Chapter 5
Desert Grassland and Shrubland Ecosystems

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INTRODUCTION

The productivity, stability, and health of the Middle Rio Grande Basin, arid and semiarid grassland and shrubland ecosystems depend upon complex interactions. These relationships occur between factors such as climate, domestic livestock, and wildlife use, and human activities such as urban development, agriculture, and recreation. These grassland/shrubland ecosystems are particularly sensitive to change because they depend highly upon water availability.

Southwestern rangelands experienced heavy livestock grazing and human activities over the past century, which substantially reduced total plant cover and density (Dortignac and Hickey 1963). The greatly reduced fuel loads resulting from livestock overgrazing may have altered the frequency of wildfires in nearby forested environments (Baisan and Swetnam 1995) and probably rangelands. The disruption of natural fire frequency has allowed fire intolerant species to increase, which adversely affects the sustainability of these ecosystems. Soil erosion from Southwestern desert grasslands and shrublands has contributed to nonpoint source pollution, which is reported to be the most serious threat to surface water quality in the Rio Grande Basin (Ellis et al. 1993). It is this alteration of surface water quantity and quality that is largely responsible for the increasing public concern about the health of our nation's rangelands (Joyce 1995).

GEOGRAPHIC DISTRIBUTION

Historical

The following summary of the historical geographic distribution of vegetation in New Mexico is taken from a review by Dick-Peddie (1993). The extensive grasslands and shrublands of North America developed in response to climate change and the uplifting of the western mountain ranges, including the Rocky, Cascade, and Sierra Nevada Mountains, which began in the early to mid-Tertiary period (65–26 million years ago). The vegetation of North America early in the Tertiary period has been grouped into three major geofloras. The Artco-Tertiary Geoflora occupied cool, moist, upper latitudes, the Neotropical-Tertiary Geoflora occupied the warm, moist, lower latitudes, and the Madro-Tertiary Geoflora occupied intermediate, drier regions. Rain shadows created by rising mountain ranges created new habitats for xeric-adapted plant species. The preadapted Madro-Tertiary Geoflora quickly expanded its range into this new habitat, while the Arcto- and Neotropical-Tertiary Geofloras were forced north and south, respectively. Interestingly, the major grass species of the present grasslands are actually xeric-adapted remnants of the Arcto- and Neotropical-Tertiary Geofloras. The Madro-Tertiary Geoflora today is represented primarily by desert scrub and pinyon pine.

Analysis of fossil pollen suggests that there were no extensive grasslands in New Mexico until approximately 12,000 years ago when coniferous woodland was replaced by grassland as the climate became warmer and drier. Although New Mexico's climate experienced several cooling and warming changes in the past several thousand years, it has remained fairly stable for the past 800–600 years.

Current

The Rio Grande Basin begins in southern Colorado and extends through New Mexico, between western

Texas and Chihuahua, Mexico, to the Gulf of Mexico. The basin itself is a major rift valley produced by a series of grabens (elongated depressions between parallel faults) that have subsided along the crests of the surrounding plateaus and mountains. The central and southern portion of the rift are included in the Basin and Range Section of the Chihuahuan Semi-Desert Province (Bailey et al. 1994). However, the central and northern portions of the rift, bounded by the Colorado Plateau and southern Rocky Mountains, are distinct morphotectonic basins (Baldridge et al. 1983). The Middle Rio Grande Basin (Cochiti Lake to Elephant Butte Reservoir) is bounded on the west by the San Juan Basin of the Colorado Plateau and on the east by the linear mountain chain including the Sandia, Manzano, and Los Pinos Mountains. This geographic area encompasses part of the Central Rio Grande Intermontane Ecosubregion (Bailey et al. 1994).

GEOLOGY/GEOMORPHOLOGY

The desert grassland and shrubland ecosystems within the Rio Grande Basin are largely established on Quaternary alluvium along streams and alluvial fan deposits near the mountain fronts. However, these vegetation assemblages are also commonly found on Miocene volcanic rocks and volcaniclastic deposits in the northern portions of the Rio Grande Basin and on Oligocene and older sedimentary rocks associated with the Great Basin grassland type along the margins of the Rio Grande Basin and with the Colorado Plateau to the west. Detailed discussions on the geomorphological distribution of the various alluvial deposits, volcanic parent materials, and sedimentary parent materials are available in Bulletin 137, New Mexico Bureau of Mines and Mineral Resources (1991), Baldridge et al. (1983), and Gile et al. (1981).

CLIMATE

Climate in Rio Grande Basin grassland ecosystems is one of extremes. Plant growth and production are predominantly controlled by soil water content which is highly variable within and between years, depending upon precipitation patterns. Grasslands, including those of the middle Rio Grande Basin, are not merely controlled by total annual precipitation, but by complex relationships such as the precipitation-evaporation ratio and the seasonality of precipitation in relation to the temperature regime and growing season (Risser et al. 1981).

Mean annual precipitation in the Middle Rio Grande Basin grassland and shrubland ecosystems ranges from a low of 200 mm to over 400 mm at the higher elevations to the north (Dick-Peddie et al. 1993). A large portion of this rainfall occurs as high intensity, short-lived thunderstorms. Snow is common during the winter months (December through March) but the contribution of these storms to the total annual precipitation is less than that of the summer thunderstorms.

The distribution and availability of water are the major factors determining the composition and structure of arid ecosystems, but plant growth and productivity in these ecosystems are greatly modified by soil parent material and topography. For example, Aguilar and Heil (1988) found that organic matter and associated C, N, and P in Plains-Mesa Grassland varied with microclimate, which was strongly correlated to landscape position and parent material. Organic matter in soils characterized along toposequences in sandstone, siltstone, and shale parent materials in southwestern North Dakota rangeland generally increased downslope. Greater quantities of organic matter on lower landscape segments were attributed to greater vegetation productivity due to higher effective precipitation and to accretion of soil organic matter from runon and organic matter-enriched sediment deposition.

