APACHE HIGHLANDS ECOREGION

The Apache Highlands Ecoregion extends from central and southeastern Arizona into southwestern New Mexico and northern Mexico. Within the New Mexico portion of the ecoregion, three key habitats types were identified: Chihuahuan semi-desert grasslands, Madrean Encinal and Madrean Pine-Oak, Conifer-Oak Forest and Woodland (Fig. 5-1).

Semi-desert grasslands in the Apache Highlands Ecoregion have been recognized for their regional biological value, especially their importance to grassland birds (Biodiversity Support Program *et al*. 1995). The Madrean woodlands and forest in the Apache Highlands ecoregion represents a confluence of temperate North American and neo-tropical tree species assemblages, with intrusions of Sonoran and Chihuahuan desert flora at lower elevations. The legume (*Fabaceae*), oak (*Fagaceae*), and pine (*Pinaceae*) families are very diverse within this region (Felger and Johnson 1995).

Woodland and forest habitat types in this ecoregion occur within the greater Madrean Archipelago/Sky Islands complex, which are so-named because of the many isolated mountain ranges spread across the region. These isolated mountain ranges are essentially “islands” of upland habitats separated from one another by plains and valleys of desert and semi-desert grasslands. Desert grasslands and scrublands in the valleys limit genetic interchange between the elevated “island” mountain range habitats, creating isolation with high evolutionary potential within plant and animal populations (Warshall 1995).

The plant and animal communities of the Apache Highlands Ecoregion reflect the meeting, merging, co-evolution and co-adaptation of species representative of the northern Rocky Mountains region in the north and the Sierra Madre Occidental and neo-tropical regions of Mexico to the south. This high level of diversity and unusual community structure has appropriately been described as a stacking of biotic communities on each mountain “island” (Marshall 1957).

The Sierra Madre Occidental and isolated mountain ranges have facilitated plant and animal migrations northward and southward, and many species in the Madrean pine-oak and oak-conifer forests and woodlands are at the northern or southern extent of their distributions (Gehlbach 1981, Felger and Wilson 1995). This phenomenon is true more for tropical organisms than for temperate species, in part because of the northward increasing gradients of winter frost and summer drought that limit the northern distribution of neo-tropical species. As a result, fewer plant and animal species encounter their southern limits than those that are at their northern-most distribution.

This phenomenon involves a wide array of species, including trees, orchids, moths, birds (Felger and Wilson 1995), and bats. Plant species diversity within Apache Highlands Ecoregion is complex because of important floral influences from the Californian, Sonoran, Intermountain, Cordilleran, and Sierra Madrean provinces (Warshall 1995).

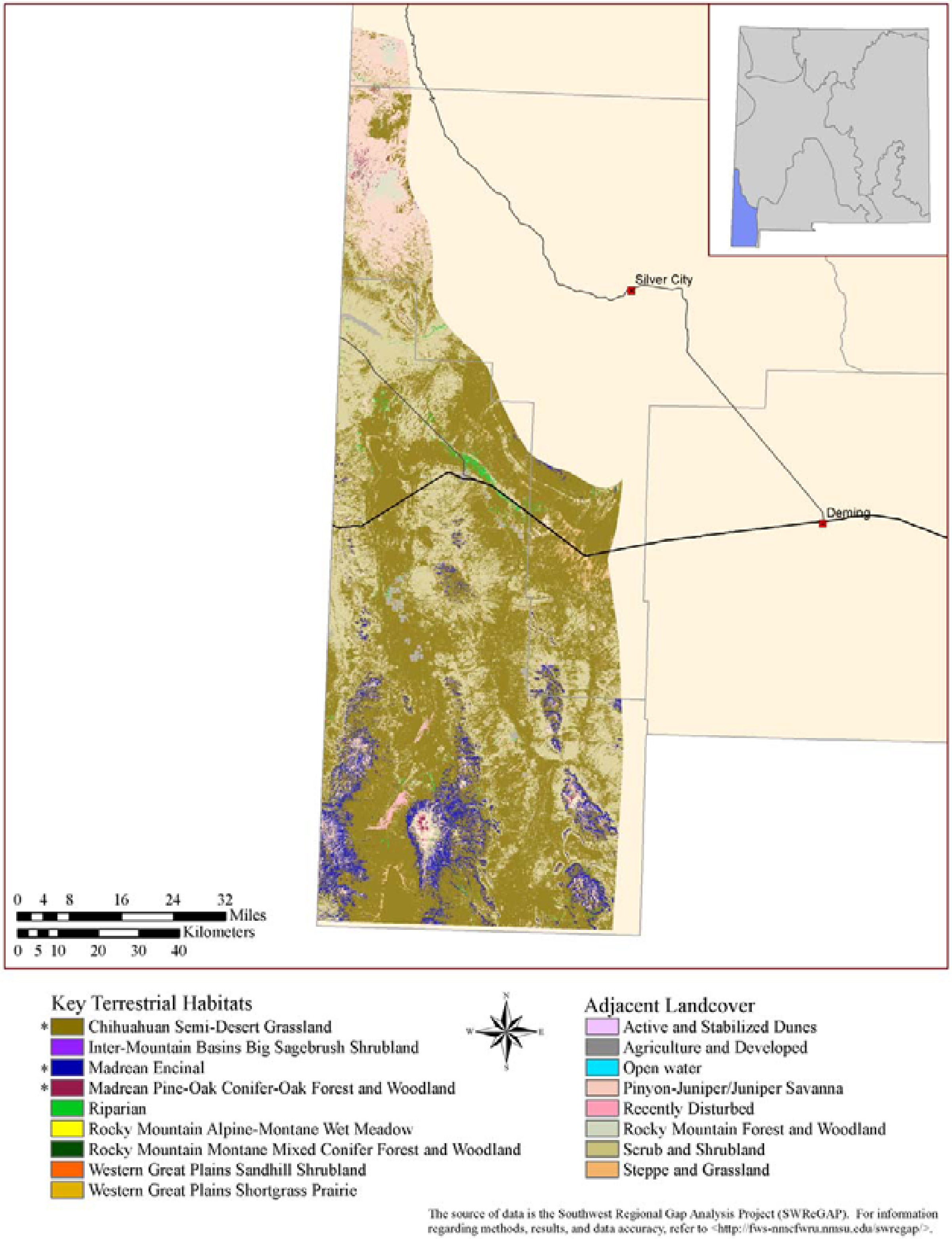

Figure 5-1. Key terrestrial habitats in the Apache Highlands Ecoregion in New Mexico. Adjacent land cover types are given to provide an indication of vegetation surrounding key habitats. Key habitats are designated with an asterisk (*).

