.

Domestic sheep and goats 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). Native American pueblos in the Southwest grazed large numbers of sheep in the late 1800s (Carson 1969), and sheep are still common on some tribal lands. Other attempts to raise sheep and goats in the desert have not met with success and this practice has largely been abandoned except in isolated areas. However, increasing demand for goat meat has resulted in renewed interest in raising goats on public land. Cattle are by far the most important class of livestock to consider here because of their abundance and widespread distribution across southwestern rangelands.

Dietary overlap is an important consideration, but if the 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) and have a lesser impact on forbs and browse. However, many forbs are highly palatable to cattle and, given their larger size, cattle remove a large volume of forbs (Lyons and Wright 2003). During drought or when the annual growth of herbaceous material is overused, cattle (and elk) can switch more heavily to

Figure 14. Healthy desert mule deer habitat contains a diversity of browse, forbs, and succulents to provide for the nutrition and cover requirements of both fawns and adults (Photo courtesy of Arizona Game and Fish Department).

Figure 15. During drought or when herbaceous material is overused, cattle and elk feed more heavily on browse (like this stunted Jojoba), which can decrease important nutritional resources for deer (Photo by Jim Heffelfinger/AGFD).

Figure 16. Under appropriate stocking rates, cattle primarily eat grass and have a lesser impact on southwestern forbs and browse (Photo by Jim Heffelfinger/AGFD).

Figure 17. Overgrazing causes long-term degradation of the soil and vegetative community that may not be reversible even with long periods of no grazing.

Figure 18. An appropriate stocking rate for the area is the key to improving or maintaining quality habitat for mule deer in arid desert regions. (Photo courtesy of Arizona Game and Fish Department)

Figure 19. Riparian and xeroriparian corridors are extremely important habitat features for mule deer in Southwest Deserts so grazing plans must provide for their protection.

browse and competition with deer increases substantially (Severson and Medina 1983).

Stocking rates of cattle on some grazing allotments in the Sonoran Desert are actually based on browse because herbaceous material is scarce or nonexistent in many years. Some "browse allotments" in the Sonoran Desert allow cattle to use 50% of the browse over large areas. Cattle in these areas mostly browse Jojoba (*Simmondsia chinensis*) and Fairy Duster (*Calliandra eriophylla*), which are important components of desert mule deer diets in the area. The actual use on these plants is not monitored, but heavy use is evident (Fig. 15; Arizona Game and Fish Department, unpublished data).

Ungulates are not the only class of animals that can affect vegetation and potentially compete with mule deer for forage. 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, it is important for managers to consider all grazers in the area and how they are using vegetation.

Deer avoid areas occupied by large numbers of cattle, and they are more abundant in areas ungrazed by cattle (McIntosh and Krausman 1981, Wallace and Krausman 1987). This may be related to nutritional resources, lack of cover, or behavioral avoidance. Overuse and, ultimately, overgrazing can reduce the amount of cover to an extent that fewer deer can occupy an area regardless of the forage available. This is especially important during parturition where cover for fawns is vital to their survival in the first few months of life (Loft et al. 1987). Horejsi (1982) reported that grazing negatively impacted fawn survival, but only during drought years. Gallizioli (1977) suggested higher productivity and better habitat conditions in ungrazed areas equate to higher overall mule deer densities. Because of the widespread presence of cattle on southwestern ranges, using appropriate grazing practices may be one of the best possibilities for improving mule deer nutrition on a landscape scale (Fig. 16, Longhurst et al. 1976).

Stocking Rate

Stocking rate is usually defined as "the amount of land allocated to each animal unit for the grazable period of the year" (Society of Range Management 1989). There are different units used to express stocking rate, but in the Southwest it is usually expressed as Cows Year Long (CYL) or Animal Unit Months (AUM) per square mile. A "cow" or "animal unit" is one cow and a calf up to 6 months of age. Selecting the appropriate stocking rate is the most important consideration in range management decisions from the standpoint of vegetation, livestock, wildlife, and economic return (Lyons and Wright 2003). Stocking rate has more influence on vegetation productivity than any other grazing factor (Holechek et al. 1998, 2000). In Southwest Deserts, studies have shown that moderate stocking levels are most profitable over the long run to the rancher and also best benefit the land (Holechek 1994, 1996). Research has shown that overstocking can prevent range improvement in an otherwise appropriate grazing system (Fig. 17, Eckert and Spencer 1987); therefore, a good grazing system alone will not result in range improvement if the stocking level is higher than sustainable. Timing and intensity of grazing are important considerations, but more than any other parameter, stocking rate determines whether an area is properly grazed or overused. This element is the key to maintaining nutritional and cover requirements of mule deer in the Southwest Deserts (Fig. 18).

As important as stocking rate is, there are other considerations that are nearly as important at times to maintaining high quality mule deer habitat. The timing of grazing, for example, can be important when the goal is providing fawning cover or retaining a herbaceous layer of forbs. In some cases, even grazing at a low or moderate stocking rate during spring forb production may negatively affect the amount of nutrition available to desert mule deer.

Rotating Livestock

Savory and Parsons (1980) claimed that by grazing pastures intensively and then moving livestock the range could be improved while simultaneously increasing the stocking rate. It was said that stocking rate could sometimes be doubled or tripled with improvements to range and livestock productivity (Savory and Parsons 1980). A synthesis of grazing studies conducted worldwide failed to show that short-duration grazing was superior to continuous grazing when stocking rates were the same (Briske et al. 2008, Holechek et al. 2000). The increased "hoof action" of a large number of cattle on the soil was shown consistently to decrease water infiltration, rather than increase it (McCalla et al. 1984, Thurow et al. 1988, Pluhar et al. 1987, Warren et al. 1986). Studies from desert rangelands showed no advantage to various kinds of rotational grazing over continuous grazing in range condition, grazing efficiency, livestock productivity, or financial returns (Briske et al. 2008, Holechek 1994, 1996, Holechek et al. 1999). Despite this, some range managers continue to allow or even promote inappropriately high stocking rates with a short-duration grazing system. Rotating livestock among different areas can improve control over how various parts of the ranch are managed, and may allow deferment of areas such as riparian corridors or fawning areas. As always, the key is maintaining a site-specific appropriate stocking rate.

Riparian and Xeroriparian

Riparian and xeroriparian (dry washes) vegetation occupy a small proportion of the land area in the Southwest, but have an extremely important function in providing for the year-round habitat requirements of mule deer. Xeroriparian habitats are used disproportionately by mule deer in the Southwest Deserts (Krausman et al. 1985). Rogers et al. (1978) reported that xeroriparian habitat comprised only 3% of his study area, but desert mule deer were found there 30% of the time. These linear habitat features provide mature trees for thermal and screening cover and the drainage patterns promote the pooling of water, the growth of forbs, and a greater diversity of important shrubs. Unfortunately these elements also attract livestock for the same reasons (Fig. 19). Belsky et al. (1999) summarized research documenting the negative effects of livestock overgrazing on riparian ecosystems in the West. Riparian and xeroriparian habitats must be carefully considered in overall grazing strategies (Figs. 20-21).

Improving Habitat with Livestock

Some work has been done to investigate the use of livestock as a mule deer habitat improvement tool (Severson 1990). This does not include simply relaxing grazing pressure to improve conditions, but actually altering the condition or structure of the forage to increase deer carrying capacity above that in the absence of livestock.

Figure 20. Riparian corridors make up a small proportion of the land area, but are vitally important to desert wildlife for the resources they provide and to facilitate landscape connectivity (Photo by Jim Heffelfinger/AGFD)

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 the grazing specifically for this purpose (Severson and Medina 1983) based upon a carefully crafted management plan.

The timing and location of the treatment needed to improve mule deer habitat may not be in the best interest of the livestock operator from a financial standpoint (Longhurst et al. 1976). Severson and DeBano (1991) showed that goats could be used to reduce shrub cover in central Arizona, but the shrub species reduced were the ones favored by deer. This emphasizes the need to be extremely careful when planning efforts to improve deer habitat using livestock as tools.

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

Qualitative Grazing Intensity Category	Percent 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 more than a mile from water show little use; about one-third to one-half primary forage plants show grazing on key areas.
Moderate	41-50	Most accessible range shows use; key areas show patchy appearance with one-half to two-thirds of primary forage plants showing use; grazing is noticeable in zone 1-1.5 miles 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 miles 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 miles from water lack stubble height.

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 Policy statement regarding livestock grazing on federal rangelands (www.wildlife.org). 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 Southwest, the goal will likely include:
   - Maintain or increase in density, vigor, cover, and diversity of vegetational species, particularly native perennial grass species.
   - Decrease exotic (e.g. Lehmann's lovegrass, buffle grass, red brome) and increaser species (e.g. burroweed, snakeweed), while increasing native palatable species.
   - Increase in health of riparian areas (see below).
2. Managers should develop grazing plans in full cooperation with rangeland management specialists familiar with the local vegetation associations. Guidelines developed in one habitat type may not be completely applicable in another.
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 to rotate the season of use of pastures annually.
4. The plan and any associated rotational system should be flexible enough for the landowner, permittee, and/or the land management agency to adapt to changing environmental conditions.
5. The plan should also identify the contingency plan when the maximum utilization level is reached (e.g. in drought conditions). Drought is defined as "prolonged dry weather, generally when precipitation is less than 75% of average annual amount" (Society for Range Management 1989). Using this criterion, over the 40-year period of 1944-1984 drought in the Southwest occurred in 43% of the years (Holechek et al. 1998). Thus, it is clear that drought strategy must be included in the planning process.
6. Management of riparian areas must be carefully planned (Elmore and Kauffman 1994). In these environments, timing of grazing may be more important than overall stocking rate.

