FIRE AS A LANDSCAPE RESTORATION AND MANAGEMENT TOOL IN THE MALPAI BORDERLANDS

Charles G. Curtin
Arid Lands Project, Box 29, Animas, NM 88020

ABSTRACT

In the U.S.–Mexico borderlands, fire research and restoration have been the cornerstone of a community-based conservation effort entitled the Malpai Borderlands Group (MBG), which is a consortium of ranchers, conservationists, and scientists. The MBG efforts are unique in emphasizing science to guide policy and conservation actions and the interaction of science with community-based conservation. The MBG and its collaborators have undertaken extensive monitoring of fire and grazing effects with >200 monitoring plots spread across the planning area—nearly 1 million acres (416,000 ha). In addition, collaborators (the Arid Lands Project and USDA Forest Service Rocky Mountain Research Station) have implemented two large-scale, experimental studies of the effects of fire in savanna and grassland ecosystems. In contrast to many previous studies, this research indicated that desert grasslands composed primarily of black grama (*Bouteloua eriopoda*) grasses were not damaged by fire, but that the effects of fire were largely determined by rainfall and soil moisture preceding and following fire events. In addition, fire had minimal impacts on rare and endangered species and is essential for sustaining the composition and function of this landscape and the human and biological systems it supports. Perhaps more important than the initial results of this research program is the process that was undertaken. The Malpai Borderlands research and restoration program demonstrates that an understanding of species response to fire is essential to implementing landscape-level fire reintroduction programs and that private-sector research and conservation programs that integrate science with conservation can attain a scale and extent of research on fire and ecosystem restoration perhaps unobtainable through conventional approaches to science and conservation.

keywords: arid grassland, Arizona, climate change, community-based conservation, ecosystem management, fire, Malpai Borderlands, New Mexico, ranching, rangeland, restoration ecology.

Citation: Curtin, C.G. 2003. Fire as a landscape restoration and maintenance tool in the Malpai Borderlands. Pages 79–87 *in* K.E.M. Galley, R.C. Klinger, and N.G. Sugihara (eds.). Proceedings of Fire Conference 2000: The First National Congress on Fire Ecology, Prevention, and Management. Miscellaneous Publication No. 13, Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

The Malpai Borderlands Group (MBG) is a grassroots, community-based organization that has implemented an ecosystem management program on a million acres (416,000 ha) of unfragmented landscape in southeastern Arizona and southwestern New Mexico (Curtin 2002). The MBG's efforts began in 1990 when several local ranchers met at the Malpai Ranch in the San Bernardino Valley near Douglas, Arizona. The ranch, and hence the name of the group, was derived from the volcanic Malpais rock common in the area. The ranchers met to discuss the future of ranching in the West and the decline of local grasslands and savannas. Changes in vegetation composition with increases in shrubs and declines in grasses were due to many reasons including historically heavy grazing, fire suppression, and climatic shifts (Hastings and Turner 1965, Bahre 1991, Curtin and Brown 2001), but a crucial element in restoring the landscape was one factor: fire (McDonald 1995, 1996).

This small group of ranchers and environmentalists met for 2 years to discuss how to preserve the open landscape. The group decided that what was needed was a landscape conservation program based on good science, a strong conservation ethic, that it should be economically feasible, and be led by the private sector with federal and state agencies as partners. Two subsequent events led to the formal formation of the MBG. The first was a small fire near the Malpai Ranch. The ranching community believed strongly that this fire should not be put out because it was helping to restore degraded grassland. However, the fire was suppressed by the authorized land management agency over the objection of the landowner whose land intermingled with public land managed by that agency. The second was the purchase of the 502-square mile (133,867 ha) Gray Ranch by the Animas Foundation from The Nature Conservancy (TNC) in the early 1990s. The Animas Foundation's commitment to protecting open space and the use of fire as a management tool was crucial in galvanizing the MBG's efforts. The Animas Foundation provided some seed money to help start the MBG operations and through its interest in the Gray Ranch, TNC became interested in the MBG's efforts and has, at the request of the ranching community, assigned some of its senior personnel to work with the MBG. These events lead to the formal establishment of the MBG as a 501(c)(3) organization in 1994 (McDonald 1995, 1996). A formal research program was begun in 1994 when the Forest Service Rocky Mountain Research Station (RMRS) was awarded one of 19 national ecosystem management grants and the Southwest Borderlands Ecosystem Research Project was initiated. In 1997 the Arid Lands Project (ALP) was formed to develop and sustain large-scale landscape studies. The