SOILS

Detailed information on general soil characteristics for specific sites within the Basin can be obtained from soil surveys published by the USDA Soil Conservation Service's (USDA-SCS, now USDA-NRCS) National Cooperative Soil Survey and Forest Service (USDA-FS). Published soil surveys encompassing the Middle Rio Grande Basin include: Soil Survey of Santa Fe Area (Santa Fe County and Part of the Rio Arriba County) August 1975; Soil Survey of Sandoval County (in press); Soil Survey of Bernalillo County and Parts of Sandoval and Valencia Counties, June 1977; Soil Survey of Valencia County - Eastern Part, April 1975; Soil Survey of Socorro County Area, December 1988; Soil Survey of Sierra County Area, June 1984, General Ecosystem Survey USDA-FS and Terrestrial Ecosystem Survey of the Santa Fe National Forest.

Soils associated with the grassland and shrubland ecosystems of the Middle Rio Grande Basin are classified within the orders of Aridisols, Entisols, and

Mollisols. Suborders of the Aridisols common in the Basin include Argids, Calcids, Cambids, and Gypsids. These calcareous and alkaline soils are characterized by relatively low organic matter and have soluble secondary salts, including calcium carbonate and in some cases gypsum, at varying depths within the soil profile. The Argids are older soils generally found on the older and more stable landscapes and have well-developed secondary clay enriched subsurface horizons and in many cases have a petrocalcic (calcium carbonate and/or silica cemented) horizon at depth.

The Entisols, soils with little pedogenic development, are represented in the Basin by the suborders Orthents, Psamments, and Fluvents. Orthents are widely distributed on some of the more active landscapes including recently active alluvial fans and arroyos and in shallow sediments over slowly weatherable parent materials such as volcanic basalts and sedimentary bedrock. Psamments, high sand content soils, are common in eolian deposits such as active or stabilized dunes. Fluvents, characterized by stratification and irregular decreases in organic matter with depth, are common on floodplains along perennial stream channels and ephemeral drainages.

Mollisols, soils with much higher organic matter contents than Aridisols and Entisols, are less extensive in the Middle Rio Grande Basin, but do occur in the more moist environments of steppe and montane meadows at higher elevations of the Basin.

Perhaps the most important property of soils in any arid or semiarids ecosystem is organic matter (Stott and Martin 1989; Aronson et al. 1993). Soil organic matter content reflects the balance of surface litter and belowground root production inputs and loss through microbial decomposition. Although soil organic matter in Middle Rio Grande Basin grassland and shrubland soils is relatively low, ranging from about 3 percent to less than 1 percent, the importance of soil organic matter to site stability and productivity far outweighs that of other soil properties. Soil organic matter influences virtually all aspects of soil fertility and plays a key role in nutrient cycling, thus inhibiting the process of desertification by increasing soil aggregate stability and resistance to erosion (Tate 1987).

HYDROLOGY

The availability of clean water for residential, commercial, agricultural, and wildlife use is the most critical resource problem within the Middle Rio Grande Basin. Vegetation in the grasslands and shrublands of the Basin depends on surficial hydrologic processes, such as runoff (surface water lost from a site), runon (surface water deposited on a site), infiltration, and evapotranspiration. High intensity thunderstorms common during the summer and early fall months (July through September) often generate large volumes of runoff. With the exception of the Rio Grande and its major tributaries (including the Jemez River, the Chama River, and the Rio Puerco), perennial surface water is relatively scarce in the Middle Rio Grande Basin. Many ephemeral channels carry water only after localized, high intensity rainstorms. Runoff water generally carries large quantities of suspended solids. The Rio Puerco, in particular, has been included among the highest sediment yielding drainage areas in the United States. As suggested by the stream's Spanish name, implying "muddy river," high sediment loads are a natural characteristic of the Rio Puerco. The Rio Puerco Watershed has a deeply incised streambank and an exceptionally high rate of gully erosion and bank erosion and collapse contributing to the stream's high sediment load (Love 1986; Love and Young 1983; Wells et al. 1983; Wells et al. 1982).

Runoff and sediment yields from grasslands and shrublands can be highly variable in the Middle Rio Grande Basin, dependent upon plant community composition, ground cover, and specific soil properties (e.g., infiltration rates). Aguilar and Aldon (1991) reported that two distinct soil/vegetation assemblages a few hundred meters apart within the Rio Puerco Watershed Resource Area had differences in runoff rates of 6 to 8 times, with differences in sediment yield of 10 to 15 times. Sediment-laden runoff from degraded sites within the Middle Rio Grande Basin has had a significant impact on the water quality of the region's perennial streams and rivers NM Water Quality Control Commission 1995).

VEGETATION ASSEMBLAGES

For the purposes of this review we are using a broad classification of grassland and shrubland ecosystems in the Middle Rio Grande Valley. Our ecosystem designations combine a previous classification (Dick-Peddie 1993) of Chihuahuan Desert Scrub, and Plains-Mesa Sand Scrub into shrubland and Desert Grassland and Plains-Mesa Grassland into desert grassland (Fig. 1). Detailed discussions of veg-