B. Stocking Rate

1. Stocking rate in Southwest Deserts should be maintained

Figure 21. Exclusion of cattle from sensitive riparian areas can have positive effects on mule deer habitat in a relatively short period of time, as seen in this pair of photos taken in 1987 (left) and 1992 (right) at Green Bush Draw on the San Pedro River in southeastern Arizona. (Photo courtesy of BLM, San Pedro Riparian National Conservation Area).

at a level below the long-term capacity of the land. Because of dramatic environmental fluctuations, stocking at full capacity results in overuse in about half the years and may necessitate supplemental feeding or liquidation of livestock. Stocking somewhat below capacity leaves some forage in wet years, which will help plants recover and build some feed reserves (Holechek et al. 1999). Martin (1975) concluded that the best approach would be stocking at or not to exceed 90% of average proper stocking, but with some reductions during prolonged severe drought.

2. Make use of sources such as the Natural Resource 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 2006). Holechek et al. (1998) recommend that lands with slopes between 11-30% be reduced in grazing capacity by 30%, lands with slopes between 31-60% be reduced in grazing capacity by 60%, and lands with slopes over 60% be deleted from the grazable land area. Also, they suggest that lands 1-2 miles from water be reduced in grazing capacity by 50% and lands more than 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 given in terms of "head per square mile yearlong," using only capable and suitable acres for the calculation of square miles in the allotment.
5. Use classes of livestock that are least apt to impact preferred deer dietary items.

C. Utilization Rates and Stubble Heights

1. Utilization rate is closely related to stocking rate. If utilization needs to be reduced, this can usually be accomplished by simply reducing the stocking rate accordingly.
2. Consider the 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.
3. Annual monitoring of grazing intensity is essential for proper management of rangeland resources. Monitoring programs are labor intensive so 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 the 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).
5. Avoid heavy grazing (>50%) averaged over the whole area (Table 4). Depending on topography, there might be some tolerance of heavy use on up to 30% of the grazable land, but immediate reduction in livestock numbers is needed anytime >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 the intensity of grazing, rather than simply the percentage of annual herbage produced (Holechek et al. 1982, Hanselka et al. 2001).
8. Holechek and Galt (2000) provide useful stubble height guidelines that are applicable to most rangelands in Southwest Deserts. These guides correlate stubble height

Table 5. Recommended grazing utilization standards for Southwest ecosystems (based on Holechek et al. 1998:207).

Representative Vegetation Types	Annual Precipitation	Utilization Maximum on Poor Ranges or Ranges Grazed in Growing Season	Utilization Maximum on Good Ranges Grazed in Dormant Season
Sonoran Desert, Mojave Desert, Chihuahuan Desertscrub	< 12"	25%	35%
Semidesert Grassland, Plains Grassland	10-21"	30%	40%
Encinal Oak, Pine-Oak, Pinyon/Juniper, Interior Chaparral, Pine Forests, Mixed Conifer, Spruce/Fir	16-50"	30%	40%

Table 6. Grazing intensity guide for key shrubs (common winterfat, fourwing saltbush, mountain mahogany) on New Mexico rangelands (from Holechek and Galt 2000).

Qualitative Grazing Intensity Category	Percent Use of Current Year Browse Production (by weight)	Percent of 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

measured to overall intensity of grazing.
9. Livestock should not be allowed to browse woody shrubs more than 50% of the annual leader growth (by weight), which equates to about 50% of the leaders browsed (Holechek and Galt 2000, Table 6).

D. Other Considerations

1. Emphasize winter grazing. Grazing southwestern rangelands in winter has been shown to have less impact on forage production and range condition than grazing during the growing season, 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 the 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).
3. All fences should meet standards for wildlife passage (Fig. 22). 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 at least 16 inches from the ground so deer can slip under.
   - Maximum height of 42 inches.

Water Availability & Hydrological Changes

Background

Human activities have caused the lowering of the water table in many areas, which has resulted in the disappearance of springs, cienegas, artesian wells, and even entire rivers. As natural water sources were disappearing, artificial sources were being developed for livestock and wildlife. These developments provide water for a variety of wildlife species, where natural sources have been depleted. Thousands of artificial water sources were established (and continue to be) throughout Southwest Deserts, however, in some cases, water is turned off when cattle are moved out of that particular pasture (Scott 1997). Most western wildlife management agencies also have ongoing water development programs specifically for wildlife. At least 5,859 such developments have been built in 11 western states (Rosenstock et al. 1999)

Issues and concerns

Habitat Use and Deer Movements

Mule deer in chaparral vegetation appear to move 1.0 - 1.5 miles to water (Hanson and McCulloch 1955, Swank 1958). Although mule deer may not be completely dependent on free water every day, they do shift their area of activity within their home range, or even move out of their home range when water sources dry up (Fig. 23, Rogers 1977). Hervert and Krausman (1986) reported that when water sources within the home ranges of several mule deer does were rendered inaccessible, some does travelled 1 - 1.5 miles to other water sources to drink. Once they drank, they immediately returned to their home range. In addition, does in the later stages of pregnancy have a higher demand for water. Studies show that pregnant does use habitat closer to reliable water sources (Clark 1953, Hervert and Krausman 1986). Fox and Krausman (1994) reported that desert mule deer fawning sites were unrelated to distance from known water sources. Does need water during the later stages of pregnancy, but with the arrival of the summer rains they are not obligated to remain near perennial water sources.

Deer in the Sonoran Desert concentrate within 0.5 or 1 mile of water sources during the dry period of the year (Ordway and Krausman 1986). Habitat use by radiocollared male and female desert mule deer was studied in the Picacho Mountains in southern Arizona. When compared to other seasons, both sexes were found significantly closer to water sources during May through October (Ordway and Krausman 1986). Krysl (1979) reported that 85% of mule deer in the Guadalupe Mountains of southern New Mexico were within 1 mile of permanent water.

In southwestern Arizona, mule deer use habitat closer to water during the dry summer months, but not during other

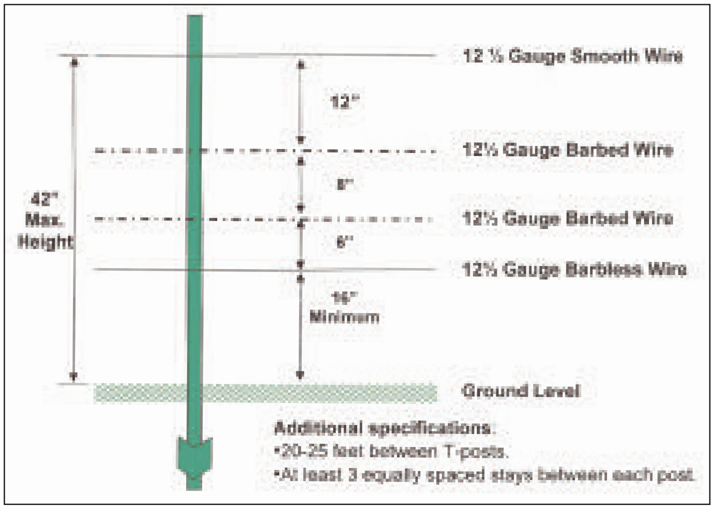

Figure 22. Specifications for a four-strand wildlife-friendly fence. Modification to existing fences can be made easiest by either removal of the bottom wire of an existing four-strand fence, or replacement of the bottom wire with a smooth wire that is at least 16 inches off the ground.

seasons (Rautenstrauch and Krausman 1989). Interestingly, some individual desert mule deer moved up to 20 miles in early summer to areas with free-standing water. Within a few weeks after the arrival of summer rains, the deer returned to the areas they occupied during the remainder of the year.

On Fort Stanton in southern New Mexico, Wood et al. (1970) reported that deer densities in the well-watered West Pasture were higher than the rest of the area. As water sources were added to the East Pasture, deer densities increased there. Since there was no area left "waterless" for comparison, it is difficult to determine what role range conditions, precipitation, and deer movements played in that increase. It appeared throughout the study that deer densities fluctuated in conjunction with the availability of water each year, possibly because of movements onto and off the area. However, overall deer densities on Fort Stanton did not appreciably increase through the 5 years of adding water sources (Wood et al. 1970).

Figure 23. Radiotelemetry data show that when water sources dry up, desert mule deer may move very long distances to remain near water until rain returns to the area (Photo by Jim Heffelfinger/AGFD).

Researchers in West Texas monitored deer densities and then closed several water sources to see what affect this treatment had on the desert mule deer on the Black Gap Wildlife Management Area and Sierra Diablo. Densities quickly declined when water became unavailable and stayed low and then increased again when the water was re-established 3.5 years later (Brownlee 1979). The change in deer density was probably due to deer movement since sharp increases were noted at a time when fawns were not being born. Also, temporary increases in deer density on the Black Gap WMA occurred immediately following periods of rainfall that filled potholes with water.

Water Quality

Small stagnant pools of water with high evaporation rates create a potential for water quality problems (Kubly 1990). Water quality has been raised as a potential concern for ungulates (Sunstrom 1968, deVos and Clarkson 1990, Broyles 1995). Concerns expressed are potentially toxic algae, bacteria, hydrogen sulfide, and ammonia (Kubly 1990, Schmidt and DeStefano 1996). Although blue-green algae grows in southwestern water sources, Rosenstock et al. (2004) found no evidence of the associated toxins microcystin and nodularin.

deVos and Clarkson (1990) measured water quality variables in 18 wildlife water developments in southwestern Arizona. Results showed that except for one tinaja all sites were within normal limits for conductivity (133-887uS/cm), alkalinity, pH (6.3-9.3, most were 7-8), dissolved oxygen (6-16 mg/l), nitrogen (nitrate), and orthophosphate. The exception was high in dissolved oxygen, conductivity, and alkalinity.