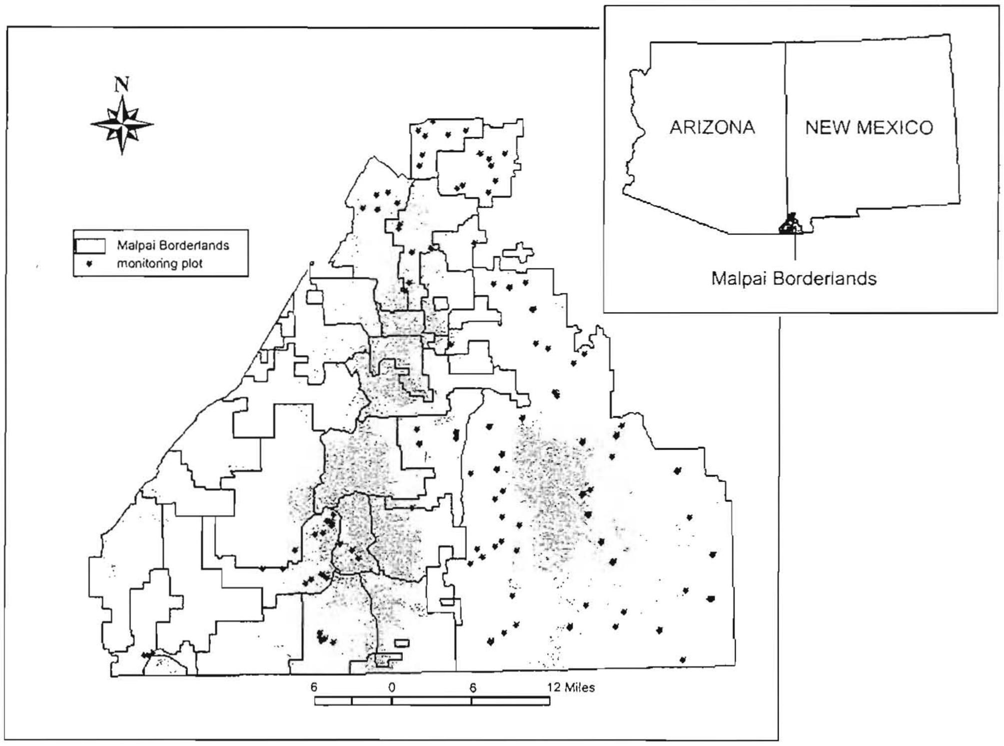

Fig. 1. Malpai Borderlands Planning Area, Arizona and New Mexico, showing the location of monitoring plots. Figure reprinted by permission of the Malpai Borderlands Group.

ALP and RMRS collaborate to support and coordinate much of the research and monitoring in the Malpai Borderlands (Curtin 2002). Here I review the experimental design and initial results of the fire effects monitoring and fire ecology experimental research program in the Malpai Borderlands.