Species of Greatest Conservation Need

The Apache Highlands Ecoregion supports a high number of endemic species, game species, and threatened and endangered species (Warshall 1995). Approximately 102 Species of Greatest Conservation Need (SGCN), excluding arthropods other than crustaceans, occur in the Apache Highlands Ecoregion (Table 5-3). Of these, 60 (59%) are considered vulnerable, imperiled, or critically imperiled both statewide and nationally. Twenty-six species (25%) are nationally secure, but are considered vulnerable, imperiled, or critically imperiled in New Mexico, and 16 species (16%) are secure both statewide and nationally. Conservation status codes (abundance estimates) for each SGCN are provided in Appendix H. Madrean Encinal and the Madrean Pine-Oak Conifer-Oak habitats had 61 SGCN, while the Chihuahuan semi-desert grasslands had 48 SGCN. Additional conservation concerns for taxa associated with this ecoregion are addressed in 1) Statewide Distributed Ephemeral Habitats and Perennial Tanks, 2) Statewide Distributed Riparian Habitats, or 3) Watersheds with aquatic key habitats sections.

Table 5-3. Species of Greatest Conservation Need in the Apache Highlands Ecoregion in New Mexico.

Common Name	Chihuahuan Semi-Desert Grasslands	Madrean Encinal	Madrean Pine-Oak / Conifer-Oak
Birds			
Ferruginous Hawk	X	X	
Northern Goshawk			X
Golden Eagle	X		X
Bald Eagle	X		
Peregrine Falcon			X
Aplomado Falcon	X		
Northern Harrier	X		
Gould's Wild Turkey		X	X
Montezuma Quail	X	X	X
Scaled Quail	X		X
Sandhill Crane	X		
Band-Tailed Pigeon		X	X
Mourning Dove	X	X	X
Common Ground-Dove	X		
Mexican Spotted Owl			X
Whiskered Screech-Owl		X	X
Elf Owl		X	X
Burrowing Owl	X		
Broad-Billed Hummingbird			X
Lucifer Hummingbird			X
Elegant Trogon		X	
Williamson's Sapsucker			X
Greater Pewee		X	X
Olive-Sided Flycatcher			X
Thick-Billed Kingbird			X
Loggerhead Shrike	X	X	X
Gray Vireo	X	X	X
Sage Thrasher	X		
Bendire's Thrasher	X		

Table 5-3 Cont.

Common Name	Chihuahuan Semi-Desert Grasslands	Madrean Encinal	Madrean Pine-Oak / Conifer-Oak
Birds Cont.			
Sprague's Pipit	X		
Pinyon Jay			X
Juniper Titmouse		X	X
Red-Faced Warbler			X
Lucy's Warbler			X
Yellow Warbler			X
Black-Throated Gray Warbler		X	X
Grace's Warbler			X
Painted Redstart		X	X
Botteri's Sparrow	X		
Baird's Sparrow	X		
Grasshopper Sparrow	X		
Varied Bunting	X		
Hooded Oriole	X		
Yellow-Eyed Junco		X	X
Mammals			
Mexican Long-Tongued Bat	X	X	X
Mexican Long-Nosed Bat	X	X	X
Lesser Long-Nosed Bat	X	X	X
Western Red Bat		X	X
Arizona Myotis Bat	X		
Allen's Big-Eared Bat		X	X
Pocketed Free-Tailed Bat	X	X	
Arizona Shrew		X	X
White-Sided Jack Rabbit	X		
Southern Pocket Gopher		X	X
Black-Tailed Prairie Dog	X		
Northern Pygmy Mouse	X		
Yellow-nosed Cotton Rat	X	X	X
Mexican Gray Wolf	X	X	X
Black Bear		X	X
White-Nosed Coati	X	X	X
Jaguar	X	X	X
Desert Bighorn Sheep	X		X
Mule Deer	X	X	X
Coues' White-Tailed Deer	X	X	X
Amphibians			
Colorado River Toad		X	
Chiricahua Leopard Frog		X	X
Lowland Leopard Frog	X	X	
Reptiles			
Sonoran Mud Turtle		X	X
Ornate Box Turtle	X	X	
Regal Horned Lizard		X	

Table 5-3 Cont.

Common Name	Chihuahuan Semi-Desert Grasslands	Madrean Encinal	Madrean Pine-Oak / Conifer-Oak
Reptiles Cont.			
Madrean Alligator Lizard		X	X
Collared Lizard	X	X	X
Bunch Grass Lizard	X		
Giant Spotted Whiptail		X	
Gray-Checkered Whiptail	X		
Mountain Skink		X	
Reticulate Gila Monster	X	X	
Sonoran Mountain Kingsnake		X	X
Milk Snake	X		
Green Rat Snake		X	
Yaqui Blackhead Snake		X	
New Mexico Ridgenose Rattlesnake		X	X
Western Diamondback Rattlesnake	X	X	
Banded Rock Rattlesnake		X	X
Desert Massasauga	X		
Molluscs			
Shortneck Snaggletooth Snail		X	
Sonoran Snaggletooth Snail		X	X
Heart Vertigo		X	
Vallonia Snail			X
Cross Holospira Snail		X	X
Metcalf Holospira Snail	X		
Animas Mts. Holospira Snail		X	
Hacheta Mountainsnail		X	X
Fringed Mountainsnail		X	X
Big Hatchet Woodlandsnail		X	X
Animas Peak Woodlandsnail		X	X
Grande Hacheta Woodlandsnail		X	X
Three-Toothed Column Snail	X	X	X
San Luis Mountains Talussnail	X		
Animas Talussnail		X	X
Big Hatchet Mountain Talussnail		X	X
Peloncillo Mountain Talussnail		X	