Rosenstock et al. (2004) repeatedly measured 20 constituents in the water of 35 natural and artificial water sources in the southwestern Arizona. Seventeen of these constituents were undetectable or below levels published for domestic animals. Arsenic and fluoride were above the most conservative guideline, but below the higher published guideline. Alkalinity ($CaCO_3$) exceeded the recommended threshold in 7 individual samples.

Broyles (1995) speculated artificial water in the desert could aid in the spread of ungulate diseases by either providing a growth medium for the pathogen or by increasing or concentrating populations of a disease vector, such as midges (Culicoidies spp.). Rosenstock et al. (2004) found midges widely distributed and locally abundant at both watered and unwatered sites in southwestern Arizona. This makes sense in light of the discovery that midges can travel >12 miles from any known or suspected larval development site (Rosenstock et al. 2004).

Only one case is known from the literature of a wildlife water development facilitating the spread of a disease. This was a case of a bighorn lamb falling into a water source and the resulting decomposition created in high levels of Clostridium botulinum. The growth of this organism in the water likely caused the deaths of >45 other bighorn due to botulism (Swift et al. 2000).

Benefits of Water

Broyles (1995, 1998) expressed concern over the lack of supportive research and potential negative consequences of adding artificial water sources. One concern raised is whether predators are attracted to water sources. If this is the case, more water may result in more predation, which would negate at least some of the benefit the water provided. DeStefano et al. (2000) found predator activity 7 times greater around water sites than non-water sites, but scant evidence of predation events near water lead them to conclude water sources were not increasing predation rate substantially on a population-wide level.

Scott (1997) speculated that if a new water source is available to cattle and in an area that was formerly lightly grazed, the new water could result in heavier grazing and lead to a reduction in deer cover and forage in that area. If the water is not solely for wildlife use, sometimes cattle stocking rates are increased with the addition of more water sources. If stocking rates result in overuse in dry periods, this would result in a net decrease in deer habitat quality. Managers need to consider these issues when planning or implementing wildlife waters, but thus far definitive, population-level negative impacts of water developments are not supported by the data and remain largely speculative (Arizona Game and Fish Department 1997, Rosenstock et al. 1999, 2004).

Deer may not benefit from water catchments during most of the year (or at all during wet years). However, in dry months deer often concentrate around water sources (Wood et al. 1970, Brownlee 1979) and may travel long distances outside their home range to drink (Hervert and Krausman 1986, Rautenstrauch and Krausman 1989). These shifts in distribution are an indication that water sources are important to deer. Well-distributed water sources likely distribute deer better through their habitat, thereby allowing them to occupy previously unused areas. This effectively increases the overall carrying capacity of the habitat and reduces the frequency of long-range movements out of their normal home ranges that could increase deer mortality. Even if deer do not shift their areas of use, the availability of open water allows them to use a greater variety of foods, including very dry forage. If this results in a better overall nutritional intake for deer, their health and survival would be improved over deer with less access to water. This has been shown in domestic sheep (Hutchings 1946) and the metabolic use of water by deer is no different than sheep (Knox et al. 1969). Water developments for wildlife, however, are not a panacea, and projects should only be initiated where there is a demonstrable need and where other limiting factors are being addressed.

Guidelines

A. Spacing

1. Desert mule deer will readily move 1.5 miles to water, but are found at decreasing densities as one moves away from a water source (Wood et al. 1970). At a minimum, water sources should not be more than 3 miles apart so all mule deer habitat is within 1.5 miles of a permanent water source (Brownlee 1979, Dickinson and Garner 1979). Because deer are found to congregate even closer to water sources during dry periods, the optimum spacing would be 1 mile between waters to provide for the times of highest water use.
2. Actual placement of additional water sources should also take into consideration all the resources mule deer need (Fig. 24). New water sources alone will not create more usable deer habitat unless they are be located near food and cover. Thoughtful placement of water sources will greatly improve their usefulness to deer.

B. Water Quality

In general, managers do not need to worry about water quality for all waters unless there is evidence a water source is being avoided or if there is other evidence of potential problems (Fig. 25, Cooperider et al. 1986:525). If a problem is suspected, a local university or Cooperative Extension Agent may be able to test a water sample. Rosenstock et al. (2004) offered several suggestions to promote water quality in southwestern water sources:

1. For natural tinajas and potholes, water quality depends on the frequency of flushing during rainfall events so these types of water sources should be designed or modified to promote periodic flushing.
2. Where possible, provide natural or artificial shade over the water source to reduce evaporation and the growth of algae.
3. Periodically remove organic debris, silt, dead animals, floating algae, and accumulated sediment.
4. Use designs that reduce the accumulation of sediment at the water margin to eliminate the presence of moist substrate used by disease vectors such as midges.

C. Design

Four primary types of water developments have been constructed in the western United States: 1) modified

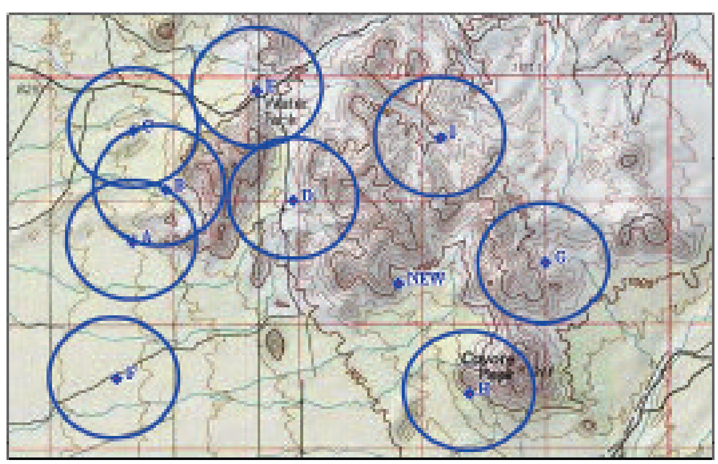

Figure 24. The spacing of available water should be evaluated by mapping sources and circumscribing with 0.5-mile radius buffers. Visualizing water distribution in this way helps to identify areas needing water ("NEW") as well as redundant water sources ("B").

natural tanks, 2) artificial catchments (Fig. 26), 3) developed springs, and 4) wells (Rosenstock et al. 1999). Within these categories, there are an unlimited number of water development designs based on the target species and available physical features of the site. No one or 2 designs will be right for every situation. However, with the decades of experience that some agencies have with designs, there are components and systems that have proven to be undesirable. Those interested in building water developments for mule deer should take advantage of this experience to avoid learning by the same mistakes. Wildlife water development standards are available that describe in detail the specification of each component that may be used in various water development designs (Arizona Game and Fish Department 2004).

D. Storage Capacity

The storage capacity of a water source is a critical part of the design. Capacity should consider the evaporation rate of exposed water, average amount and timing of precipitation, and the number of animals using the water during critical times. Evaporative rates are difficult to calculate because of the complex variables involved, but designs should incorporate effective evaporation control measures. The local precipitation patterns will govern the size of the apron when designing water catchment systems. For every 160 square feet of catchment apron, 100 gallons will be captured for each one-inch of rainfall. Depending on topography, a small dam may be used to divert additional rainfall into the storage tank or may be the sole collection apparatus for the catchment. When diverting natural flows, water rights issues must be considered. The number of animals drinking will impact the amount of water that will be needed to sustain availability year-round. When there is very little moisture in deer forage plants, mule deer may consume 4 to 10 quarts (average = 6.3 qts.) per day (Elder 1954, Hervert and Krausman 1986).

E. Other Considerations

Experience has shown there are criteria that can significantly increase the usefulness, dependability, and lifespan of a water source. The Arizona Game and Fish Department (2003) has developed such a list of "Criteria for Success":

1. Has a long lifespan (40-50 years for storage and collection systems, 25 years for drinking troughs).
2. Meets clearly articulated biological needs.
3. Provides year-round, acceptable water quality for wildlife use.
4. Maximizes passive designs elements, while using proven components applied or installed per manufacturer's specifications.
5. Does not require supplemental hauling except in rare or exceptional circumstances.
6. Has minimal visual impacts and blends in with surrounding landscape.
7. Has vehicular access to development or close by, to facilitate routine maintenance and inspections.
8. Is built with the greatest possible time and cost efficiency.
9. Requires minimal routine maintenance.
10. Is accessible to and used by target species (including fawns) and excludes undesirable/feral species to the greatest extent possible.
11. Minimizes risk of animal entrapment and mortality.
12. Camping or other extended, high recreational use should be prohibited in close proximity.

Figure 25. Although water quality in artificial catchments rarely affects the health of the animals using it, these water sources should be maintained as free from organic debris as possible. (Photo by S. Rosenstock/AGFD)

Figure 26. A water catchment with collection apron and drinker can be built anywhere in mule deer habitat using any one of a multitude of designs. Catchments should be designed to have as little visual impact on the environment as possible (Photo courtesy of Mike Demlong/AGFD)

Non-native Invasive Species

Background

Habitat alteration is a critical issue for native fauna in semi-arid rangelands (Bock and Bock 1995). In the United States, invading non-native species cause significant environmental damage. About 42% of the species on the threatened or endangered species lists are at risk because of factors related to non-native species. In addition, economic losses are thought to exceed $138 billion per year (Pimentel et al. 1999).