STUDY AREA

The Malpai Borderlands are an 880,000-acre (356,131-ha) landscape in the Arizona–New Mexico borderlands. Including several hundred thousand acres (approximately 125,000 ha) of lands held by collaborators in Mexico, the total ecosystem cooperatively managed contains >1 million acres (416,000 ha) (Figure 1). The formal planning area extends from Douglas, Arizona, north along highway 80 through Rodeo, New Mexico, to Animas, New Mexico, and south along the east boundary of the Gray Ranch to Antelope Wells, New Mexico, and west along the Mexican border back to Douglas. The area encompasses the San Bernardino, San Simon, Animas, and Playas valleys, and the Animas, Peloncillo, and San Louis mountains. The elevation of the area ranges from 4,500 feet (1,500 m) with lowland habitats characterized by tobosa grassland (*Hilaria mutica*) or desert shrubs, up to 8,500 feet (2,615 m) in the Animas Mountains with ponderosa pine (*Pinus ponderosa* var. *arizonica*) and Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) plant associations. The area contains numerous rare and endangered species, including the Chiricahua leopard frog (*Rana chiricahuensis*), northern aplomado falcon (*Falco femoralis septentrionalis*), and the black-tailed prairie dog (*Cynomys ludovicianus*). The area is predominantly cattle ranching country with fewer than 100 families living in the area. Ownership includes 53% private land and 47% public land made up of state trust land in New Mexico and Arizona or public lands managed by the Bureau of Land Management (BLM) or the USDA Forest Service (McDonald 1996).

METHODS

Fire Management

Combined efforts of the MBG and the Coronado National Forest have been leading to the development of a Programmatic Fire Plan to allow natural fires and to facilitate the ignition of controlled burns. Fire planning is currently underway for the entire Malpai Borderlands area with a number of cooperating agencies. This planning has included a number of workshops in which maximum thresholds of take of endangered species were set, and research and monitoring protocols established, to determine potential impacts to species of concern. Starting in 1995, a fire management map was developed, which outlined the management status of cooperating landowners in the borderlands and specified what type of fire management should occur within different land management areas. In this map, the fire management stipulations are adjusted each year in response to weather and management constraints facing landowners to allow proactive management of wildfire. The New Mexico side of the planning area is included in the Bootheel Fire Management Plan, approved in 1997 by the New Mexico State Forestry Department and the Las Cruces District of BLM (Allen 1999). The Natural Resources Conservation Service and the Arizona State Land Department are conducting planning for the San Bernardino Valley in Arizona. The bulk of prescribed fire in the Malpai Borderlands conducted by federal agencies occurs in the Coronado National Forest in the Peloncillo Mountain Unit and is coordinated through the Peloncillo Programmatic Plan (Allen 1999). On the Mexican side of the border, lack of resources and the remoteness of the landscape result in a primarily natural fire regime despite frequent cattle grazing (Swetnam et al. 2001). Lightning strikes, anthropogenic fires near Route 2 in Mexico, and fires from farming and ranching activities cause frequent burns.

Since the formation of the MBG, >300,000 acres (125,000 ha) of natural and prescribed fires have occurred in the borderlands. Most of these burns still occur through natural ignitions on the Gray Ranch where >200,000 acres (83,333 ha) have burned since 1990. On the Gray Ranch, prescribed wildfires are coordinated through a number of fire management units which, like the regional map for the entire planning area, specify the management status and fire prescription for the different burn units each year. The largest prescribed fire to date in the U.S., the 47,000-acre (19,583-ha) Baker Burn II, was completed in June 2003.

Vegetation Monitoring

Over 200 vegetation monitoring plots have been established in the borderlands since 1993 (Figure 1). These plots employ the same standardized protocol in which frequency and point cover sampling were conducted within permanently marked plots. The plots were intended to detect grazing effects and thus were predominantly established on relatively level, grassy ground at approximately ½ mile (1 km) from water. The plots are primarily composed of 80 × 30-m study areas. At each plot, fifteen 30-m transects were placed perpendicular to the 80-m baseline, with 40-cm^2 sampling frames placed at 2-m intervals. The plant species rooted within the frame were recorded, regardless of the number of individuals of a given species. The result of this sampling was a measure of species frequency expressed as the percentage of the total number of frames (225 in most plots) in which a species was present. Canopy cover was documented by lowering a pin straight down at each corner of the sampling frame and recording everything the pin contacted. The results of this sampling were expressed as a percentage of the total number of points (900 in most plots) that landed on the live tissue of a particular species, litter, or on bare ground (Sundt 1999*a*). In addition, each monitoring plot is photographed periodically.