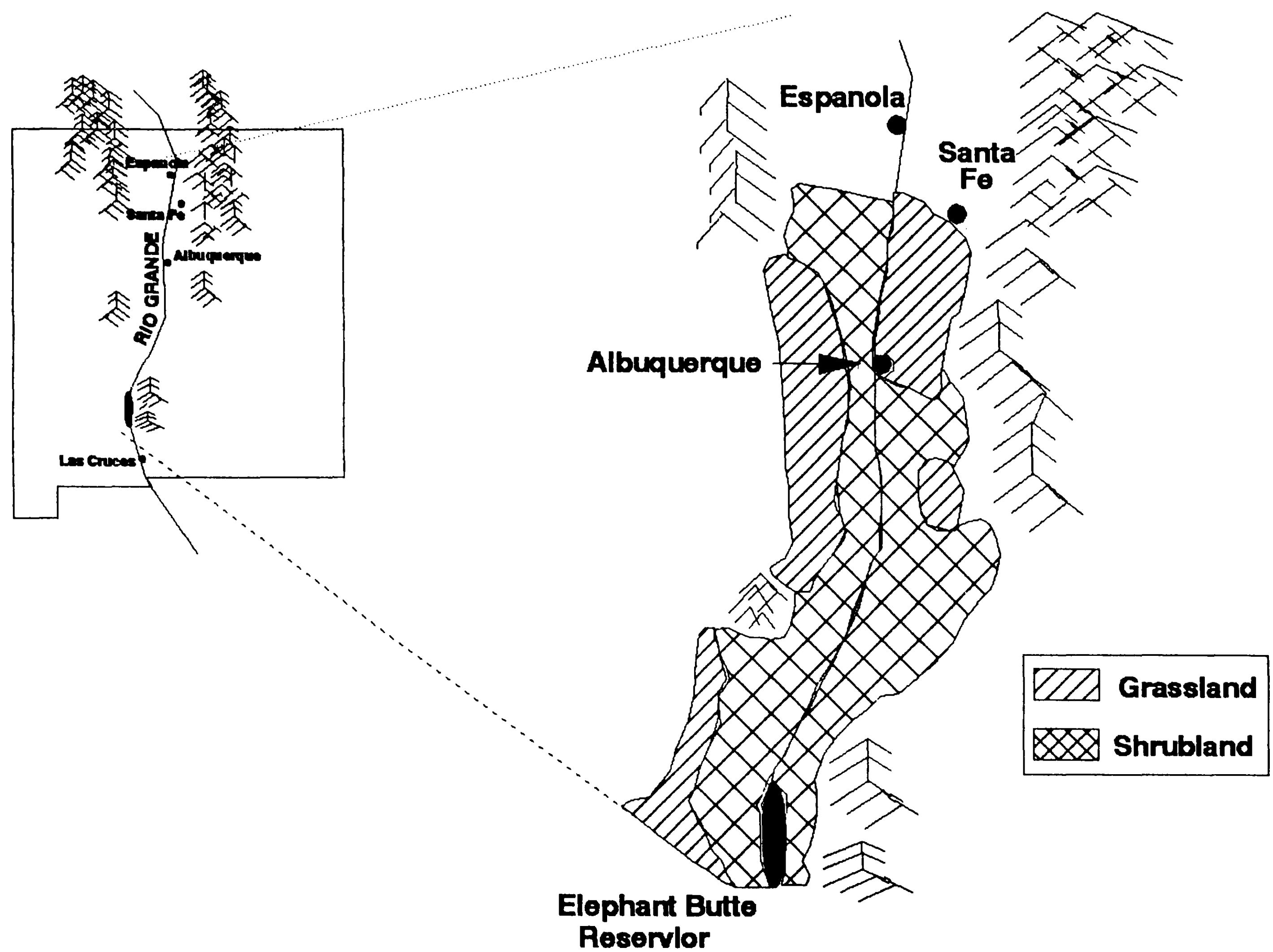

Figure 1.—Distribution of the major grassland and desertshrubland ecosystems in the Middle Rio Grande Valley, New Mexico.

etation types found in the Southwestern United States and New Mexico can be found in Brown (1982) and Dick-Peddie (1993), respectively.

Chihuahuan Desert Scrub is confined to alluvial terrace sites in the southern portion of the Middle Rio Grande Valley. The northernmost extent of this plant community is near Isleta Pueblo, Bernalillo County, NM. Chihuahuan Desert Scrub occupies regions that receive 200 to 300 mm of rainfall annually, most of which comes from highly variable summer thunderstorms (Brown 1982). The dominant indicator species in this northern region of the Chihuahuan Desert Scrub is creosotebush (*Larrea tridentata*).

Plains-Mesa Sand Scrub is a shrub dominated community that occupies deep, sandy soils throughout the basin. Dominant shrubs include sand sage (*Artemisia filifolia*), broom pea (*Dalea scoparia*), and honey mesquite (*Prosopis glandulosa*).

Chihuahuan Desert Scrub grades into Desert Grassland or Semidesert Grassland which occupies an elevational range of approximately 1,100 to 1,600 m (Brown 1982). Desert Grassland receives an average of 250 to 450 mm of rainfall annually, again mostly in summer and fall. Both Brown (1982) and Dick-Peddie (1993) describe Desert Grassland as a plant community between Chihuahuan Desert Scrub and Plains-Mesa Grassland, but with a distinct vegetation assemblage. Desert Grassland generally has a greater shrub component than Plains-Mesa Grassland. Dominant shrub species in this region include the small soapweed (*Yucca glauca*), soaptree yucca (*Yucca elata*), tree cholla (*Opuntia imbricata*), and broom snakeweed (*Gutierrezia sarothrae*), and the dominant grasses include black grama (*Bouteloua eriopoda*), galleta (*Hilaria jamesii*), three awn (*Aristida spp.*), burrograss (*Scleropogon brevifolius*), and sacaton/dropseed (*Sporobolus spp.*).

At higher elevations and to the north, Desert Grassland mixes with Plains-Mesa Grassland (Plains and Great Plains Grassland). The Plains-Mesa Grassland occupies an elevational range of approximately 1,200 to 2,300 m and receives an average of 300 to 450 mm of rainfall per year. Rainfall in the Plains-Mesa Grassland community is more evenly distributed throughout the year than in the other two vegetation types. The dominant shrub species in this region include Bigelow sagebrush (*Artemisia bigelovii*), winterfat (*Ceratoides lanata*), rabbitbrush (*Chysothamnus nauseosus*), and broom snakeweed (*Gutierrezia sarothrae*), while the grass species include blue grama (*Bouteloua gracilis*), sideoats grama (*B. curtipendula*), galleta (*Hilaria jamesii*), ring muhly (*Muhlenbergia torreyi*), indian ricegrass (*Oryzopsis hymenoides*), and sacaton/dropseed (*Sporobolus spp.*).