Mule deer habitat in most Southwest Deserts has been altered by land management practices to improve cattle production. In addition to direct impacts from cattle grazing, fenceline development, and changes to availability of water sources; agriculturalists in some regions have promoted the expansion of non-native plant species. The negative effects of non-native plant invasion have gone largely unnoticed, but this factor has had an insidious effect on the overall quality of mule deer habitat.

Figure 27. Planted buffel grass pasture in Lower Sonoran Desert. Shrubs and trees were mechanically cleared, removing cover and food for mule deer (Photo by Carlos Alcalá-Galván).

Figure 28. Native vegetation in the Lower Sonoran Desert providing good cover and food to mule deer (Photo by Carlos Alcalá-Galván).

The 3 most significant non-native plant species that have invaded Southwest Deserts are buffel grass (*Pennicetum ciliare*), Lehmann's Lovegrass (*Eragrostis lehmanniana*), and red brome (*Bromus rubens*). The importance of these 3 species is based upon their wide-ranging area of occurrence, and their ability to survive, reproduce and disperse. Each of these species has a different origin and somewhat separate geographic distribution.

Buffel Grass

The buffel grass made its way into southwestern United States and northern Mexico after extensive testing by Texas A&M University (Holt 1985). Along with many other species, this exotic was introduced in an effort to stabilize the soil against erosion and to boost feed production for cattle. Buffel grass, like other African perennial grasses, is an ideal plant for erosion control because its rooting structure is well suited to hold soil in place (Bock and Bock 1995, Martin et al. 1998). Buffel grass is also fire-tolerant, and survival and persistence would allow it to expand out of seeded areas. Natural dispersion of buffel grass allows this species to dominate over native grasses (Fig. 27-28; Cox et al. 1990, Ibarra et al. 1995).

At the time of introduction in the 1950s, few people were aware that buffel grass might have detrimental effects on native wildlife and vegetation associations. At the time, botanists and ranchers were only concerned about the effects of droughts on rangeland in the American West (Cox et al. 1983). The use and popularity of buffel grass with ranchers and federal agencies in the American Southwest spread to ranchers in Mexico, who evaluated the grass for use on their rangelands. Sonoran state officials and local ranching associations broadly promoted the spread of buffel grass (Cox et al. 1988, Camou-Healy 1994, Cota and Robles 1996, Perramond 1999).

Since the 1970s, buffel grass introductions occurred in the central region of Sonora, Mexico. Subsidies from the state of Sonora and low-interest loans from banks made funds available for more widespread plantings of buffel grass in the 1980s (Camou-Healy 1994). The vegetation composition of a large portion of the state of Sonora was transformed in the twentieth century, as native brush communities were cleared and new buffel grass pastures were established (Sanderson 1986, Perez Lopez 1993). The success of this exotic, especially at lower elevations and with the presence of fire is especially apparent during rainy seasons (Ibarra-Flores et al. 1995). By the early 1990s, buffel grass stands were present on 3 million acres in Sonora; approximately 10% of Sonoran rangeland (Yetman and Búrquez 1994). Spatial modeling of conditions under which buffel grass grows predicted 53% of the State of Sonora and 12% of the country of Mexico is susceptible to invasion by this non-native (Arriaga et al. 2003).

Figure 29. Near monoculture of Lehmann's Lovegrass on the Buenos Aires NWR in southeastern Arizona. This provides cover, but lack of a diverse assemblage of native forbs and grasses diminishes the quality of the habitat for mule deer (Photo courtesy of USFWS/Buenos Aires NWR).

Figure 30. Stand of native grasses and forbs free of invasive species in southeastern Arizona (Photo courtesy of Pat O'Brien/AGFD).

Figure 31. Dense stands of red brome thrive with winter precipitation and out-compete native grasses for nutrients and moisture (Photo by Russ Haughey/AGFD).

Lehmann's Lovegrass

Another important plant species introduced from Africa is the Lehmann's lovegrass. Introduced in southwestern United States during the early 1900s, this non-native grass was also promoted as cattle forage. Lehmann's lovegrass is an introduced, warm-season, perennial bunchgrass growing from 1.5 to 2 feet in height (Ruyle and Young 2002). It forms prostrate stems, which root at the nodes and is readily established by seeding. This growth form often results in somewhat continuous stands where individuals are difficult to identify. Lehmann's lovegrass produces a high number of small seeds, numbering 4.2 - 6.5 million per pound (Allison 1988). Seeds remain dormant at least for 6 to 9 months before germination.

Occurrence of Lehmann's lovegrass in Southwest Deserts is mainly associated with soil conservation activities in the upper Sonoran Desert, the Mojave Desert, and northwestern Chihuahuan Desert (Figs. 29-30). In southeastern Arizona, high seedling emergence typically occurs following summer rains on sites where the canopy has been removed by burning, mowing, or grazing (Roundy et al. 1992).

Lehmann's lovegrass has persisted and spread primarily in desert shrub and desert grassland ecosystems of southeastern Arizona at elevations between 3,250 and 4,800 feet. The plant has a narrow range of climatic and edaphic requirements, growing best on sites with sandy to sandy loam soils, and where winter temperatures rarely drop below 32°F. In southeastern Arizona, Lehmann's lovegrass grew vigorously and colonized adjacent unplanted areas where summer rainfall was between 6 and 8.6 inches (Cox et al. 1987, Cox and Ruyle 1986). On areas where summer rainfall was between 2.8 and 3.3 inches established stands died, however, with about 4 inches stands were able to maintain themselves but not spread.

Red Brome

Red brome is an annual bunchgrass originally from the Mediterranean region. It was introduced into the southwestern United States in the mid 1800s, and is now spreading throughout both the Sonoran and Mojave deserts due to favorable climatic conditions (Felger 1990). Red brome was reported in southern Arizona as early as 1909. It was probably first introduced to the area when it was used as a potential forage plant in the Santa Rita Experimental Range (Felger 1990).

Currently, this invasive species continues to spread into many other areas in the Sonoran Desert uplands. This non-native grass is normally found on deserts and chaparral hillsides, open hillsides and woodlands. It is particularly common on degraded rangelands that have experienced a reduction in native perennial grasses (Ruyle and Young 2002).

High production of seeds and dense growth allow red brome to rapidly spread and take over natural environments that have been disturbed by human activities (Fig. 31). Dense stands of red brome compete with native plants for winter moisture and soil nutrients and may affect the diversity or abundance of spring annuals. Because red brome occurs in denser stands than native grasses, the abundance of these fine fuels has increased the incidence and intensity of wildfires (James 1995).

Issues and Concerns

General Impacts of Non-native Invasive Species

Widespread buffel grass planting has created large-scale modifications of mule deer habitat in the lower Sonoran Desert. Mule deer habitat in Sonora has been dramatically modified to favor cattle production since the 1960s. By the 1990s clearcuttings and establishment of buffel grass pastures have altered about 20% or 3 million acres of mule deer range in the lower Sonoran Desert.

Martin et al. (1998) has suggested that buffel grass has not been beneficial to native wildlife in the Sonoran Desert and lower regions. However, the effects of buffel grass on wildlife and its interaction with native vegetation are not well known and more research is necessary. Specific effects of buffel grass on mule deer habitat are currently being evaluated in some studies conducted by the Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (Mexican Institute for research on forestry, agriculture and livestock) INIFAP-Mexico and the University of Arizona. The goal of this research is to identify and quantify effects of habitat alterations from buffel grass introductions on the habitat use, diet, and movements of desert mule deer.

A major concern about the increasing risk of wild fires has been issued by different ecologists (Yetman and Burquez 1994). Areas where buffel grass is not grazed may accumulate large loads of dry fuel that causes fires of high intensity. These fires affect cacti, shrubs, and trees that provide important food and cover for mule deer (Fig. 32). However, large areas with buffel grass in the Lower Sonoran Desert are cattle-grazed at levels that the amount of fuel is reduced and wild fires are not common. Vegetation stages after high intensity fires favor also the dominance of buffel grass because of its fire tolerance and rapid growth response.

Because of the capacity of Lehmann's lovegrass and red brome to disperse and aggressively occupy adjacent areas, these grasses are also dominating large areas of mule deer habitat in Southwest Deserts. Actual and potential effects on mule deer are mainly associated with reducing vegetation diversity, especially the reduction in forbs availability for mule deer. Because of the changes in forbs diversity and the reduced forage value of the introduced species, mule deer have to move out in search for better foraging areas. In addition, the low palatability for cattle and native herbivores and its short period of growth causes a proliferation of fine fuels that increases the occurrence and intensity of fire, which reduces shrubs and woody plants that also provide food and cover for mule deer.

Mule deer habitat is also impacted by non-native grasses because of the aggressive way the land is prepared to plant and nurture the grass. However, the presence of thick stands of non-native grass may also represent direct and/or indirect improvements to deer habitat if the range was formerly overgrazed and deteriorated with large areas of bare ground. For instance, buffel grass is not an important component in the mule deer diet, however, well-established plants provide useable cover. Water sources developed in proximity to buffel grass pastures also appear to be an important factor determining mule deer use in those areas, regardless of the comparative reduction of shrubs and tree cover.

Non-native plants are established through 2 general scenarios. The first is when the exotic is intentionally introduced to an area by planting in pastures specifically for livestock forage. The second scenario is where the exotic has become dominant as the result of natural dispersion with no direct human involvement.