Fire Effects

Fire effects on vegetation have been regularly monitored since 1994. In 1994, 80,729 (3,267 ha) acres burned on the Gray Ranch. Of the >100 monitoring plots established in 1993, 15 burned in the April and June fires. The 15 burned plots, along with 2 unburned control plots, were resampled in the late summer and fall of 1994 and every year thereafter until 1998 (Sundt 1996, 1999*a*). In upland savanna and forest habitats in the Peloncillo Mountains in 1994, lightning caused two fires north of the Baker drainage. Land management agency policy at the time required suppression of all fires, but allowed for judgment in the selection of a cost-effective strategy for suppression. All fires in the Peloncillos were assigned low priority for suppression and a confine–contain strategy was adopted. The Sycamore Fire burned primarily on BLM, state, and Coronado National Forest land and covered about 24,000 acres (9,713 ha). The Peloncillo Fire burned about 200 acres (81 ha) of Coronado National Forest land (Allen 1995). Following the Sycamore Fire, the local rancher and botanists established >10 photo points. During 1997, botanists established two monitoring plots adjacent to the photo points to evaluate post-fire vegetation changes (Sundt 1999*b*).

During June 1995, following 8 months of planning, the Baker Canyon prescribed burn was conducted following a 4-season cessation from grazing. The fire burned the majority of a 6,000-acre (2,430-ha) target area primarily on Coronado National Forest lands. In a research project independent from the overall borderlands monitoring program, birds and vegetation were studied just prior to the burn and for 2 years afterward at 32 sampling stations on 4 linear transects with a total length of 10 km (Scott 1999). In addition to the vegetation and bird studies, a pilot study was conducted to obtain baseline information on how prescribed burning may effect the nectar and pollen production and the reproductive success of Palmer agave (*Agave palmeri*), which is the primary food source of the federally listed lesser long-nosed bat (*Leptonycteris curasoae*). The study also examined how fire may impact the use of agaves by bats. The nectar and pollen studies were conducted after the fire in August 1995 during the peak flowering period and when the migratory lesser long-nosed bats are usually present in the borderlands. Two sites within ¼ mile (0.3 km) of a roost within the primary burn area were selected for study to determine if fire negatively impacted the bats. The 24-hour nectar accumulation, nectar sugar percentage, and pollen production were measured in burned and unburned plots at each site. To evaluate fire effects on the reproductive output of agaves, fruit set of plants was determined in burned and unburned plots on both sites. To estimate agave use by bats and to estimate foraging behavior in burned and unburned areas, observations of bat visitation were made using night vision goggles and videotaping (Slauson et al. 1999).