WILDLIFE

Many mammals, birds, reptiles, and amphibians utilize the grassland and shrubland habitat of the Middle Rio Grande Basin. Although the number and distribution of larger mammals (carnivores and hoofed mammals) are not great nor unique to the desert grassland/shrubland habitat, a rich community of small mammals (Table 1) unique to these habitats is supported (Grant et al. 1982). Due to the periodic but explosive production of seeds by arid-adapted plants in the Southwest, granivorous, pocket mice and kangaroo rats (family Heteromyidae) represent a large component of the small mammal fauna (Findley 1987). Other rodents utilizing seeds, grasses, and other vegetative, animal, or insect matter in grasslands and shrublands are antelope squirrels, spotted ground squirrel, pocket gophers, harvest mice, several species of *Peromyscus*, grasshopper mice, cotton rats, and woodrats. Current populations of black-tailed prairie dog are drastically lower than historic levels as a result of pest control measures of the past. Also common are the black-tailed jackrabbit and the desert cottontail.

In addition to foraging habitat, desert grasslands provide breeding or year-round habitat for many bird species (table 2) The geographical break of several bird species distributions and the northern end of year-round range all occur in the vicinity of the Middle Rio Grande Basin for several bird species. Reptiles and amphibians in grasslands and shrublands are represented by one species of salamander, two species of turtles, and several species of frogs, toads, lizards, and snakes (Table 3) (J. Stuart, [personal communication]). Of these species, the western box turtle, the lesser earless lizard, the desert-grassland whiptail lizard, the western hognose snake, and the western hooknose snake are all endemic species centered on Desert Grassland (as opposed to Plains-Mesa Grassland) ecosystems (Brown 1982).

CURRENT ISSUES IN GRASSLAND AND SHRUBLAND MANAGEMENT

Degradation and Desertification

Livestock production has been a major means of economic survival for the many cultures in the Middle Rio Grande Basin. Most authorities believe the Basin's grasslands have been greatly depleted and deteriorated because of livestock overgrazing over the past 100–150 years (Dortignac and Hickey 1963; Sheridan 1981; Grover and Musick 1990; Dick-Peddie 1993). Leopold (1951) documented that there had already been great local reductions in grass forage in the vicinity of Spanish communities within the Rio Grande Basin by the time the second wave of European immigrants moved into New Mexico from the eastern plains during the latter part of the 19th century. Dick-Peddie (1993) reported that New Mexico grassland must still have been very productive even after the turn of the century, considering the amount of livestock present in the state (over one million cattle and almost six million sheep). According to Dick-Peddie, these large numbers of livestock indicated "native forage potentials far in excess of those found today."

Although grassland desertification is often attributed to anthropogenic disturbance, the influence of short-term climatic fluctuation should not be overlooked. A review of rangeland vegetation changes by Branson (1985) reported that during the drought of 1932–1936, basal cover of vegetation in the Mixed Grass or Shortgrass Prairie (Plains-Mesa Grassland) decreased from around 80 percent to often less than 10 percent. Apparently, this kind of response to periodic drought in grasslands is not uncommon and Branson concluded that forage production displayed far greater variation in response to changes in an-

Table 1.—Mammals of grasslands/shrublands in the Middle Rio Grande Basin, NM.

Order	Common name	Scientific name
Artiodactyla	mule deer	*Odocoileus hemionus*
	pronghorn antelope	*Antilocapra americana*
Carnivora	coyote	*Canis latrans*
	kit fox	*Vulpes macrotis*
	long-tailed weasel	*Mustela frenata*
	badger	*Taxidea taxus*
	spotted skunk	*Spilogale putorius*
	striped skunk	*Mephitis mephitis*
	bobcat	*Lynx rufus*
Chiroptera	pallid bat	Antrozous pallidus
	California myotis	*Myotis californicus*
Insectivora	desert shrew	*Notiosorex crawfordi*
Lagomorpha	black-tailed jackrabbit	*Lepus californicus*
	desert cottontail	*Sylvilagus auduboni*
Rodentia	silky pocket mouse	*Perognathus flavus*
	Plains pocket mouse	*Perognathus flavescens*
	banner-tailed kangaroo rat	*Dipodomys spectabilis*
	Ord's kangaroo rat	*Dipodomys ordii*
	Merriam's kangaroo rat	*Dipodomys merriami*
	white-tailed antelope squirrel	*Ammospermophilus leucurus*
	Texas antelope squirrel	*Ammospermophilus interpres*
	spotted ground squirrel	*Spermophilus spilosoma*
	black-tailed prairie dog	*Cynomys ludovicianus*
	Gunnison's prairie dog	*Cynomys gunnisoni*
	Botta's pocket gopher	*Thomomys bottae*
	yellow-faced pocket gopher[a]	*Pappogeomys castanops*
	desert pocket gopher[a]	*Geomys arenarius*
	western harvest mouse	*Reithrodontomys megalotis*
	Plains harvest mouse	*Reithrodontomys montanus*
	white-footed mouse	*Peromyscus leucopus*
	deer mouse	*Peromyscus maniculatus*
	cactus mouse[a]	*Peromyscus eremicus*
	pinon mouse[a]	*Peromyscus truei*
	brush mouse[a]	*Peromyscus boylii*
	rock mouse[a]	*Peromyscus difficilis*
	northern grasshopper mouse	*Onychomys leucogaster*
	southern grasshopper mouse	*Onychomys arenicola*
	southern plains woodrat	*Neotoma micropus*
	white-throated woodrat	*Neotoma albigula*
	porcupine[a]	*Erethizon dorsatum*

[a]*Indicates occasional presence or presence at periphery of grasslands and shrublands.*

nual precipitation than to differences in livestock grazing intensities.

Most sources agree that a combination of long and short term climate change, historic overgrazing, and direct and indirect fire suppression were probably responsible for the degradation and/or desertification of many southwestern grasslands (Westoby et al. 1989; Grover and Musick 1990; Schlesinger et al. 1990; George et al. 1992; Tausch et al. 1993; Milton et al. 1994). The process of degradation and conversion of productive grassland to less productive shrubland, sometimes included as desertification, is especially common in arid and semiarid regions. In the United States alone, over 225 million acres are estimated to have experienced severe or very severe desertification (Sheridan 1981).