Planted Pastures

Some areas in Southwest Deserts have been substantially altered to facilitate establishment of introduced grass. These habitat alterations include the use of heavy machinery to remove bushes and trees, as well as preparation of the soil for planting seeds.

Figure 32. When dense stands of non-native grass species invade desert plant communities they increase the fuels available to carry fire and consequently increase the occurrence of fire as was the case here with red brome in the Sonoran Desert (Photo by Russ Haughey/AGFD).

Actions for establishment, maintenance, and utilization of planted pastures produce varied effects on mule deer habitat and behavior. In the short term, preparation of the land by heavy machinery, vehicles, and workers creates a disturbance that may alter deer movements or use of habitat. Also, clearing of native brush community causes a drastic reduction of cover and food availability for mule deer. Soil plowing and preparation for seeding the introduced species generally benefit mule deer on a short term basis. Food abundance and availability may increase from the early growth of forbs and native grasses appearing before germination of the non-native seeds. In the long term, however, the well-established stand of the non-native vegetation will reduce the production of native plant species.

Invaded Areas

Many areas in Southwest Deserts have non-native plant species that were never planted purposefully, but have invaded and are dominant in what is now a modified herbaceous community. Generally, spreading and subsequent dominance of non-natives occurs on deteriorated areas as a consequence of overgrazing or other disturbances. Roads are major contributing factors to the ongoing spread of exotic plants (Gelbard and Belnap 1999).

If the invasion of non-native plants occurred on areas with abundant stands of shrubs, trees, and cacti, the increase in fine fuels can increase the frequency and intensity of fire. As with the planted areas, dominance of a non-native plant causes a reduction in the amount of herbaceous forage available to mule deer. If the invasion occurred on areas that lack shrubs and trees, the main impact would be limited forage. Depending on the overall condition of the habitat, cover provided by thick stands of non-native grasses might actually be beneficial to mule deer during fawning periods.

Guidelines

A. The Management Plan

The evaluation of habitat condition in a specific area with invasive species should start with the assessment of the extent of distribution of the invaders. In some cases habitat management units can be defined using differences in topography (altitude, slope, exposure, etc.), vegetation association, and the availability of water or cover.

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

The magnitude of negative and/or positive effects of the 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 the invasive species were absent. Outcomes of evaluations must be data driven and be verifiable. On a small scale, managers may want to use the map 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 the management of the land. In areas of predominantly private land, habitat management plans will not be successful without full cooperation and coordination with the landowner. Sometimes alterations by non-native species would be the lesser of 2 evils when compared to complete habitat destruction or fragmentation by urban development.

B. Specific Guidelines

1. Mitigate the negative effects of past pasture plantings, allow the natural successional appearance of shrubs and trees to create cover for mule deer.
2. Promote native species production with the focus on those plants used or preferred by mule deer.
3. Evaluate native seed bank before purchasing seed to determine if seed resources are truly lacking.
4. Use proper livestock grazing practices such as appropriate stocking rates and rotation to favor native browse establishment to benefit mule deer. Also, use intensive grazing on invasive species during the period of higher vulnerability to reduce seed production, plant vigor, and storage of nutrients.
5. Never introduce non-native plant species in an attempt to "improve" habitat conditions.
6. 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.
7. Seed native species and practice proper range management to expedite rehabilitation of deteriorated areas. Identify areas that are deteriorated but lacking invasive plant species and make these a high priority for proactively seeding native species.
8. Where Lehmann's lovegrass is a dominant species, it can sometimes be decreased, while allowing native perennial grasses to increase, by grazing pastures in the spring and resting them in the summer growing season (monsoon season).
9. Consider the potential for non-native plant invasion when deciding whether to build, improve, or maintain roads (Gelbard and Belnap 1999).
10. It is unlikely non-native species will be eliminated from invaded areas, but the primary management goal should be to change vegetation composition to reduce the non-native dominance, promote higher plant diversity, and reduce its spread.

Figure 33. Housing development in the foothills of the Catalina Mountains near Tucson, Arizona (Photo by Jim Heffelfinger/AGFD).

Human Encroachment

Background

Human activity can impact habitat suitability in 3 ways: displacing wildlife through habitat occupation (e.g., construction of buildings), reducing habitat suitability by altering the physical characteristics of that habitat (e.g., habitat damage resulting from off highway vehicle use), or displacing wildlife by altering wildlife perception of the suitability of the habitat through other than physical alteration (e.g., noise, activity).

Issues and Concerns

Displacement by Occupation

Wildlife habitat is appealing in many ways to humans. Because of the appealing nature of the landscapes occupied by wildlife, humans are increasingly moving to these habitats to live. The occupation of these habitats brings with it the construction of homes, fencing, roadways, agriculture, and supporting infrastructures, such as communities, stores, and health facilities (Fig. 33). People that 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 habitats that fill critical wildlife needs during periods of migration or winter stress. When people move to habitats that contain wildlife, the resultant development destroys many of the features that initially drew people to those habitats. This is the greatest impact of human disturbance on wildlife populations. During the mid 1990s alone, this development occupied 2.2 million hectares of open space in the West (Lutz et al. 2003).

However, human occupation may provide some advantages to local wildlife populations (Tucker et al. 2004). Wildlife in some urban areas may have more water from artificial sites (e.g., pools, ponds) and enhanced forage (e.g., lawns, plantings, golf courses, agricultural fields) than in surrounding areas (Fig. 34). The lack of predators in these habitats can also reduce mortality for wildlife that inhabit the area.

Enhanced forage conditions and decreased predation may result in unhealthy densities of wildlife that will be susceptible to diseases or might actually increase the probability that predators will move into the urban area from surrounding areas to prey on naïve wildlife. Ultimately, these predators may prey on domestic pets as well. Incidences of predators preying on humans in these environments are increasing (Fitzhugh 2003).

A major concern for mule deer is the encroachment upon, and development within, important habitats. A primary example of this is the impact of land development on winter range. Improved forage and decreased predation notwithstanding, increased housing density can result in decreased mule deer abundance (Vogel 1989). Mineral exploration-extraction or urban development can preclude use of winter ranges that are critically important to migratory deer herds during severe winters (Lutz et al. 2003). Road development can limit mule deer access to important habitat as well. Agricultural developments often make habitats more desirable to mule deer; however, these same developments sometimes include efforts by those managing the agricultural lands to limit wildlife use of the area.

Reduction of Habitat Suitability

Human activity has the ability to alter habitat suitability through the direct alteration of habitat characteristics, thereby influencing habitat quality. Improper use of off highway vehicles (OHVs) can alter habitat characteristics through destruction of vegetation, compacting soil, increasing erosion (Fig. 36). Perry and Overly (1977) found roads through meadow habitats reduced deer use, whereas roads through forested habitat had less effect.

Figure 34. Human activities, like farming of agricultural crops in remote areas, may have both a positive and negative impact on wildlife populations (Photo by Jim Heffelfinger/AGFD).

Figure 35. Conservation easements such as this one in southeastern Arizona can be an effective tool for conserving vulnerable open space for all wildlife (Photo by Matt Walton/AGFD).

Figure 36. Off Highway Vehicle traffic can damage vegetation and cause disturbance in areas important to desert mule deer (Photo by Jim Heffelfinger/AGFD).

The most obvious negative impact on habitat suitability is the elimination of linkages between important habitats. These impacts 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 U.S. (Noss and Cooperrider 1994, Trombulak and Frissell 2000, Farrell et al. 2002). These impacts are especially severe in the 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 impact to mule deer and other wildlife.

The 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., and Schwabe and Schuhmann (2002) estimated this loss at 700,000 deer/year while Conover et al. (1995) estimated that >1.5 million deer-vehicle collisions occur annually. In addition to effects on populations, many human injuries and loss of life occur with deer-wildlife collisions annually. There is substantial loss of recreational opportunity and revenue associated with deer hunting, and the damage to property from collisions is tremendous (Romin and Bissionette 1996, Reed et al. 1982). 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), and the problem is further compounded by the dramatic explosion of human residential and other development within mule deer winter range in the Intermountain West. Conover et al. (1995) estimated that collisions involved 29,000 injuries and 200 deaths to humans 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).

Of all the impacts associated with highways, the most important to mule deer and other wildlife species is attributable to barrier 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 special or vital habitat areas. This barrier effect fragments habitats and populations, reduces genetic interchange among populations or herds, and limits dispersal of young; all serve to ultimately disrupt the processes that maintain viable mule deer herds and populations. Furthermore, the effects of long-term fragmentation and isolation render populations more vulnerable to the influences of stochastic 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 impact were typically approached as single-species mitigation measures (Reed et al. 1975). Today, the focus is more on preserving ecosystem integrity and landscape connectivity benefiting multiple species (Clevenger and Waltho 2000). Farrell et al. (2002) provide an excellent synopsis of strategies to address ungulate-highway conflicts.

Several states in the U.S. have made tremendous commitments to early multi-disciplinary planning, including Washington (Quan and Teachout 2003), Colorado (Wosti 2003), and Oregon; some receive funding for dedicated personnel within resource agencies to facilitate highway planning. Florida's Internet-based environmental screening tool is currently a national model for integrated planning (Roaza 2003). To be most effective, managers must provide scientifically credible information to support recommendations, identifying important linkage areas, special habitats, and roadkill hotspots (Endries et al. 2003).