In the spring of 1996, 16 photo stations were established to monitor the effects of the Maverick prescribed burn planned in the Peloncillo Mountains on Coronado National Forest lands. In November 1996, vegetation monitoring plots were established adjacent to six of the stations. In June 1997, following 2 years of planning, the Maverick prescribed burn was conducted following 2 growing seasons of rest from grazing. The proposed treatment area contained approximately 12,500 acres, and about 58% (7,200 acres [2,914 ha]) of the area burned. Because only 1 of the 6 plots burned in the fire, 10 additional sampling plots were established in 1997, and 3 years of post-fire sampling occurred in the fall of 1997, 1998, and 1999 (Sundt 1999*b*). Using radiotelemetry, herpetologists evaluated the effects of the Maverick prescribed burn on the mortality and behavior of three species of montane rattlesnakes (*Crotalus molossus* [n = 1], *C. lepidus* [n = 5], and *C. willardii obscurus* [n = 3]) (Holycross et al. 1999). Of particular concern were the effects of fire on the federally threatened New Mexico ridgenosed rattlesnake (*C. w. obscurus*) or its habitat. Prior to the study, 11 *C. w. obscurus* had been documented in the Peloncillo Mountains, 8 within the primary fire perimeter and 3 within the secondary fire perimeter. Radiotelemetry was conducted between 5 May and 30 July 1997 within the primary fire boundary at locations about 3 km apart. Following surgical implantation of radiotransmitters, snakes were released at point of capture and located every day for a total of 483 observations. Locations of the snakes were recorded with a Global Positioning System receiver. Each snake was characterized as being subterranean (deep within a refuge), in a cavity or crevice (near surface, <50% body exposed), or above ground with >50% of body exposed. Observations were divided into prior to the fire, post-fire until the onset of the monsoon, and from the onset of the monsoon to the end of the study (Holycross et al. 1999, Smith et al. 2001).

Fire and Grazing

In 1998 the Arid Lands Project initiated an experimental study of the effects of fire, herbivory, and climate on the McKinney Flats pasture on the Gray Ranch. The study site at 5,200 to 5,400 feet (1,630 m) includes four pastures, each approximately 2,200 acres (917 ha) in area, and including within them a 0.62-mile^2 (1-km^2) research area. The research area is grazed with a four-pasture rest–rotation system in which three pastures are grazed each year and the fourth is rested. This allowed local progressive grazing practices to be mimicked while four replicated treatment areas were created, and allowed each rested pasture to build up the necessary fine fuels to effectively carry a fire. Within each research area are four treatments: fire and livestock grazing, fire and no livestock grazing, no fire and livestock grazing, and no fire and no grazing (Figure 2). Within each research area, the distribution and abundance of lizards (3× per year), small rodents (3× per year), and vegetation (1× per year) are sampled within the study plots. These organisms were selected to represent different response variables to the fire and grazing treatments, and each represents a fundamental consumer group or, in the case of vegetation, the primary biomass within the system. In addition, there are smaller 36-m^2 livestock, large native grazer (deer [Cervidae] and pronghorn [*Antilocapra americana*]), folivore (rabbit [*Lepus* spp. and *Sylvilagus* spp.] and javelina [*Tayassu* sp.]), and small rodent (primarily Heteromyidae) exclosures in the grazed portion of the research areas to more precisely determine the relative impacts of these organisms. These plots are in both burned and unburned areas to measure the interaction between fire and different guilds of herbivores (Figure 2). Because, based on the initial years' rainfall data, a 30% rainfall gradient appears to exist across the research area, with the eastern two pastures receiving around 8 inches of rain (20 cm) per year and the western two pastures receiving 12 inches (28 cm) of rain per year, the research can also experimentally examine the interaction of herbivory and fire with rainfall. In May 1999, a 21,356-acre (8,643-ha) wildfire occurred which burned the entire pasture and much of the surrounding landscape. This pre-treatment meant that the studies started with a burned, rather than an unburned baseline. Perhaps more important, since initial vegetation sampling had been completed, it allowed for the determination of how effective the sampling regime was in assessing fire effects on vegetation and allowed fine-tuning the study protocol prior to initiating the full experimental design. This burn also meant that two additional seasons of rest were needed prior to initiating the fire and grazing treatments. Two hundred head of cattle were placed in the grazing treatments in September 2000 with the initial fire treatment beginning in June 2001.