Grasslands are generally considered fire dependent ecosystems because they require periodic disturbance by fire in order to maintain the composition and function of grassland plant species (Desert Grassland is perhaps one exception). Stable grasslands consisted of a mosaic of vegetation and bare interspaces (George et al. 1992; Montana 1992). The dynamics of these stable grassland communities may have been similar to systems described by Watt (1947), where the spatial arrangement of vegetation and interspaces changed through time but the overall amount of space occupied by each component

Table 2.—Birds of grasslands/shrublands in the Middle Rio Grande Basin, New Mexico.

Family	Common name	Scientific name	Occurrence
Accipitridae	ferruginous hawk	*Buteo regalis*	spr/sum or year-round
	Swainson's hawk	*Buteo swainsoni*	spr/sum
	American kestrel	*Falco sparverius sparverius*	spr/sum or year-round
	prairie falcon	*Falco mexicanus*	spr/sum or year-round
Laniidae	loggerhead shrike	*Lanius ludovicianus*	year-round
Strigidae	burrowing owl	*Speotyto cunicularia hypugaea*	year-round
Cuculidae	roadrunner	*Geococcyx californianus*	year-round
Caprimulgidae	common nighthawk	*Chordeiles minor*	spr/sum
	common poor-will	*Phalaenophtilus nutallii*	spr/sum or year-round
Corvidae	common raven	*Corvus corax*	year-round
	Chihuahuan raven	*Corvus cryptoleucus*	spr/sum or year-round
	American crow	*Corvus brachyrhynchos*	year-round
Columbidae	mourning dove	*Zenaida macroura*	year-round
Phasianidae	scaled quail	*Callipepla squamata pallida*	year-round
Charadriidae	mountain plover	*Charadrius montanus*	spr/sum
Alaudidae	horned lark	*Eremophila alpestris*	year-round
Hirundinidae	barn swallow	*Hirundo rustica erythrogaster*	spr/sum
Remizidae	verdin	*Auriparus flaviceps ornatus*	year-round in south
Troglodytidae	cactus wren	*Campylorhynchus brunneicapillus couesi*	year-round in south
Mimidae	mockingbird	*Mimus polyglottos leucopterus*	spr/sum or year-round
Fringillidae	house finch	*Carpodacus mexicanus frontalis*	year-round
Tyrannidae	western kingbird	*Tyrannus verticalis*	spr/sum
	ash-throated flycatcher	*Myriarchus cinerascens cinerascens*	spr/sum
	Say's phoebe	*Sayornis saya*	spr/sum or year-round
Emberizidae	meadowlark	*Sturnella neglecta*	year-round
	brown-headed cowbird	*Molothrus ater*	year-round
	lark sparrow	*Chondestes grammacus strigatus*	spr/sum
	Cassin's sparrow	*Aimophila cassinii*	spr/sum or year-round
	lark bunting	*Calamospiza melanocorys*	spr/sum

remained the same. Soil erosion from these systems may have been minimal because of the connectivity of the vegetation and the relative stability of interspace soils, which were probably stabilized by desert pavements and/or cryptogamic (microphytic) crusts (West 1990).

Fire suppression in semiarid grasslands would eliminate the dominant stabilizing force in these fire dependent ecosystems and would allow ecological succession to proceed to shrubland at lower elevations or juniper savanna or Pinyon-Juniper (P-J) woodland at higher elevations (Fig. 2). Extensive livestock grazing exacerbates the situation by decreasing herbaceous plant cover which formerly carried the fire, and disturbing the structure and stability of surface soils, particularly interspace soils. Loose interspace soils can then be blown under the canopy of vegetation (phase I). It is this process of intrasite soil and nutrient redistribution that results in the formation of islands of fertility (Garcia-Moya and McKell 1970; Schlesinger et al. 1990). Often these processes result in the conversion of grassland to shrubland, dominated by non-palatable species, or to P-J Woodland. If this scenario truly results in a redistribution of resources as hypothesized by Schlesinger et al. (1990), and not a net loss of resources, then this process may be reversible.

Continued disturbance of grasslands, shrublands, or P-J Woodlands would result in the expansion and coalescence of bare interspaces. Soil erosion, particularly in areas with moderately steep to steep slopes, would increase because connected interspaces would serve as paths of least resistance to water flow (erosion corridors). Soil erosion via these corridors represents nutrient and water export and loss from the system. At this point (phase II) the system is losing the very constituents it most requires for stabilization and recovery. The ultimate fate of this ecosystem is now under the control of hydrologic and geomorphic processes rather than biological processes. Without intervention, the system can become locked into a cycle of increasing degradation that may eventually stabilize at a state of drastically reduced site productivity (Naveh 1988; El-Tayeb and Skujins 1989; Klein 1989).

Table 3.—Herpetofauna of grasslands/shrublands in the Middle Rio Grande Basin, New Mexico.