There is a tremendous need for states to complete large-scale connectivity and linkage analyses to identify priority areas for protection or enhancement in association with highway planning and construction. Such large-scale connectivity analyses, already accomplished in southern California (Ng et al. 2004), New Mexico, Arizona, and Colorado, serve as a foundation for improved highway planning to address wildlife permeability needs. More refined analyses of wildlife connectivity needs, particularly to identify locations for passage structures are of tremendous benefit, and run the gamut from relatively simple GIS-based "rapid assessment" of linkage needs (Ruediger and Lloyd 2003) to more complex modeling of wildlife permeability (Singleton et al. 2002). Strategies for maintaining connectivity may include land acquisition (Neal et al. 2003) or conservation easements.

Structures designed to promote wildlife permeability across highways are increasingly being implemented throughout North America, especially large bridged structures (e.g., underpasses or overpasses) designed specifically for ungulate and large predator passage (Fig. 37; Clevenger and Waltho 2000, 2003). Whereas early passage structures were approached as single-species mitigation measures (Reed et al. 1975), their use today is focused more on preserving ecosystem integrity and landscape connectivity benefiting many species (Clevenger and Waltho 2000, 2003). Transportation agencies are increasingly receptive to integrating passage structures into new or upgraded highway construction to address both highway safety and ecological needs (Farrell et al. 2002). However, there is increasing expectation that such structures will indeed yield benefit to multiple species and enhance connectivity (Clevenger and Waltho 2000), and that scientifically sound monitoring and evaluation of wildlife response will occur to improve future passage structure effectiveness (Clevenger and Waltho 2003, Hardy et al. 2003).

Displacement through Disturbance

Research has documented that wildlife modify their behavior to avoid activities that they perceive as threatening, such as the avoidance of higher traffic roads by

Figure 37. Highway underpass fenced to direct deer safely under the vehicle traffic. (Photo by Norris Dodd/AGFD).

Figure 38. Even when OHV use does not damage habitat, it can cause disturbance in areas important to desert mule deer, such as xeroriparian corridors (Photo by Joan Scott/AGFD).

elk. However, this avoidance is generally temporary and once removed, wildlife returns to their prior routine. Extensive research has failed to document population level responses (e.g., decreased fitness, recruitment, conception) as a direct result of disturbance. White-tailed deer in the eastern U.S. have acclimated to relatively high densities of people and disturbance. Even direct and frequent disturbance during the breeding season has not yielded any population level responses (Bristow 1992).

Information regarding the response of deer to roads and vehicular traffic is scarce and imprecise (Mackie et al. 2003). Perry and Overly (1977) found that main roads had the greatest impact on mule deer, and primitive roads the least impact. 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. The USDA Forest Service estimates that OHV use has increased sevenfold during the past 20 years (Wisdom et al. 2004). OHV use has a greater impact on avoidance behavior than does hiking or horseback riding (Fig. 38, Wisdom et al. 2004), especially for elk.

Guidelines

A. Planning and Coordination

1. Develop and maintain interagency coordination in land planning activities to protect important habitats.
2. Land and wildlife management agencies should play a proactive role in city and county planning, zoning, and development.
3. Identify important habitats, seasonal use areas, migration routes, and important populations of mule deer.
4. Coordinate with agricultural producers to consider wildlife needs in the selection of crops, locations, and rotations. Identify acceptable wildlife use.
5. Analyze linkages and connectivity of habitats to identify likely areas for impact hazards as new roads are developed or altered for higher speed and greatervolume traffic.

B. Minimizing Negative Effects of Human Encroachment

1. Develop consistent regulations for off highway vehicle (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 the use of native vegetation in landscaping human developments to minimize the loss of usable habitat.
5. Examine records of road-killed deer 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/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 right-of-way passage structures or away from areas of high 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. 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 compared to human activity.
2. Locate passage structures 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. Spacing between structures is dependent on local factors (e.g., known deer crossing locations, roadkill "hotspots," deer densities adjacent to highways, proximity to important habitats).
4. Where appropriate and available, use models and other tools to assist in location of passage structures (Clevenger et al. 2002, Barnum 2003, and Claar et al. 2003).
5. Passage structures should be designed to maximize structural openness (Reed 1981, Foster and Humphrey 1995, Clevenger and Waltho 2003, Ng et al. 2004, Ruediger 2001). The openness ratio (width x 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 (Gordon and Anderson 2003, Clevenger and Waltho 2000).
6. Underpasses designed specifically for mule deer should be at least 20 feet wide and 8 feet high (Gordon and Anderson 2003, Forman et al. 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. More natural conditions within underpass (e.g., earthen sides and naturally vegetated) has been found to promote use by ungulates (Dodd et al. in review). In Banff National Park, Alberta, deer strongly preferred (10x more use) crossing at 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 free deer movement.
9. Where possible, fences should be tied into existing natural passage barriers (e.g., large cut slopes, canyons; Puglisi et al. 1974).
10. When fencing is not appropriate to reduce deer-vehicle collisions, alternatives include enhanced signage to alert motorists (Farrell et al. 2002), Swareflex reflectors (with generally inconclusive results [Farrell et al. 2002]), deer crosswalks (Lehnert and Bissonette 1997), and electronic roadway animal detection systems (RADS, Huijser and McGowen 2003).

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." As pressure mounts to explore and develop more areas (i.e., Arctic National Wildlife Refuge, Otero Mesa, etc.), careful attention must be given to how this industry can expand to satisfy increasing energy demands without damaging the environment. Sawyer et al. (2002) suggests that extensive energy development could pose the most serious threat to mule deer and pronghorn populations in western Wyoming through disruption and removal of important habitat.

There appears to be no lack of debate with how the nation's energy policy should proceed. However, that 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.

Otero Mesa, in south central New Mexico and west Texas, is an example of an area where oil and gas production could affect mule deer habitat. Increased interest in this area by the oil and gas industry resulted from a natural gas find in 1998. Since then, large numbers of lease nominations prompted the Bureau of Land Management (BLM) to review and amend its Resource Management Plan for this region (Fig. 39, USDI 2004).

Tessmann et al. (2004) reports that exploration and extraction of non-renewable oil and gas resources has and continues to cause a range of adverse effects. All disturbances to the landscape constitute an impact at some level. The severity of the impact to mule deer depends upon the amount and intensity of the disturbance, the specific locations and arrangements of the disturbance, and the ecological importance of the habitats affected. Small, isolated disturbances within non-limiting habitats are of minor consequence within most ecosystems. However, larger-scale developments within habitats that limit 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 development have the potential to affect ungulate population dynamics, especially when impacts are concentrated on winter ranges (Sawyer et al. 2002).

In addition to issues of oil and gas extraction, many industries depend upon many other materials (e.g., copper, gold, coal, etc.) for their products or services. Extracting these raw materials can have the very same effect on wildlife and the environment as oil and gas development. Although the issues and concerns as well as guidelines discussed in this section are focused predominantly toward oil and gas development, in most circumstances they are relevant and applicable to mineral extraction 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 ("Section," as used in this document refers to a legal section of 640 acres or an area equivalent to 640 acres). The density of well locations has bearing on the intensity of disturbances associated with oil and gas field operations while the 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. The density 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.

Measures to reduce impacts should be considered when well densities exceed 4 wells per section or when a road density exceeds 3 miles of road per 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

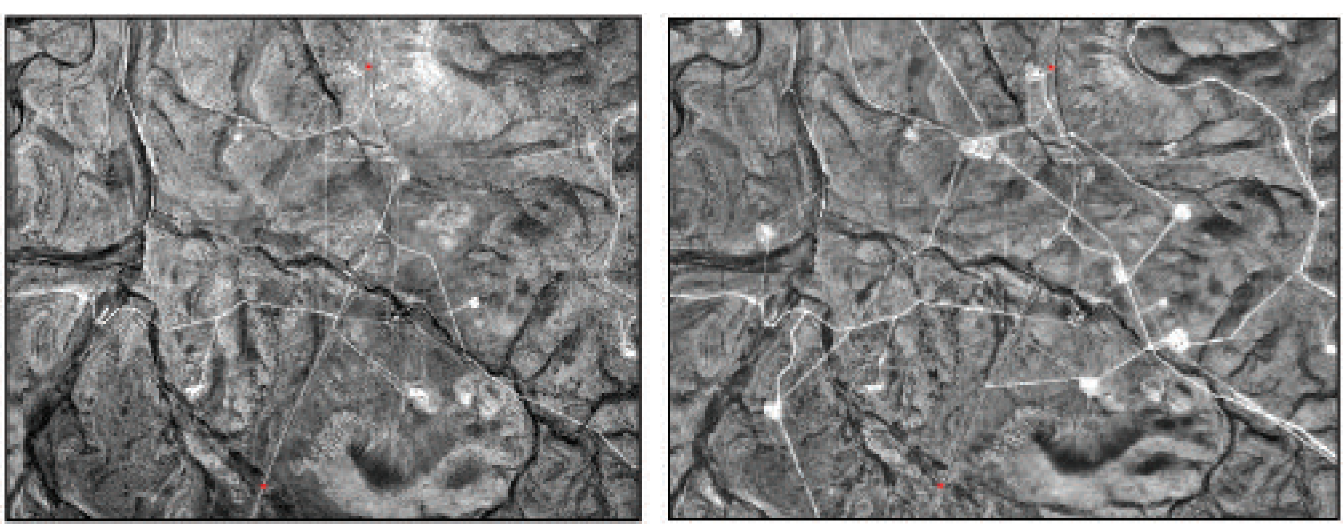

Figure 39. Satellite images of a developing gas and oil field (approximately 36 square miles) within the Permian Basin west of Carlsbad, New Mexico. Note expanded development between 1981 (left) and 1996 (right). (Photo courtesy of BLM; Carlsbad Field Office)

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 & 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 disturbance per section	5-16 wells and 20-80 acres disturbance per section	>16 wells or >80 acres disturbance per section

and intensive. This amount of development will impair the ability of animals to use critical areas (winter range, fawning grounds, etc.) and the 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 the function and effectiveness of critical areas.