Chihuahuan Semi-Desert Grassland

Habitat Condition

The Chihuahuan semi-desert grassland is a discontinuous mosaic of desert scrub and grassland distributed from the "boot heel" of New Mexico southwest through Arizona into Mexico (Dick-Peddie 1993). This intermingled and naturally fragmented habitat type contains a highly varied flora and fauna. Soils are equally varied. Thin soils with low organic matter and high amounts of calcium carbonate are found on upland slopes and hilltops and finer alluvial soils are deposited at the bottoms of slopes in depressions, playas, or bolsons (Schmutz *et al.* 1991). Chihuahuan sem-desert grasslands experienced a marked shift from perennial grassland to shrub dominated desert scrub in the mid-1800s, as with other grassland communities in the western United States (Barnes 1936, Buffington and Herbel 1965, Branson 1985, Archer 1989). The exact cause of this shift is debated, but excessive livestock grazing, climatic change, and fire suppression are contributors to this change (Barnes 1936, Allred 1996, Fredrickson *et al.* 1998). In turn, grassland conversion and human-caused fragmentation have increased runoff and erosion, decreased biological diversity through isolation, reduced carrying capacity (Saunders *et al.* 1991), caused shifts in avian assemblages, increased invasion by non-native species, and decreased livestock and wildlife forage (Branson 1985, Vickery *et al.* 1999). Today, portions of the Chihuahuan semi-desert grassland appear to be undergoing additional desertification (Asner 2005).

Problems Affecting Habitat or Species

Biodiversity in Chihuahuan semi-desert grasslands is influenced by habitat conversion factors and non-consumptive and consumptive resources uses. Dinerstein *et al*. (2000) also reported that livestock grazing, fire suppression, and urban development were factors leading to loss of biodiversity in the northern Chihuahuan Desert.

Grazing Practices
Domestic livestock grazing is an extensive land use activity in the Chihuahuan Desert (See Chapter 3, New Mexico's Biodiversity). Grazing of Chihuahuan Desert grasslands may not always lead to altered habitats. Impact of livestock grazing on rangeland wildlife is largely dependent on the grazing management practices used. However, improper grazing practices (grazing practices that reduce long-term plant and animal productivity) on native grasslands may lead to the loss of grassland cover, mortality of plant species, and increased erosion (Wilson and MacLeod 1991). Further, improper grazing practices and increased intense agriculture production may lead to habitat fragmentation and loss by promoting conditions favorable for shrub encroachment and through increased infrastructure development, such as roads and fences (Dinerstein *et al*. 2000). The effects of these land management activities are compounded by extended drought periods and altered hydrological functions in the Chihuahuan Desert. An additional discussion of grazing practices is offered in the Statewide Assessment and Strategies (Chapter 4).

Fire Regimes
Altered fire regimes, resulting from both fire suppression and the removal of fine fuels by domestic grazers and wildlife, may have also promoted the establishment of both woody vegetation and introduced non-native species. However, the extent to which fire occurred in southwestern grasslands varied geographically and is related to climatic variables such as seasonal and annual rainfall and physiographic variables such as elevation, slope and aspect (Archer 1994). Fire may have been rare in desert grasslands and limited in extent due to low biomass and a lack of continuity in fine fuels (Hastings and Turner 1965, York and Dick-Peddie 1969).

Development and Exploration
Housing developments and agriculture are increasing in areas around Deming and Lordsburg. Development contributes to the loss of native vegetation and erosion through soil compaction and the concentration of runoff. Agricultural production results in loss of natural plant and animal communities and fragmentation of landscapes through habitat conversion, roads, fences, and groundwater pumping. Chihuahuan semi-desert grasslands in the “boot heel” portion of Hidalgo County are now being explored for geothermal energy and oil and gas potential. This activity can ultimately cause habitat fragmentation and loss through conversion (clearing), road building with increased vehicular traffic, and groundwater pumping (Dinerstein *et al.* 2000).

Borderland Security Activities
Security measures are being implemented throughout the United States/Mexico borderlands region to intercept drug shipments, illegal immigrants, and other unauthorized activities (US Department of Justice, Immigration and Naturalization Service 2000). Increased road building and traffic along the borderlands causes habitat destruction, loss, and fragmentation, diminishes the utility of habitat for wildlife, and increases road kill (Forman *et al.* 2003).

Off-Road Vehicles
Recreational off-road vehicle use has also increased in the Chihuahuan semi-desert grasslands. While the impacts of these activities on the Chihuahuan semi-desert grasslands are poorly understood, increased off-road vehicle use negatively impacts wildlife by destroying and fragmenting habitat, causing direct mortality of wildlife, or altered behavior through stress and disturbance (Busack and Bury 1974, Brattstrom and Bondello 1983).

Invasive Species
Many ecologists have acknowledged the problems caused by invasion of non-native species into ecosystems and the associated negative effects on global patterns of biodiversity (Stohlgren *et al.* 1999). Once established, invasive species have the ability to displace native plants and animals, including threatened and endangered species, disrupt nutrient and fire cycles, and alter the character of the native community by enhancing additional invasions (Cox 1999, Deloach *et al.* 2000, Zavaleta *et al.* 2001, Osborn *et al.* 2002). Little is known about the extent of invasive species in Chihuahuan semi-desert grasslands. As such, the development of early detection protocols, and estimators of vectors and pathways of potential invasive species may assist in the development of strategies to control invasive species.

Information Gaps

Although there is a large body of literature on Chihuahuan semi-desert grasslands, there are numerous information gaps (outlined below) that limit our ability to make informed decisions.

- The intensity, scale, extent, and causes of grassland fragmentation in the Chihuahuan Desert are unknown.

- The response of SGCN to human disturbances is poorly understood.

- The effects of habitat fragmentation on SGCN are unknown.

- Environmental conditions or thresholds that limit populations of SGCN are poorly understood.

- Methods to identify early detection landscape degradation attributes that would inform land managers of when grasslands were approaching transitional thresholds are needed, to alleviate the need for expensive restoration projects.

- The extent to which invasive species may alter semi-desert grasslands and limit populations of SGCN is unknown.