Order	Common name	Scientific name
Caudata (salamanders)	tiger salamander	*Ambystoma tigrinum*
Salientia (frogs/toads)	Plains spadefoot toad	*Scaphiopus bombifrons*
	Couch's spadefoot toad	*Scaphiopus couchi*
	New Mexico spadefoot toad	*Scaphiopus multiplicatus*
	Great Plains toad	*Bufo cognatus*
	Plains leopard frog	*Rana blairi*
	bullfrog	*Rana catesbeiana*
Testudines (turtles)	yellow mud turtle	*Kinosternon flavescens*
	western box turtle	*Terrapene ornata*
Squamata- Suborder Lacertilia (lizards)	greater earless lizard	*Cophosaurus texanus*
	collared lizard	*Crotaphytus collaris*
	leopard lizard	*Gambelia wislizenii*
	lesser earless lizard	*Holbrookia maculata*
	Texas horned lizard	*Phrynosoma cornutum*
	round-tailed horned lizard	*Phrynosoma modestum*
	desert spiny lizard	*Sceloporus magister*
	eastern fence lizard	*Sceloporus undulatus*
	side-blotched lizard	*Uta stansburiana*
	Chihuahua whiptail lizard	*Cnemidophorus exsanguis*
	little striped whiptail lizard	*Cnemidophorus inornatus*
	New Mexico whiptail lizard	*Cnemidophorus neomexicanus*
	western whiptail lizard	*Cnemidophorus tigris*
	desert-grassland whiptail lizard	*Cnemidophorus uniparens*
	Plateau striped whiptail lizard	*Cnemidophorus velox*
	Great Plains skink	*Eumeces obsoletus*
Squamata- Suborder Serpentes (snakes)	Texas blind snake	*Leptotyphlops dulcis*
	glossy snake	*Arizona elegans*
	ringneck snake	*Diadophis punctatu*
	western hooknose snake	*Gyalopion canum*
	western hognose snake	*Heterodon nasicus*
	night snake	*Hypsiglena torquata*
	common kingsnake	*Lampropeltis getulus*
	coachwhip	*Masticophis flagellum*
	striped whipsnake	*Masticophis taeniatus*
	gopher snake or bullsnake	*Pituophis melanoleucus*
	long-nosed snake	*Rhinocheilus lecontei*
	patch-nosed snake	*Salvadora deserticola*
	ground snake	*Sonor semiannulata*
	Plains black-headed snake	*Tantilla nigriceps*
	checkered garter snake	*Thamnophis marcianus*
	western diamondback rattlesnake	*Crotalus atrox*
	western or prairie rattlesnake	*Crotalus viridis*
	Massasauga	*Sistrurus catenatus*

Threatened, Endangered, and Candidate Species

Recent changes in Middle Rio Grande Basin vegetation are also attributed to direct human activities such as farming, off-road vehicle recreation, road construction, and urbanization. Not only do these land-use practices affect grasslands and shrublands directly, but these practices also exert indirect effects, through fragmentation and loss of contiguous, larger expanses of habitat.

Protection of biological diversity (flora, fauna) is necessary to maintain ecosystem integrity (Grumbine 1994). Simberloff (1993) stated that fragmentation of habitat is the major global environmental change occurring today and the one most likely to sacrifice the sustainability of biodiversity and ecological processes in the near future. Within the United States, loss of habitat due to human land use was the most common underlying factor in the endangerment of 667 threatened and endangered plant and animal species. Seven of the 10 regions of high species en-

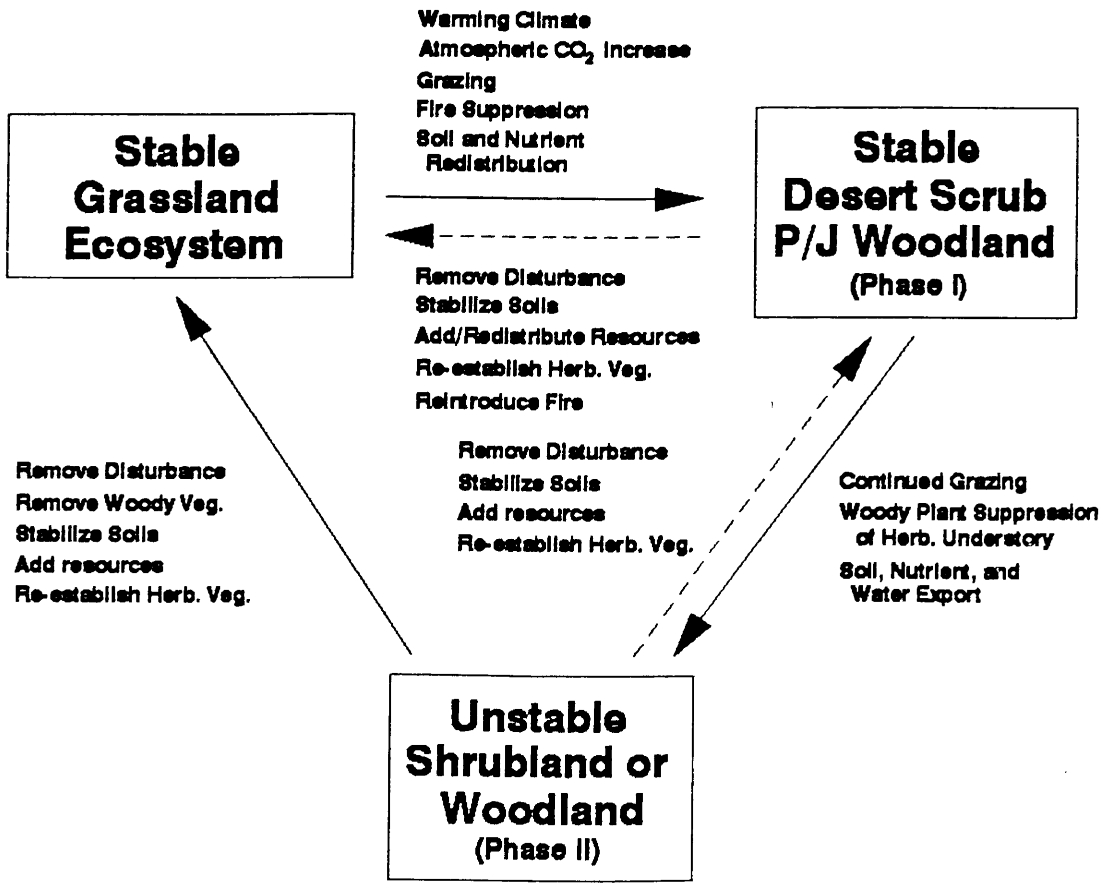

Figure 2.—A conceptual model of desertification/degradation in a semiarid grassland ecosystem. Periodic disturbance by fire is necessary to maintain a grass-dominated ground cover. Climate warming and increased atmospheric CO_2 levels may have promoted the growth of woody perennial plants but these processes are beyond the control of the local land manager. Certain land management practices can initiate desertification.

dangerment in the United States were located in the Southwest. In these Southwestern regions, endangerments were predominantly associated with rangeland ecosystems and regions of rapid human population growth and development (Flather and Joyce 1994).