Extreme Impact—The function and effectiveness of habitat would be severely compromised (Fig. 40). The 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 the 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 the potential to significantly influence whether deer can maintain some reasonable existence in the developed area or abandon it altogether.

Issues and Concerns

Direct Loss of Habitat

Direct loss of habitat results primarily from construction and production phases of development. The presence of well pads, roads, pipelines, compressor stations, and out buildings directly removes habitat from use. Production activities require pervasive infrastructure and depending upon scale, density, and arrangement of the developed area, collateral loss of habitat could be extensive (USDI 1999). As an example, within the Big Piney-LeBarge oil and gas field in Wyoming, the actual physical area of structures, roads, pipelines, pads, etc. covers approximately 7 square miles. However, the entire 166 square mile landscape is within one-half mile of a road, and 160 square miles (97% of landscape) is within one-quarter mile of a road or other structure (Stalling 2003).

In the Rocky Mountains, they found that while 50% of a disturbed area could be minimally reclaimed within a 3 to 5 year period after construction, a fully productive habitat (proper species composition, diversity, and age) could require up to 20 years. The remaining 50%, which constitutes the working surfaces of roads, well pads, and other facilities, could represent an even greater long-term habitat loss (USDI 1999). Most certainly these reclamation times would be much longer in the arid Southwest, especially for overstory development. Saquaro cactus, for example, take well over 100 years to mature.

Physiological Stress

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

During winter months, this could be particularly important because the energy balance is already operating at a deficit. In addition, the diversion of energy reserves can be detrimental for other critical periods during the life cycle such as gestation and lactation. Kuck et al. (1985) suggested in their simulated mine disturbance experiment, that increased energy costs of movement, escape, and stress caused by frequent and unpredictable disturbance may have been detrimental to elk calf growth. An EIS 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 the developed area by wildlife (Fig. 42).

Figure 40. An example of extreme impact to mule deer habitat from open pit mining at the Tyrone copper mine near Silver City, New Mexico (Photo courtesy of New Mexico Department of Game and Fish [NMDGF]).

Figure 41. Successful reclamation of an open pit coal mine on the Vermejo Park Ranch in northern New Mexico (Photo courtesy of NMDGF).

Figure 42. Frequent traffic on maintenance roads leads to avoidance behavior by wildlife as well as more frequent wildlife-vehicle collisions. (Photo courtesy of NMDGF)

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 quarter mile radius for mule deer (Freddy et al. 1986).

Significant differences in elk distribution between construction and no 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.

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 the habitat near disturbances while over use 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 (Fig. 44). Meffe et al. (1997) suggested the largest single threat to biological diversity is the 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. 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."

Should development occur within or proximate to migration corridors, isolation may result. Isolation could lead to adverse genetic effects such as inbreeding depression and decreased genetic diversity. Without an ability to move into or from areas critical to normal needs or life stages (e.g., fawning areas, winter range, etc.), abandonment could ultimately result.

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 very 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 the structure of the habitat (e.g., less cover, more edge, etc.). As a result, less quality forage is available while potentially increasing rates of predation.

Use of migration corridors also depends on 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). In much of the Southwest, mule deer do not migrate, but may have to make long-distance movements based on seasonal variation in water and food availability. Flexibility in movement across ranges can be ultimately reflected in the survival and productivity of the deer population and likely enhances their ability to recover from population declines.

Secondary Effects

Secondary effects may be as significant as those direct effects described above. Activities associated with the support and/or service industries linked to the development can aggravate adverse impacts. These impacts can, and are, similar to those that occur during construction and operations—only intensified. Vehicular traffic to support operations would likely increase significantly. Additional human presence from increased support industries as well as community expansion will contribute to human-wildlife interactions.

Roads, pipelines, and transmission corridors not only directly remove habitat but also have the potential to contaminate ground and surface water supplies. Noxious weeds can infiltrate the roadside impact zones and bring negative impacts such as non-native bacteria, viruses, insect pests, and/or chemical defense compounds with toxic and/or allergenic properties (NMDGF 2004).

Erosion of sediment from roads and pipeline corridors will cause increased surface runoff into watercourses can reduce infiltration, lower the water table, and result in lower rangeland productivity. This problem will increase if some of the recommendations outlined in the National Energy Policy are implemented. Those recommendations include expanding the nation's energy infrastructure in order to match supply and demand. As a result, it is projected that an additional 38,000 miles of new gas pipelines will need to be developed (National Energy Policy 2001).

All these events can increase the amount of area rendered unavailable to mule deer and other wildlife. Finally, inadequate interim mitigation and/or final reclamation practices have the potential for rendering the area useless to wildlife unless careful consideration is given to planning and implementing a quality reclamation program.

Figure 43. Remote monitoring stations can be used to minimize traffic at the well site.(Photo courtesy of NMDGF)

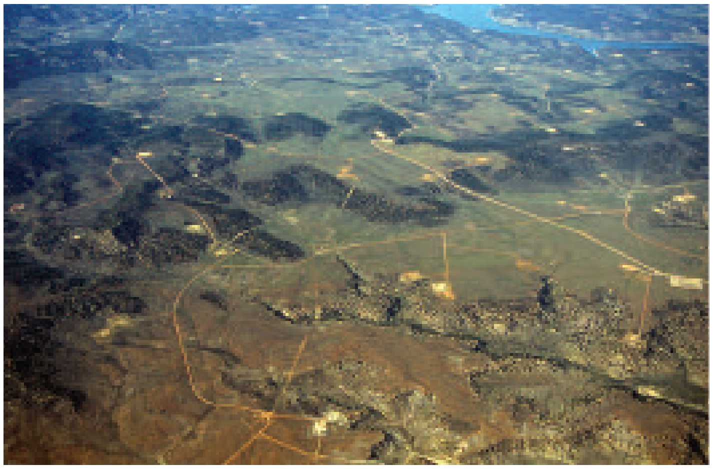

Figure 44. Fragmentation has a cumulative impact upon the amount of habitat lost through oil and gas production. (Rosa oilfield east of Farmington, New Mexico in 2000; Photo courtesy of NMDGF)

Figure 45. Maintenance roads to service oil wells should be reclaimed by disrupting the soil and making the road impassible in conjunction with reclamation protocols that ensure habitat recovery to the extent possible (Photo courtesy of NMDGF.)

Figure 46. Example of the large footprint left by the variety of support facilities at a gas production area near Carlsbad, New Mexico (Photo courtesy of NMDGF).

Figure 47. Planners should use natural terrain to locate buildings and other facilities out of sight (Photo courtesy of NMDGF).

Figure 48. Failed reclamation of an oil well site. Support structures should be removed during reclamation. (Photo courtesy of NMDGF)

Guidelines

To minimize impacts of energy and mineral development activities upon deer and their habitat, several recommendations are provided for consideration and implementation. These recommendations are compiled from a number of sources and support the 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 the appropriate state and federal wildlife agencies during pre-planning exercises.
2. Design configurations of oil and gas development to avoid or reduce unnecessary disturbances, wildlife conflicts, and habitat impacts. Where possible, coordinate planning among companies operating in the same oil and gas 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. 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.
6. Cluster drill pads, roads, and facilities in specific, "low-impact" areas.
7. 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; Figs. 46-47).

B. Roads

1. Use existing roads and two-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.
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 the roads.

C. Wells

1. Drill multiple wells from the same pad using directional (horizontal) drilling technologies (up to 10 wells per pad).
2. Disturb the minimum area (footprint) necessary to efficiently drill and operate a well.

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").

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).

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. Produced water should not be pumped onto the surface within big game crucial winter ranges. However, produced water of suitable quality may be used for supplemental irrigation to improve reclamation success.
3. Hydrogen sulfide should not be released into the environment.
4. 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. 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.

Figure 49. Successful interim reclamation for a producing well. (Photo courtesy of BLM; Farmington Field Office)

Figure 50. Typical oil well pad and associated structures with an overall footprint of the pad approximately 1-2 acres in size (Photo courtesy of NMDGF).

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 the degree of impact to specific resources, or the effectiveness of mitigation, companies should fund special 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 employees to clean mud from boots/work shoes 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 (Fig. 49).
2. Where practical, salvage topsoil from all construction and re-apply during interim reclamation.
3. A variety of native grasses 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. Replant a mixture of forbs, grasses, and shrubs that are native to the area and suitable for the specific ecological site.
3. Restore vegetation cover, composition, and diversity to achieve numeric standards that are commensurate with the ecological site (Fig. 41).
4. Do not allow grazing on revegetated sites until the plants are established and can withstand herbivory.
5. Continue to monitor and treat reclaimed areas until plant cover, composition, and diversity standards have been met.
6. 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.