- The full extent in which border patrol activities or military maneuvers alters semi-desert grasslands and limits populations of SGCN is unclear.

- Information is needed on grazing management practices that produce sustainable levels, composition, and structure of native grasses needed by SGCN.

- The extent to which off-road vehicle use is impacting Chihuahuan semi-desert grassland SGCN populations is unknown.

- Our understanding of the role of fire in sustaining the Chihuahuan semi-desert grasslands and appropriate fire management protocols is poor.

- Short and long-term effects of land management practices or uses such as energy exploration and development, grazing systems, invasive species and shrub encroachment management are unclear. Availability and distribution of this information would allow land managers to make more informed conservation decisions.

Research, Survey, and Monitoring Needs

Research, survey, and monitoring needs for the Chihuahuan semi-desert grasslands are primarily derived from our perception of factors that influence the integrity of semi-desert grasslands. Research, survey, and monitoring needs include:

- Estimate the extent, fragmentation, and structural characteristics of Chihuahuan semi-desert grasslands to provide greater predictive power and applicability to an ecosystem management approach.

- Research is needed to obtain basic life history information for SGCN inhabiting Chihuahuan semi-desert grasslands to develop effective species/habitat monitoring and conservation strategies.

- Studies are needed on the type and extent of human-caused fragmentation in Chihuahuan semi-desert grasslands and how such habitat alterations influence patch size, edge effect, and use by wildlife. This information is also important in understanding how different intensities and frequencies of disturbances effect small-mammal species, avifauna, and herpetofauna.

- Since this habitat type has experienced a shift from perennial grassland to shrub-dominated desert scrubland (Buffington and Herbel 1965, Archer 1989), early detection methods are needed that indicate when grasslands habitats are shifting to another habitat type. In addition, cost effective measures need to be investigated that restore semi-desert grasslands to functional mosaics.

- Consistent rangeland health and condition descriptions or protocols need to be developed across the states, regions, and nations (National Research Council 1994). These protocols would facilitate land management decisions by establishing standardized indicators and reference points.

- Investigate invasive species early detection protocols, and estimate vectors and pathways of potential invasive species.

Desired Future Outcomes

Desired future outcomes for the Chihuahuan semi-desert grasslands include:

- That the Chihuahuan semi-desert grasslands exists in the condition, connectivity and quantity necessary to sustain viable and resilient populations of resident SGCN and host a variety of land uses with reduced resource use conflicts.

- Ecological conditions that sustain viable populations of the SGCN are established and garner wide public support.

- That colonization of Chihuahuan semi-desert grasslands by invasive plant species is stopped and existing populations are controlled or eliminated.

- That energy development on Chihuahuan semi-desert grasslands is managed to preserve habitat integrity and functionality and that disturbed sites are restored to native habitats.

Prioritized Conservation Actions

Approaches for conserving New Mexico's biological diversity at the species or site-specific level are inadequate for long-term conservation of SGCN. Conservation strategies should be ecosystem-based and include public input and support (Galeano-Popp 1996). Monitoring of species and habitat will be employed to evaluate the effectiveness of the conservation actions described below. Those found to be ineffective will be modified in accordance with the principles of adaptive management. Conservation actions, in order of priority, which assist in achieving desired future outcomes, are outlined below.

1. Work with land management agencies, private land managers, and the agriculture industry to identify and promote grazing systems on rangelands that ensure long-term ecological sustainability and integrity and are cost effective for livestock interests. Such practices may include collaborative development of grazing management plans, altering domestic and wildlife stocking rates, time and use, and distribution where forage

availability is inadequate, and promoting "grass banking" opportunities that allow degraded rangelands to recover.

2. Work with public and private land managers to reduce shrub encroachment in Chihuahuan semi-desert grasslands habitats important to SGCN. Implementation of this conservation action may include chemical or mechanical manipulation, reseeding with native grasses, or reduction of processes that promote shrub encroachment.

3. Work with federal, state, private organizations, research institutions, and universities to design and implement projects outlined in the Research, Survey, and Monitoring Needs or Information Gaps section outlined above.

4. Work with public and private land managers and the energy industry to encourage energy development in a manner that preserves the integrity and functionality of Chihuahuan semi-desert grasslands and restores disturbed sites.

5. Form partnerships with effected communities and federal land management agencies to facilitate and encourage maintenance and restoration of Chihuahuan semi-desert grasslands.

6. Collaborate with federal and state agencies to designate areas for off-road vehicle use that avoid disturbance to SGCN or their habitats and discover ways to mitigate such disturbance where it currently occurs.

7. Collaborate with federal and state land management agencies and other publics to identify legislative actions, land acquisition and easement protection that will conserve the Chihuahuan semi-desert grasslands.

8. Work with federal, state, and private organizations to develop public education projects that increase awareness and understanding of the fragility of Chihuahuan semi-desert grasslands and their importance to a wide array of species.

Madrean Encinal and Madrean Pine-Oak Conifer-Oak Forest and Woodland

The Madrean Encinal and Madrean Pine-Oak, Conifer-Oak Forest and Woodland in the Apache Highlands Ecoregion have similar problems, information gaps, research, survey, and monitoring needs, desired future outcomes, and conservation actions. We present information on these two habitat types collectively.

Habitat Condition

Madrean Encinal oak woodlands in the Apache Highlands ecoregion generally occur at elevations between 4,000 ft (1,220 m) and 4,986 ft (1,520 m). At the lower ecotone where conditions are drier, Madrean Encinal oak woodlands merge with oak savanna and eventually semi-desert grassland. At middle elevations, Madrean Encinal oak woodlands grade into

Madrean pine-oak forests, and at the highest elevations into conifer-oak and pine forests (Ffolliott 2002).

Emory oak (*Quercus emoryi*) is the most common tree species in Madrean Encinal and is found in associations with varying intermixtures of Mexican blue oak (*Q. oblongifolia*), gray oak (*Q. grisea*) silverleaf oak (*Q. hypoleucoides*), and Arizona white oak (*Q. arizonica*) (Ffolliott 1980, Brown 1982, McPherson 1992, 1997, McClaran and McPherson 1999). Interspersed within the Madrean Encinal are shrubs, grasses, forbs and succulents.