Current federally listed or candidate animal species that may utilize Middle Rio Grande Basin grasslands include: Arizona black-tailed prairie dog (*Cynomys ludovicianus arizonensis*), ferruginous hawk, loggerhead shrike, mountain plover, and the Texas horned lizard (50 CFR 17.11 & 17.12). Although the number of federally listed or candidate animal species utilizing Plains-Mesa and Desert Grassland habitat is not as great as those using other habitats (such as riparian), the Middle Rio Grande Basin, with its growing population and current land use practices, certainly has the characteristics of a high endangerment region and thus, the potential for future problems with other sensitive grassland and shrubland species.

Grazing and Fire Effects on Wildlife

The major human impacts in these habitats, grazing and fire suppression, have both direct and indirect effects on wildlife populations. Direct impacts include competition and physical disturbance of habitat. Cattle compete with wildlife for vegetation biomass that would typically be shared between insects and other herbivorous animals. Thus, energy and water in vegetation eaten by cattle ultimately leave the grassland system instead of supporting a network of wildlife species along the food chain. Cattle also may physically disturb ground-nesting birds and cause degradation of arroyo banks in which small rodents may burrow and nest.

Changes in vegetation composition and structure caused by soil erosion and loss of plant cover are the means by which grazing and fire suppression may cause indirect, yet severe, impacts on wildlife. These changes affect two main requirements for wildlife: food and cover. When grasslands convert to alternative habitats, plant species composition, food quality, and food quantity are altered. Diet requirements for many species may no longer be met. More time may be spent searching out appropriate foods in sufficient quantities, thus altering time and energy budgets, water balance, and eventually the survival and success of the individual and the population.

The loss of ground cover associated with the conversion of grassland to shrubland or P-J Woodland reduces protection of ground-nesting and foraging wildlife from predators and the elements. Scrubland encroachment and formation of islands of woody vegetation due to fire suppression resulted in increased predation of ground-nesting birds in prairie habitat (Burger et al. 1994).

Support for the hypothesis that small mammal community composition in grasslands is primarily determined by vegetation structure was provided by a study of small mammals and grazing-induced changes in vegetation cover (Grant et al. 1982). Lizard abundance and species diversity decreased in heavily grazed desert grasslands, most likely due to the changes in vegetation structure (loss of low-height vegetation) (Jones 1981). Populations of the Plains-Mesa Grassland-inhabiting little striped whiptail lizard may be declining due to encroachment of P-J Woodland and the associated plateau striped whiptail lizard at higher elevations and with the encroachment of Desert Grassland/Chihuahuan Desert Scrub and the associated New Mexico and desert-grassland whiptail lizards at lower elevations (Behler and King 1988; (J. Stuart, personal communication, National Biological Survey, 1994). The loss of habitat by one species is the gain of habitat to another. Thus, studies have not always found negative impacts on wildlife from grazing. Mentioned previously, the conversion of Plains-Mesa Grassland to alternate habitat types allows three species other than the little striped whiptail lizard to utilize the habitat. For songbirds, grazing in Plains-Mesa Grassland had a positive influence on horned lark and lark sparrows, but a negative influence on Cassin's sparrows and western meadowlarks (Saab et al. 1995). Degraded grasslands with many open spaces may not provide suitable habitat for small rodents that prefer dense, grassy cover such as silky pocket mice, harvest mice, and cotton rats (Hall and Willig 1994; Findley 1987). If maintenance of grassland ecosystem integrity is the objective, then wildlife species associated with grasslands must be protected by maintaining current grassland habitat, restoring degraded grassland habitats, and preventing the encroachment of woodland and shrubland.

RESEARCH NEEDS

The ultimate application of research results is to guide the development and implementation of management objectives. The current trend in management within the USDA-FS and many other Federal and State land management agencies is a holistic approach termed "ecosystem management." The USDA-FS Rocky Mountain Forest and Range Experiment Station has published a document that outlines the guiding principles of Forest Service ecosystem management (Kaufmann et al. 1994). In brief, the principles are (1) ecosystem sustainability for human and nonhuman use, (2) conservation of abiotic and biotic components of ecosystems, (3) conservation of natural ecosystem processes, and (4) protection of ecosystems from adverse human impact. Research that addresses all aspects of ecosystem management in the grassland and shrubland ecosystems of the Middle Rio Grande Basin is needed. Information is needed on the impacts of different land use practices on the abiotic and biotic ecosystem components (soils, vegetation, wildlife, livestock, and humans) and effects on ecosystem processes such as surface and ground water hydrology, soil erosion and sediment yields, nutrient cycling, and plant community productivity and stability. The following discussion describes current and future research objectives of the Rocky Mountain Forest and Range Experiment Station for the grasslands and shrublands of the Middle Rio Grande Basin.

Restoration of a Pinyon-Juniper/Grassland Ecosystem in Central New Mexico

Pinyon-juniper woodlands occupy about seven million acres in the Southwest, of which approximately 3.5 million acres are considered to be in unsatisfactory soil and watershed condition (USDA Forest Service 1993). The encroachment of P-J Woodland into grasslands, coupled with the loss of herbaceous understory vegetation, can decrease productivity, increase soil erosion, and decrease watershed condition in many grassland ecosystems (Fig. 2). At some sites, converting P-J woodland to P-J grassland Savanna with a productive herbaceous understory would improve the watershed condition while retaining the older and larger trees. Researchers with the USDA-FS Rocky Mountain Station, the National Park Service, and the National Biological Survey have initiated a project within Bandelier National Monument and the Santa Fe National Forest that is designed to test the effects of different management techniques on restoration of a P-J Grassland Savanna. Previous research on the Monument suggests that tree thinning and/or seeding with native herbaceous vegetation may increase herbaceous ground cover and decrease soil erosion (Chong 1994). Management officials with the Santa Fe National Forest are supportive of this research because it represents a practical approach to the solution of ecosystem degradation. One of the major concerns for Bandelier National Monument is that soil erosion is destroying valuable Anasazi archeological sites. The specific objectives of the proposed research are to:

- experimentally test restoration techniques designed to stop ecosystem degradation (soil erosion);
- accelerate the recovery of herbaceous understory biomass; and
- protect threatened historical sites within threatened grassland ecosystems.