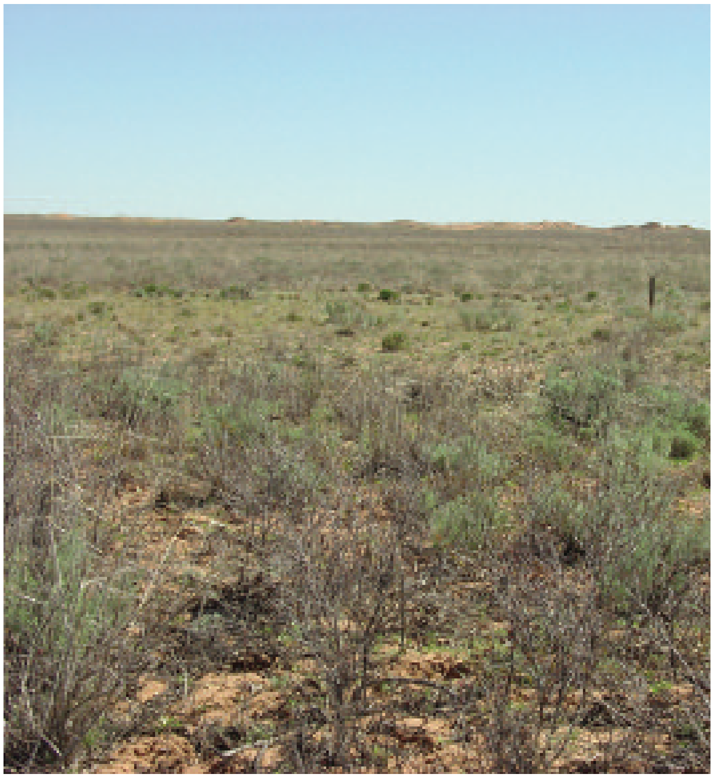

Figure 51. Example of a successful final reclamation effort of an oil well near Carlsbad, New Mexico. (Photo courtesy of NMDGF)

SUMMARY

There are a myriad of interactions between factors leading to the current status of mule deer habitats in the Southwest Deserts Ecoregion. Mule deer habitat in the Desert Southwest has not reached its current condition because of any one factor or contributing cause. Many factors are closely interrelated and all generally lead to a decrease in mule deer habitat quality or quantity. Obviously, precipitation amounts and timing are prime drivers of short-term habitat condition in desert ecosystems. Another key and often overlooked factor leading to deterioration in some mule deer habitats is ecological succession. During the past century, the absence of fire where it originally occurred has been a major contributing factor to declines in quality mule deer desert habitats. Conversely, increases in invasive annual grasses have lead to greater intensity and frequency of fires in some plant communities resulting in catastrophic destruction of mule deer habitat.

The single or combined impacts of these contributing factors either directly or indirectly alter key plant species by determining structure, composition, and function of plant communities. Natural disturbances to the system are needed to produce quality mule deer habitats in some areas. Disturbances can result in positive or negative changes in deer habitat. Unfortunately, most of the on-going disturbances do not result in positive outcomes for mule deer. Form, magnitude, and timing of the disturbance are critical to achieving positive outcomes and management is required to achieve these results.

One of the most common factors impacting desert habitats is grazing by herbivores. Herbivory by both wild and domestic herbivores is a large factor in resulting plant composition and structure. Herbivores either directly or indirectly influence likelihood that a plant community will burn by changing the amount of combustible understory herbage. Overgrazing by herbivores also increases the likelihood that invasive plants will take hold by removing valuable native species. Furthermore, herbivory directly influences the hydrologic cycle of plant communities by altering moisture infiltration and runoff. A common result of continuous overgrazing is drying of the landscape.

Inadequate availability of water may be a key limiting factor for mule deer in many desert habitats. Development and maintenance of appropriately spaced artificial water sources benefit mule deer and these need to be maintained even after cattle are removed from individual pastures. Often, initiation of appropriate livestock grazing regimes will result in improved hydrological conditions and natural water will return to previously dry springs or streams. This should be a long-term goal for habitat managers. If artificial water sources are required, much experience has been gained in the design and maintenance of these sources and the manager should use development approaches that are proven to be successful.

High levels of human activity in mule deer habitats can produce undesirable outcomes for deer populations. The direct loss of habitat and landscape connectivity to cities, ranchettes, aqueducts, highways, roads, and energy developments is obvious, with limited actual mitigation being utilized. Accelerated rates of energy developments across the Southwest Deserts are a growing threat to mule deer habitats. These activities encourage proliferation of invasive species onto adjacent intact habitats that may not have been directly impacted by the original development and may also lead to unplanned and harmful fires. Increased roads and recreational vehicles negatively influence distribution of mule deer and may render otherwise suitable habitats unsuitable for mule deer. Recreational pursuits must also be managed to provide areas free of constant human activity.

Mule deer have smaller rumens as compared to elk or livestock and thus must depend on a more diverse habitat consisting of a variety of plant species and plant structures. Diversity in forage choices provide concentrated and more digestible nutrients that are needed by mule deer. A common outcome of the limiting factors discussed in this section is a tendency towards less plant diversity and in many cases plant monocultures dominated by less desirable or invasive plant species. These outcomes almost always mean plant communities with lower nutritional quality for mule deer.

The appropriate mix and age structure of native shrub species is important to good quality Southwest Desert mule deer habitats. The contributing factors discussed in the guidelines play a large role in determining distribution and age structure of the shrub community. Shrubs provide needed cover for mule deer and must be sufficiently abundant and distributed in the landscape in a manner that provides adequate shelter from weather and predators. Old shrubs are lower in nutrition and often produce biomass that is out of reach of deer, but may provide valuable thermal cover in hot months. Too much woody cover suppresses the amount and diversity of valuable understory herbaceous forage. Active management is required to maintain an appropriate balance of forage and cover requirements in shrub communities. Prescribed fire appears to be the most effective tool to achieve these needs in most desert habitats.

Hopefully, guidelines provided in this document will aid resource managers in creating habitat conditions in desert environments conducive to mule deer. Desert habitats can be very productive for mule deer, but active and thoughtful management is required. These guidelines were prepared to help meet that need.

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Appendix A.

List of important forage plants [Common name (Scientific name)] eaten by mule deer in the Southwest Deserts. Adapted from Heffelfinger (2006). Names based on Lehr (1978).

Shrubs

Acacia, Catclaw (*Acacia greggii*)
Acacia, White Thorn (*Acacia constricta*)
Apache Plume (*Fallugia paradoxa*)
Aspen, Trembling (*Populus tremuloides*)
Buckbrush (*Ceanothus* spp.)
Catclaw (*Mimosa biuncifera*)
Ceanothus (*Ceanothus* spp.)
Ceanothus, Desert (*Ceanothus greggii*)
Ceanothus, Fendler (*Ceanothus fendleri*)
Chamise (*Adenostoma fasciculatum*)
Cliffrose (*Cowania mexicana*)
Ebony (*Pithecellobium leptophyllum*)
Fairy duster (*Calliandra eriophylla*)
Fendlera or Fendlerbush (*Fendlera rupicola*)
Guayacan (*Porlieria angustifolia*)
Hackberry, Desert (*Celtis pallida*)
Hackberry, Mountain (*Celtis reticulata*)
Holly-leaf Buckthorn (*Rhamnus crocea*)
Ironwood (*Olneya tesota*)
Jojoba (*Simmondsia chinensis*)
Juniper (*Juniperus* spp.)
Juniper, Alligator (*Juniperus deppeana*)
Kidney wood (*Eysenhardtia polystachya*)
Madrone (*Arbutus arizonicus, A. glandulosa*)
Manzanita (*Arctostaphylos pungens*)
Manzanitia, Mission (*Arcostaphylos bicolor*)
Mesquite (*Prosopis glandulosa*)
Mountain Mahogany (*Cercocarpus* spp.)
Mountain Mahogany, Birchleaf (*Cercocarpus betuloides*)
Oak (*Quercus* spp.)
Oak, Arizona White (*Quercus arizonica*)
Oak, Emory (*Quercus emoryi*)
Oak, Gambel (*Quercus gambelii*)
Oak, Mohr Shrub (*Quercus mohriana*)
Oak, Turbinella (*Quercus turbinella*)
Oak, Wavyleaf (*Quercus undulata*)
Ocotillo (*Fouquieria splendens*)
Oregon Grape (*Berberis repens*)
Palo Verde (*Cercedium* spp.)
Ratany (*Krameria parvifolia*)
Sage, White (*Salvia apiana*)
Sagebrush, Big (*Artemisia tridentata*)
Sedge (*Carex* spp.)
Silktassel (*Garrya wrightii*)
Spurge (*Euphorbia* spp.)
Sumac, Littleleaf (*Rhus microphylla*)
Sumac, Threeleaf or Skunkbush (*Rhus trilobata*)

Succulents

Cactus, Barrel (*Ferocactus* spp.)
Cactus, Prickly Pear (*Opuntia engelmannii*)
Lechuguilla (*Agave lechuguilla*)
Yucca (*Yucca* spp.)

Forbs/Grass

Bladderpods (*Lesquerella* spp.)
Brickellia (*Brickellia californica*)
Buckwheat (*Eriogonum* spp.)
Copperleaf (*Acalypha pringlei*)
Dalea (*Dalea* spp.)
Desert Vine (*Janusia gracilis*)
Ditaxis (*Ditaxis neomexicana*)
Dogweed, Common (*Dyssodia pentachaeta*)
Filaree (*Erodium cicutarium*)
Globemallow (*Sphaeralcea* spp.)
Goldeneye, Skeletonleaf (*Viguiera stenoloba*)
Grass, Squirreltail (*Sitanion hystrix*)
Gumhead (*Gymnosperma glutinosum*)
Lupine (*Lupinus* spp.)
Milkvetch or Locoweed (*Astragalus* spp.)
Milkvetch, Slender (*Astragalus recurvus*)
Mistletoe (*Phoradendron* spp.)
Needleleaf Bluets (*Hedyotis acerosa*)
Vetch, Deer (*Lotus* spp.)

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Yukon Department of Environment