Within Madrean pine-oak and oak-conifer forests and woodlands, pines or other conifers generally form the overstory while oaks generally form the understory. There are extensive areas of pine-oak woodland in the Apache Highlands Ecoregion of the southwestern United States. Pine-oak woodland is included within the concept of Madrean evergreen woodland. The pine forest is called Madrean Montane Conifer Forest (Brown 1982). Within this habitat type, the abundance of oaks may be a consequence of over harvesting of pines (Felger and Johnson 1995).

At higher elevations within the pine-oak forest and woodland, pines become more dominant as their density increases so that the vegetation could be called forest rather than woodland. This pine-oak forest is dominated by one species of pine, usually Arizona pine (*Pinus ponderosa* var. *arizonica*), ponderosa pine (*P. ponderosa* var. *scopulorum*), or white pine (*P. strobiformis*). Scattered individuals or small groups of oaks, primarily Gambel oak (*Q. gambelii*), and net-leaf oak (*Q. rugosa*), occur with these pine stands. Gambel oak is the only winter-deciduous oak in this area. In the northernmost of the isolated mountain ranges, Arizona pine is replaced by ponderosa pine at higher elevations (Felger and Johnson 1995).

Precipitation in the Madrean woodlands and forests ranges from 12 - 40 in (305 - 1,015 mm) per year, with generally half of this precipitation occurring between May and August. The frequency of freezing temperatures increases northward within the Madrean woodlands and forest, which limits plant species diversity (Gottfried *et al.* 1995). Bi-modal emergence of perennial and annual plants occurs in early spring following winter rains and during the summer monsoons (McPherson 1994, 1997).

The distribution, structure and health of Madrean woodlands and forest in the Apache Highlands Ecoregion have been affected by human activities since prehistoric times. The Madrean woodlands and forest were important to prehistoric people (Propper 1992), who gathered fuel wood for fires and construction materials, acorns for food and ceremonial purposes, and piñon nuts and juniper berries for winter food (Gottfried *et al.* 1995). Settlers, miners, and ranchers utilized woodlands in the late 1800s and early 1900s, for timber and smelter fuel (Bahre and Hutchinson 1985). Madrean woodlands and forest were heavily grazed by livestock in the 1880s and continue to be grazed today, although at much lower stocking rates (Weltzin and McPherson 1995). However, Madrean woodlands and forests have not been subjected to large-scale range improvement practices (Ffolliott and Guertin 1987, McClaran *et al.* 1992).

Natural mortality of oak trees appears to be low, possibly due to the long history of harvesting older trees. All evergreen oak tree species in the Madrean Encinal of New Mexico and Arizona are susceptible to infection by a fungus, *Inonotus andersonii*, a major cause of wood decay (Fairweather and Gilbertson 1992). Oak densities within Madrean woodlands and forest vary considerably, and range from a few scattered individuals to several hundred stems per hectare. Volumes of wood vary from less than 1, to more than 53 yd^3 per ac (2 to more than 100 m^3 per ha) (Ffolliott and Gottfried 1992). Annual growth rate is relatively slow, ranging from 0.13 - 0.26 yd^3 per ac (0.25 - 0.50 m^3 per ha), with an annual growth rate of less than 1% (Gottfried *et al.* 1995).

Tree density and openness is related to local site characteristics such as soils, fire disturbance and land use histories (Gottfried *et al.* 1995, Ffolliott 2002). Tree species composition and density changes with elevation gradients, latitude, previous disturbances, slope, and aspect. Stand-level disturbances by fire, disease, vegetation control, and land-clearing activities have been relatively minor in Madrean woodlands and forests (Kruse *et al.* 1996). However, these disturbances when they do occur are likely to affect stand structure and productivity (Ffolliott and Gottfried 1992, Gottfried *et al.* 1995, McClaran and McPherson 1999). Historically, fires effected species composition, stand density, and size-class distributions (Niering and Lowe 1984, Barton 1991, Kruse *et al.* 1996).

The Madrean woodlands and forests are an area of exceptionally high biological diversity and biogeographical interest (DeBano and Ffolliott 1995). These habitat types occur within a topographically and geologically complex region (Felger and Johnson 1995). The complex topography and steep elevation gradients within the Madrean pine-oak and oak-conifer forests and woodlands result in a rich assemblage of floral and faunal species. The complex geology and topography of the region creates unusual and striking assemblages of habitats and plant and animal associations. Floral and faunal species occur here that are more commonly associated with the New World tropics than with the southwestern borderlands. Plant and animal species co-mingle here that would otherwise be separated by large distances and climatic regimes (Felger and Wilson 1995).

Problems Affecting Habitats or Species

A general analysis based on the scientific literature and NMDGF staff opinion reveals that climate change, fire management, urban and residential development and habitat loss and fragmentation associated with roads/highways/utility corridors are the greatest factors adversely affecting Madrean woodlands and forests in the Apache Highlands ecoregion.

Climate Change and Drought
Climate change may occur in the Southwest from increased atmospheric concentrations of CO_2 and other greenhouse gases. Effects may include increased surface temperatures, changes in the amount, seasonality, and distribution of precipitation, more frequent climatic extremes, and a greater variability in climate patterns. Such changes effect vegetation at the individual, population, or community level, precipitate changes in ecosystem function and structure (Weltzin and McPherson 1995), and will likely affect competitive interactions between plant and animal species currently co-existing under equilibrium conditions (Ehleringer *et al*. 1991) (See Chapter 4 for greater details).

Subsequent specific outcomes for Madrean forest and woodland habitats are unpredictable and remain uncertain (Weltzin and McPherson 1995). However, plants respond differently to changes in atmospheric gases, temperature and soil moisture, in part based on their C_3 or C_4 photosynthetic pathways (Bazzaz and Carlson 1984, Patterson and Flint 1990, Johnson *et al*. 1993). For example, increases in winter precipitation favor tree establishment and growth at the expense of grasses, while increases in temperature and summer precipitation favor grasslands expanding into woodlands (Bolin *et al*. 1986). Recent research has investigated shifts in the Madrean Encinal oak woodland/semi-desert grassland boundary (Hastings and Turner 1965, Bahre 1991, McPherson *et al.* 1993). Paleo-ecological data gathered from packrat middens suggest that Madrean Encinal oak woodland have moved higher in elevation as a result of warmer and drier climatic conditions since the Pleistocene. Bahre (1991) suggests that the distribution of Madrean Encinal oak woodland has been stable since the 1860s.