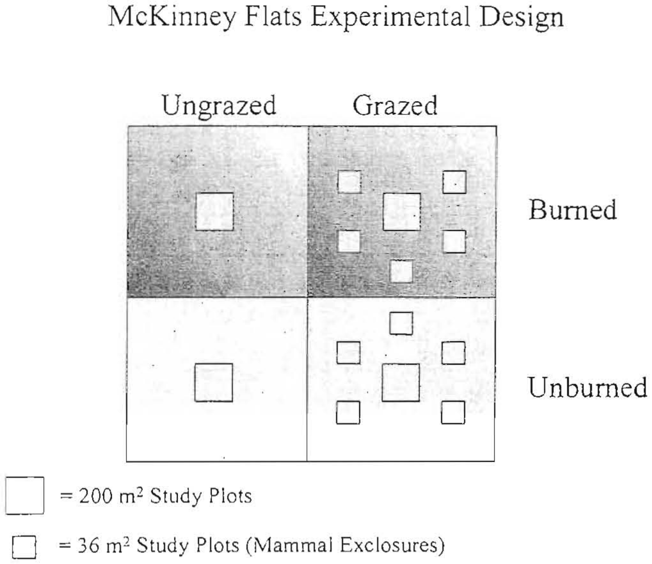

Fig. 2. Experimental design of one of four replicated plots on the McKinney Flats Experimental Area, Gray Ranch, New Mexico, established in 1998 to study the effects of fire, herbivory, and climate.

Fire Timing and Intensity

During 1999, a second experimental research project was undertaken by the USDA Forest Service Rocky Mountain Research Station, in collaboration with the Arid Lands Project and the Malpai Borderlands Group, on the Cascabel Ranch in the foothills of the Peloncillo Mountains at 5,600 feet (1,723 m). In

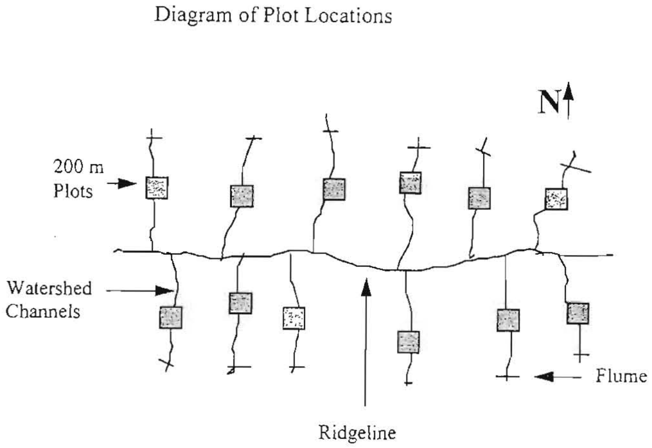

Fig. 3. Schematic diagram of fire timing and intensity studies initiated by the USDA Forest Service Rocky Mountain Research Station in collaboration with Malpai Borderlands researchers in 1999. Twelve watersheds are divided into cool-season, warm-season, and no-burn treatment plots on the Cascabel Ranch, Animas, New Mexico. Watersheds average 40 to 60 acres (17 to 25 ha) in area; total area of the site is approximately 5 km^2.

this study, 12 approximately 60-acre (25-ha) watersheds are divided into 4 summer burn, 4 winter burn, and 4 control treatments to examine the effects of fire timing and intensity on ecosystem structure and plant and animal composition (Figure 3). Ecosystem properties, including erosion and run-off, are being examined through a series of Parshall flumes constructed at the bottom of each watershed. Results from this study will be reported elsewhere. Also starting in 1999, a gap analysis was undertaken to examine the distribution of sampling plots. This analysis will likely lead to an expansion of the sampling program to include a wider array of rainfall gauges, inclusion of livestock exclosures, and an expansion of sampling plots to include more burn areas and under sampled habitats including tabosa grasslands.