Response of Southern Plains-Mesa Grassland to Fire

The importance of frequent fire to the stability of grasslands was previously discussed. Unfortunately, some of our statements concerning the role of fire in grasslands of the Middle Rio Grande Valley are necessarily conjectural because there have been very few grassland fire studies conducted in this region. We are initiating a project that would evaluate the short- and long-term response of grassland and shrubland ecosystems to prescribed fire.

The Rocky Mountain Station is collaborating with researchers from the University of New Mexico, Department of Biology, as well as with management officials with the City of Albuquerque Open Space Division, the Cibola National Forest, and the National Park Service. Two sites have been chosen for the proposed fire study. The Bernalillo Watershed site is in the western foothills of the Sandia Mountains on the Cibola National Forest and adjacent to the Bernalillo Watershed Research Natural Area. The vegetation at the Bernalillo Watershed is a blue grama/galleta grassland which contains a high proportion of broom snakeweed even though the area has received only intermittent grazing since the mid 1950s. The second site is west of Albuquerque on property owned by Albuquerque's Open Space Division. This area has been free from livestock grazing for at least 20 years. The vegetation at this site is dominated by Indian ricegrass, galleta, and dropseed with scattered broom snakeweed, fourwing saltbush, and winterfat (*Ceratoides lanata*) shrubs. The importance of fire in this grassland can be observed by comparing undisturbed areas with areas recently burned by wildfires. The undisturbed vegetation contains a substantial shrub component and plant mortality appears to be high, while within the adjacent area burned by wildfire, shrubs are less abundant and individual plants appear to be much more healthy and robust. The specific objectives of this research project are to:

- experimentally test the effects of prescribed fire on soils and vegetation in a semiarid grassland ecosystem; and
- experimentally test the effects of prescribed fire on the surface hydrology of a semiarid grassland ecosystem.

Recovery From Livestock Grazing

As discussed earlier, one of the most significant changes to grassland ecosystems resulting from heavy livestock grazing has been a decrease in vegetation cover and a depletion in soil organic matter. Removal of livestock grazing pressure may ultimately increase vegetation cover and plant litter additions, which in turn would slowly replenish diminished soil organic matter. However, this "passive approach" to rangeland restoration would be slow and the recovery may take decades. Additional research is needed to determine the rate of vegetation and soil fertility recovery in the absence of livestock grazing. Is recovery going to occur without additional manipulations aside from livestock exclusion?

Restoration With Soil Amendments

Research in Middle Rio Grande Basin grasslands and shrublands is needed to support ongoing research at the Rocky Mountain Forest and Range Experiment Station which has shown that degraded semiarid rangeland sites respond favorably to surface applications of organic amendments such as municipal sewage sludge biosolids. Responses include significant increases in soil fertility accompanied by increased biomass production and ground cover (Fresquez et al. 1990a & b; Fresquez et al. 1991; Loftin and Aguilar 1995; Loftin et al. 1995). More recent research has shown that organic amendments on degraded rangeland significantly increase rainfall infiltration, thereby reducing runoff and sediment yields (Aguilar et al. 1994).

Additional information is needed on the effects and feasibility of active restoration practices, such as increasing soil fertility and site productivity using soil amendments with different types of soils and degrees of ecosystem degradation.

Research Needs for Wildlife

As discussed earlier, the Middle Rio Grande Basin has the characteristics of a high endangerment region for wildlife species because of its rapidly growing human population. The following is a list of important research issues to be addressed for the region:

- Assess the detrimental effects of grassland habitat fragmentation on vertebrate species, composition and abundance.
- Identify species sensitive to loss of continuous grassland habitat and encroachment of desert scrub or pinyon-juniper habitat (i.e., little striped whiptail lizard).
- Determine critical components and minimum habitat requirements (food, cover, etc.) for sensitive and potentially sensitive species.
- Investigate differences in plant productivity and wildlife composition and abundance (mammals, birds, reptile/amphibians, arthropods) between grazed and ungrazed, or burned and unburned grasslands. Research is needed to determine if alternate grazing practices may retard, halt, or reverse the process of desertification and the associated changes in wildlife composition. Also the effects of prescribed burns at different times of the year and different fire intervals must be investigated.
- Compare the quality, quantity, and use versus availability of different plant foods by wildlife in degraded and nondegraded grasslands. Does grazing increase production of secondary plant chemical defenses by plants or does grazing and fire suppression cause increases in the prevalence of plants containing defensive plant chemicals or armed with physical anti-herbivore defenses?
- Investigate the interactions among species assemblages at interfaces between grasslands and pinyon-juniper or desert scrub habitat (i.e., nest predation of grassland nesting birds by cowbirds, predation by forest carnivores on grassland species).

SUMMARY

Human populations and development in the Middle Rio Grande Basin will increase and continue to impact the health and stability of grassland and shrubland ecosystems. Increasing demands for the region's already limited water supplies will undoubtedly bring about greater pubic awareness of the importance of ecosystem health for sustaining water quality and quantities.

Maintaining or improving the existing grassland and shrubland ecosystems in the Middle Rio Grande Basin will require a better understanding of their current state and their future directional shift upon the application of various management practices. Some of the more important management concerns for the basin will undoubtedly include the restoration of those highly degraded areas that are currently characterized by extremely high erosion and sediment problems. However, we also need to gain a better understanding on how these ecosystems should function and what degree of restoration they require. Other priority research should be directed towards increasing our knowledge of the relationships between wildlife species within these grassland and shrubland ecosystems and gaining a comprehensive understanding of the effects of development and land use on all wildlife species. Current and anticipated future land use practices such as livestock grazing, protected wildlife habitat, (i.e., refuges), and urban development must be re-evaluated with a broader focus on the effects of these practices on the stability and future health of the grassland and shrubland ecosystems of the Middle Rio Grande Basin.

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