Drought, defined as an extended period of abnormally dry weather, is one of the principal factors limiting seedling establishment and forest productivity (Schulze *et al*. 1987, Osmond *et al*. 1987). Soil moisture is directly altered by drought conditions. The distribution and vigor of some oak woodlands and savannas is controlled primarily by soil moisture gradients (Griffin 1977, Pigott and Pigott 1993). Drought and climate change can have a substantial effect on the Madrean forest and woodland habitats. Further, these factors can alter fire frequency, intensity, and timing by changing the amount and accumulation of fine fuels (Clark 1990, Haworth and McPherson 1994). Unfortunately, due to the complexity of interactive relationships between global, regional and local biotic and abiotic factors, and political decisions at national and international levels, the effects of climate change on fire regimes in the Madrean forests and woodlands are difficult to predict (Weltsin and McPherson 1995).

Natural Disturbance Regimes
Natural disturbances in the Madrean woodland and forests are fire, wind, and insects. Changes in the frequency, intensity, and timing of natural fires have altered the distribution of current vegetation. Madrean woodland and forest density was relatively low prior to European settlement (Moody *et al*. 1992, Covington and Moore 1994). In these less dense woodlands, most fires were low intensity ground fires that tended to reduce understory vegetation (Gottfried *et al*. 1995). The elimination of episodic fires after 1893 may be attributed to livestock grazing and fire suppression (Grissino-Mayer *et al*. 1995, Weltzin and McPherson 1995). Historic (late 1800s) improper grazing practices in Madrean woodlands and forests eliminated the herbaceous fine fuels layer. The reduction of these fine fuels prevented the spread of low-intensity, ground-hugging fires, and reduced grass competition, thereby allowing tree establishment (Gottfried *et al*. 1995). Fire suppression has further eliminated the natural fire regime that historically kept stand densities relatively low. Fire suppression allowed the increase of ladder fuels and heavy fuel loading conditions. Catastrophic, stand-replacing crown fires have become more common because of these changes (Covington and Moore 1994).

Grazing Practices
Livestock grazing has economic and cultural values that are important to individuals, communities and the State. Impacts to rangeland wildife by livestock grazing are largely dependent on the grazing management practices used. Domestic and wildlife grazing practices that reduce the ability of the land to sustain long term plant and animal production (Wilson and

MacLeod 1991) have influenced plant communities and fish and wildlife habitat in New Mexico for more than a century. Peer-reviewed scientific literature implies that livestock grazing has impacted terrestrial and riparian/aquatic habitats in New Mexico (Armour *et al*. 1994, Fleischner 1994, The Wildlife Society 1996, Belsky and Blumenthal 1997). Improper grazing by livestock can reduce vegetative cover, increased soil erosion, and aggravated local flooding (Felger and Wilson 1995).

Many of these impacts began as early as the late 1800s when large herds of livestock were present. Impacts of improper grazing practices have included: 1) competition with wildlife for water, forage, and space; 2) degradation of forage and cover by altering vegetation composition and structure; 3) impacts on stream hydrology, siltation, and water quality; and 4) reduced soil permeability and potential to support plants due to soil compaction. Improper grazing can diminish wildlife habitat in Madrean woodland and forest. In contrast, prescribed grazing is a management tool that can be used to benefit wildlife (Holechek *et al*. 1982, Kirby *et al*. 1992, Holecheck *et al.* 2004).

Animal Herbivory

Animal herbivory is the most common source of mortality for low-elevation oaks of southern Arizona (McPherson 1993, Peck and McPherson 1994). Herbivory by invertebrates is a potentially important source of seedling mortality that is commonly overlooked in field studies. Invertebrates have been found to defoliate oak seedlings primarily during the summer (Peck and McPherson 1994, Weltzin and McPherson 1995). Vertebrates kill Emery oak seedlings primarily during autumn and winter months (Weltzin and McPherson 1995). Differential population dynamics of herbivorous animal species, combined with temporal and spatial variability of herbivory (McPherson 1993, Peck and McPherson 1994, Weltzin and McPherson 1995) combine to determine the timing and intensity of herbivory-related mortality on young oaks (Weltzin and McPherson 1995).

Loss of Biological Diversity

Intact Madrean woodland and forest habitats once extended into the American tropics, but accelerating deforestation is fragmenting habitats and populations of plant and animal species (Felger and Johnson 1995). Trees within Madrean woodland and forest habitats are most often harvested for fuel wood and fence posts, but also for value-added wood products such as furniture and home construction (Ffolliott 1989, Ffolliott and Gottfried 1992, Maingi and Ffolliott 1992).

Natural regeneration of Madrean oak woodlands is low. Factors that may be responsible for low recruitment of oaks include herbivory by livestock and wildlife, competition for water, light and minerals from herbaceous plants, and climatic and edaphic conditions. A combination of these and possibly other unknown factors likely interact to produce low rates of seedling re-establishment (Weltzin and McPherson 1995). However, demands for oak woodlands are expected to increase (Conner *et al*. 1990, Van Hooser *et al*. 1990, Ffolliott and Gottfried 1992, Gottfried *et al*. 1995).

Biological diversity in the Madrean woodland and forest is rapidly eroding (DeBano and Ffolliott 1995). Cutting trees of the tallest height classes reduces the structural diversity of oak forests and woodlands stands (Sharman and Ffolliott 1992). Taller trees provide more habitat niches for non-game birds than do shorter trees (Balda 1969). Thus, tree harvesting can reduce bird diversity by simplifying woodland structural diversity (Ffolliott 2002).

Non-Native Species
In 1998, non-native species were implicated in the decline of 42% of species federally listed under the Endangered Species Act (Center for Wildlife Law 1999). Once established, non-native species have the ability to displace native plant and animal communities, disrupt nutrient and fire cycles, and alter the character of the community by enhancing additional invasions (Cox 1999, Deloach *et al.* 2000, Zavaleta *et al.* 2001, Osborn *et al.* 2002). Exotic species colonization of the Madrean Archipelago region is increasing, with more than 60 non-native plants having successfully established in the isolated mountain ranges of Arizona (Warshall 1995).