RESULTS AND DISCUSSION

Vegetation and Fire Effects

The most significant effects of the 1994 wildfires on the Gray Ranch in the initial 2 years following the fires was an increase in bare ground and a decrease in three-awn grasses (*Aristida* spp.) and hairy grama (*Bouteloua hirsuta*), increases in blue grama (*Bouteloua gracilis*) on several plots, and the sharp, yet temporary, decline in broom snakeweed (*Gutierrezia sarothrae*) and annual forbs (Table 1). Populations of rabbitbrush (*Chrysothamnus nauseosus*), cholla (*Opuntia spinosior*), one-seed juniper (*Juniperus monosperma*), and mountain mahogany (*Cercocarpus montanus*) were significantly reduced, while densities of honey mesquite (*Prosopis glandulosa*), catclaw mimosa (*Mimosa biuncifera*), and sacahuiste (*Nolina microcarpa*) did not change significantly. Though most of these plants were top-killed, they resprouted within 1 season. Shrubby buckwheat (*Eriogonum wrightii*) appears to be fire-tolerant and may replace some less fire-tol-

Table 1. Vegetation monitoring plots (pre- and post-fire), Gray Ranch, New Mexico, 1993–1996 (after Sundt 1996). Changes in frequency and cover after wildfire for selected species in burned plots are shown. Symbols indicate relative changes between 1993 (pre-burn) and 1994 (4 months post-burn), and between 1994 and 1995 (16 months post-burn): + = relative increase, − = relative decrease, and 0 = no significant change. Entries indicate the number of plots in which a species showed a significant change (80% confidence interval) between any 2 or more years.

Variable	Change in frequency and cover									
	++	+0	0+	−+	−−	−0	0−	+−	Sum[a]	Total[b]
Frequency										
Annual forbs				15					15	15
Blue grama	4	3			2	1	1		11	15
Three-awn grasses		2			3	6	2		13	15
Hairy grama				1	2	1	2	1	7	9
Black grama		1				1	1		3	10
Broom snakeweed				5					5	10
Absolute cover										
Bare ground		2						13	15	15
Litter		1	3	3	2	1	1	2	13	15
Perennial live				5	4	4	1		14	15
Annual forbs			1	13	1				15	15
Blue grama	1	2	1	1		4		1	10	15
Three-awn grasses				2	2	7			11	15
Hairy grama				1	2	3		1	7	9
Black grama		1				2	1		4	10
Broom snakeweed				1		2			3	10
Relative cover										
Blue grama	1	4				2	1		8	15
Three-awn grasses				3	4	3	2	1	13	15
Hairy grama		1				2	1	1	5	9
Black grama		1			1	1	1		4	10
Broom snakeweed				3		3			6	10

[a] Number of plots in which a species shows a significant change.
[b] Number of burned plots in which a species was detected.

erant grasses. Broom snakeweed showed a similar short-term response with mortality immediately following the fire, followed by the population rebounding in subsequent years (Sundt 1996). Results for 2 additional years (1997 and 1998) showed little change from the 1995 and 1996 data (Sundt 1999*a*). It should be noted that these studies were conducted during a period of moderate drought in the region. In contrasts of two burned and two unburned plots with similar grassland vegetation, both sets of plots showed increases in bare ground in the season following the fire, although this trend was more distinct in the burned plots, with one plot in 1995 actually dropping below its immediate post-fire vegetation cover. Though the sample sizes were too small to be conclusive, these results suggest that the effects of the drought were more important than the effects of the fire (Sundt 1996).

Following the 1994 Sycamore burn, data from 1997 and 1999 in plot 1 showed a decline in bare ground (57% to 48%) and slight increases in perennial grasses (27% to 28%), woody species (9% to 12%) and annuals (1% to 4%). In plot 2, bare ground increased (58% to 71%), perennial grasses declined (28% to 19%), woody species increased (6% to 8%), and annuals increased (1% to 7%) (Sundt 1999*b*).