Habitat Alteration and Fragmentation
Human populations are increasing in the region and demands for fuel wood are accelerating. Privately owned forest and woodlands are being converted to residential areas, fragmenting wildlife habitats, increasing wildland/urban interface fire risks, and generally accelerating land management conflicts. Associated increasing demands for water in these communities are outpacing the ability of natural systems to provide new freshwater sources (Felger and Wilson 1995). Sustainability of Madrean woodland and forest habitats is questionable under increasing pressures from human activities and altered fire regimes (Gottfried *et al*. 1995).

Much of the Madrean woodlands and forests of southwestern New Mexico and southeastern Arizona is administered by the US Forest Service. It is charged with potentially conflicting mandates of multiple use including: 1) conservation of wildlife, habitats and ecosystem function; 2) generating revenue from timber sales; 3) maintaining livestock grazing leases; and 4) providing increasing opportunities for urban recreation (Felger and Wilson 1995). There is growing pressure to develop more Madrean woodland and forest habitats within national forests for camping, hiking, mountain biking, off-road vehicle use, and new or improved roads to access these sites (Warshall 1995).

Groundwater Depletion
Groundwater levels in the United States and regional wetlands have dropped significantly from groundwater pumping for agricultural irrigation of crops. One example in Madrean woodlands and forests is San Simon Cienega, which was once a functioning wetland, but has since been drying out due at least in part to groundwater pumping (Dinerstein *et al*. 2000).

Mining
Historic and current hard rock mining activities pose a threat to ecosystem function, resilience and sustainability within the Madrean woodland and forests in the Apache Highlands. Large underground bodies of primarily copper deposits have led to huge industrial mining complexes in the area. Associated ecosystem stressors include: 1) habitat fragmentation and loss; 2) acid rock drainage from chemical reactions to surface waste rock that create heavy metal contamination poisonous to wildlife (Drabkowski 1993, Starnes and Gasper 1996, Reece 1995, Hilliard 1994); 3) huge permanent pit lakes that contain toxic water (a danger primarily to waterfowl) (Miller *et al.* 1996); 4) groundwater pollution; 5) air pollution and associated acid

rain fallout; 6) increased frequencies of road killed fauna; 7) the potential for bioaccumulation of heavy metals in soils and vegetation at levels dangerous to wildlife.

Borderland Security Activities
Security measures are being implemented throughout the United States/Mexico borderlands region to intercept drug shipments, illegal immigrants, and stop other unauthorized activities (US Department of Justice, Immigration and Naturalization Service 2000). Increased road building and traffic along the borderlands causes habitat destruction, loss, and fragmentation, diminishes the utility of habitat for wildlife, increases road kill, poaching, and illegal collecting (Forman *et al.* 2003).

Recreation and Tourism
Recreation and tourism activities in the Madrean woodland and forests generate income for the region. Hunting for species such as deer, quail and collared peccary (*Tayassu tajacu*) has long been a dominant recreational use (McClaran and McPherson 1999). Non-consumptive recreational uses in Madrean woodland and forests include hiking, camping, sightseeing, bird watching, and picnicking (Conner *et al.* 1990). Although comprehensive statistics documenting the level of these recreational uses are lacking, it is clear that recreational uses of Madrean woodlands and forests are increasing and their impact on habitats and species should be considered in conservation planning (Conner *et al.* 1990, McClaran *et al.* 1992).

Information Gaps

Information gaps that impair our ability to make informed conservation decisions are outlined below.

- The location, timing, duration, frequency and intensity of all of the problems identified that potentially affects Madrean woodland and forest habitats and/or SGCN.

- The ongoing activities of the Joint Task Force Six activities on the borderland of New Mexico. These activities include maneuvers and encampments that can destroy habitat, spread invasive weed species, increase road kill, and alter sensitive wildlife behavior.

- The impacts on Madrean woodland and forest SGCN and habitats from increased daytime and nighttime traffic associated with Border Patrol surveillance and monitoring activities and illegal immigration.

Research, Survey, and Monitoring Needs

The processes that have impacted the Madrean forests and woodlands in the past and the anticipated levels of future development serve as a backdrop for defining current research, survey, and monitoring needs. Research, survey, and monitoring needs that would enhance conservation efforts in these habitats are outlined below.

- Enhance our understanding of habitat connectivity by acquiring population-level information of dispersal behavior, daily and seasonal movements of SGCN through

Madrean woodland and forest habitats, how different types of habitat fragmentation (such as timber removal, housing developments) affect these movements, and how climate change may ultimately affect species distributions.

- Determine the extent, age class, structural characteristics, and regeneration rates of the Madrean woodlands and forests so as to provide predictive power and applicability to ecosystem-based management.

- Determine the minimum viable habitat size and forest age-class structure necessary to support SGCN that migrate vertically among the bands of Madrean habitats within the isolated mountain ranges of the Madrean Archipelago.

- Determine how global and regional climate change will affect vegetation patterns and community and ecosystem-level dynamics in Madrean pine-oak, conifer-oak forests and woodlands.

- Conduct research to enhance information of the natural history, population biology, and community ecology of SGCN within Madrean woodland and forest habitats.

- Conduct research to increase our knowledge of SGCN distribution, abundance, and population trends within the Madrean woodland and forest habitats of the Apache Highlands Ecoregion.

- Evaluate the effectiveness of prescribed fire in reducing the potential for catastrophic stand-replacing fires in the Madrean woodlands and forests.

- Determine how SGCN of Madrean woodland and forests respond to prescribed livestock grazing, fuel wood harvesting, increased recreational use, exotic species invasions and increased human population.

- Assess the impacts of prescribed livestock grazing on the structure of Madrean woodlands and forests.

- Determine how the timing, intensity, and duration of prescribed livestock grazing affect SGCN.

- Determine how prescribed grazing affects natural disturbance regimes such as wildland fire in Madrean woodland and forest habitats.

- Identify wildlife travel corridors connecting the Madrean woodland and forest habitats in isolated mountain ranges so they may be protected and managed to maintain connectivity. Information needed for understanding habitat connectivity includes population-level information of dispersal behavior, daily and seasonal movements of SGCN through Madrean habitats, how different types of habitat fragmentation (such as timber removal, housing developments, etc.) affect these movements, and how climate change may ultimately affect species distributions.

- Determine the effects of natural and prescribed fire on the structure of vegetative communities in the Madrean woodlands and forests and the subsequent effects upon vertebrate and invertebrate populations. Evaluate the effectiveness of prescribed fire as a tool to reduce the potential for catastrophic fire (DeBano and Ffolliott 1995).

- Assess the potential impacts of fire on SGCN such as the Lucifer hummingbird (*Calothorax lucifer*), the New Mexico ridgenose rattlesnake (*Crotalus willardi obscurus*) and the whiskered screech owl (*Otus trichopsis*) and elegant trogon (*Trogon elegans*), two cavity-nesting birds that breed only in the Peloncillo Mountains. Assess impacts on the Mexican long-nosed bat (*Leptonycteris nivalis*) and the lesser long-nosed bat (*Leptonycteris curasoae yerbabuenae*), which are exclusively dependent upon agave (*Agave parryi* and *A. palmeri*) for nectar.

- Determine if coppicing (post-cutting sprouting from roots and stumps) is an effective supplement to the episodic regeneration of oaks from seed. Is coppicing sufficient to maintain habitat composition, structure, and biological diversity?

- There is a need for additional investigations of hydrologic relationships in the Madrean woodlands and forests that will provide a better understanding of interception, transpiration, and infiltration processes (Lopes and Ffolliott 1992, Haworth and McPherson 1994, Baker *et al*. 1995, Ffolliott and Gottfried 1999). This information is crucial for determining effective and sustainable conservation and management practices at the watershed level (Ffolliott *et al*. 1993).

- There is a need to develop collaborative survey and monitoring protocols for invertebrate SGCN that are not currently being monitored.

Desired Future Outcomes

Desired future outcomes for Madrean forests and woodlands include:

- Madrean woodland and forest habitats exist in the condition, connectivity and quantity necessary to sustain viable and resilient populations of resident SGCN and host a variety of land uses with reduced resource conflicts.

- A scientific basis for ecosystem management has been established and implemented in the Madrean woodlands and forests. Systems management of the ecosystem, rather than functional management of individual species or other natural resources such as timber, is policy and is validated through forest plans ecosystem-wide.

- Long-term conservation strategies to restore viable native species population are established and garner wide public support.

- Special habitats within the Madrean woodland and forests, such as cienegas, limestone outcrops, talus slopes, caves, and perennial streams are protected and are being monitored long-term for condition as necessary to ensure conservation for SGCN that rely on these habitats.

- Prescriptions for sustainable harvest have been developed that allow adequate levels of human harvest for fuel wood and other wood products and major harvest activities replicate natural disturbance patterns.

- Partnerships have been established among state and federal government agencies, non-governmental organizations and private landowners for the implementation of collaborative and coordinated initiatives to conserve SGCN and the functionality of the Madrean woodland and forest habitats upon which they depend.

- Colonization of Madrean woodland and forest habitats by exotic species is stopped. Existing populations of non-native species are controlled or eliminated.

Prioritized Conservation Actions

Approaches for conserving New Mexico's biological diversity at the species or site-specific level are inadequate for long-term conservation of SGCN. Conservation strategies should be ecosystem-based and include public input and support (Galeano-Popp 1996). Monitoring of species and habitat will be employed to evaluate the effectiveness of the conservation actions described below. Those found to be ineffective will be modified in accordance with the principles of adaptive management. Conservation actions, in order of priority, which assist in achieving desired future outcomes, are outlined below.

1. Collaborate with affected interests to pursue enactment of state laws or policies to protect closed basins within Madrean woodlands and forests from the impacts of dredge and fill activities and future development.

2. Work with willing private landowners to obtain conservation easements for lands that have historic or potential value as corridors connecting Madrean mountain ranges.

3. Collaborate with state and federal agencies, universities, Wildlands network, other NGOs and private landowners to identify and protect riparian corridors and other corridors linking Madrean mountain ranges.

4. Collaborate with state and federal agencies and private landowners to develop measures (such as closure of unnecessary roads) within and adjacent to Madrean woodlands and forests to reduce habitat fragmentation.

5. Promote protection and restoration of unique habitats such as cienegas, limestone outcrops, talus slopes, caves, and perennial streams that Madrean SGCN depend upon.

6. Encourage the US Forest Service to conserve the biological diversity of the Madrean woodland and forest habitat through development and implementation of an ecosystem management approach.

7. Work with government and private landowners to develop strategies for the sustainable harvest of wood products in Madrean woodland and forests that will maintain oak regeneration and native biodiversity.

8. Encourage thinning and fuel-reducing initiatives in Madrean woodland and forest habitats, where necessary, to open dense stands that have become susceptible to insects, diseases, or stand-replacing wildfires.

9. Encourage government and private land managers to protect and restore Madrean watersheds through management practices that reduce erosion, gully formation, soil loss, and maintain native biodiversity.

10. Maintain awareness of the introduction and spread of non-native plants and animals into Madrean woodlands and forests and encourage control or eradication where necessary to maintain or restore native biodiversity.

11. Provide the US Forest Service with recommendations regarding the timing of prescribed burning in Madrean woodlands and forests to protect breeding birds, avoid riparian areas, and otherwise conserve biodiversity.

12. Encourage the US Forest Service to schedule prescribed burns avoiding desert bighorn sheep lambing areas from mid-December through mid-February.

13. Work with land management agencies, private land managers, and the agriculture industry to identify and promote grazing systems on rangelands that ensure long-term ecological sustainability and integrity and are cost effective for livestock interests. Such practices may include collaborative development of grazing management plans, altering domestic and wildlife stocking rates, time and use, and distribution where forage availability is inadequate, and promoting "grass banking" opportunities that allow degraded rangelands to recover.

14. Create public awareness and understanding of ecosystem functions, values, products and human impacts on Madrean habitats important to SGCN.