In the 1995 Baker burn, the pre-burn vegetation was shrubby with a ground cover dominated by bare ground, rock, and herbaceous litter. Ground cover of grasses and forbs averaged 10% and 8%, respectively. Shrub diversity was high due to a mixing of several vegetation associations with common woody plants including red barberry (*Berberis haematocarpa*), honey mesquite, whitethorn acacia (*Acacia constricta*), little leaf sumac (*Rhus microphylla*), and one-seed juniper. The breeding bird community of 59 species, sampled in late June, featured species typical of scrub rather than grassland. The five most common species detected were northern mockingbird (*Mimus polyglottus*), phainopepla (*Phainopepla nitens*), Gambel's quail (*Callipepla gambelii*), ash-throated flycatcher (*Myiarchus cinerascens*), and Bewick's wren (*Thryomanes bewickii*). The burn was patchy at two scales. First, in 38% of sampling stations there was some area burned within a 100-m radius. Second, the area burned within the burn perimeter averaged 48%. An average of 80% of all shrub species survived the burn, although only 20% of one-seed juniper survived. Sixty-five percent of burned shrubs were completely burned above ground and resprouted the following year (averaging 1 m in height of new growth 2 years later). More species of birds and individuals were counted 1 year after the fire (745 birds in 53 species) than just prior to it (703 birds in 45 species) or 2 years later (544 birds in 41 species). Yet the between-year differences did not appear to be related to the fire and were probably more a reflection of environmental variation (Scott 1999).

Studies of bats and agaves indicated that 24-hour nectar accumulation in burned plants was significantly higher at the Cowboy Flats site and significantly lower at the Geronimo Trail site than in unburned plants. Nectar availability was not found to be a limiting factor for lesser long-nosed bats during the study. Nectar accumulation in flowers in burned and unburned plots was well within the normal range of nectar production reported in previous studies (L. Slauson, Arizona State University, personal communication) with burned plants tending to have high sugar concentrations. The increased nectar and sugar concentration are thought to be a physiological response to burn damage and stress but may not continue through the entire period of inflorescence (L. Slauson, Arizona State University, personal communication). On the Geronimo Trail site, no significant differences were detected between exclosed and standing nectar or pollen crops in burned or unburned plots, implying that little nectar was used by bats during the study period though lesser long-nosed bats were present in a cave near Cowboy Flats. On the Cowboy Flats site, nectar production was significantly lower in standing crop flowers that may have been due to the proximity to a roost. No significant difference in bat visitation was noted between burned and unburned sites. The initial results from this pilot study suggest a complex interaction between fire and the physiology of agave, but also suggest that the endangered bats are not significantly affected by fire because numerous unburned agaves remained in the mosaic of habitat after the fire with many of these unburned patches well within the 25-km foraging range of lesser long-nosed bats (Slauson et al. 1999). Surveys of agave numbers indicated that agave mortality was well below the 20% take threshold established by the pre-burn biologist's workshop (P. Warren, The Nature Conservancy, personal communication).

Following the 1997 Maverick burn, there was a significant reduction in the cover of woody species and a significant increase in perennial grasses (Figure 4). The notable exceptions were plots 19 and 20, where only a slight increase in cover by grasses occurred. Both plots had dense pre-fire shrub cover and approximately 10% cover by grasses. In the rattlesnake studies (Holycross et al. 1999), all snakes were located <18 hours pre-fire and <24 hours post-fire. Eight snakes exposed to low-intensity fire survived, while one snake exposed to high-intensity fire died. Pooled data on snake activity before and after the fire did not document significant changes in snake activity following the fire (Holycross et al. 1999). While some woodland habitat considered key to one rattlesnake population was reduced by the fire (A. Holycross, Arizona State University, personal communication), documented snake mortality was well below the threshold established by the biologist's workshop.

Fire and Grazing

The 1999 fire on McKinney Flats, unlike the fires of the mid-1990s, was followed by a relatively wet summer. Initial analysis of 1998 and 1999 vegetation from before and after the May 1999 fire indicate, in contrast to data following the 1994 fires on the Gray Ranch, a statistically significant increase in only hairy grama (Table 2). While black grama declined non-significantly overall, this average is misleading because

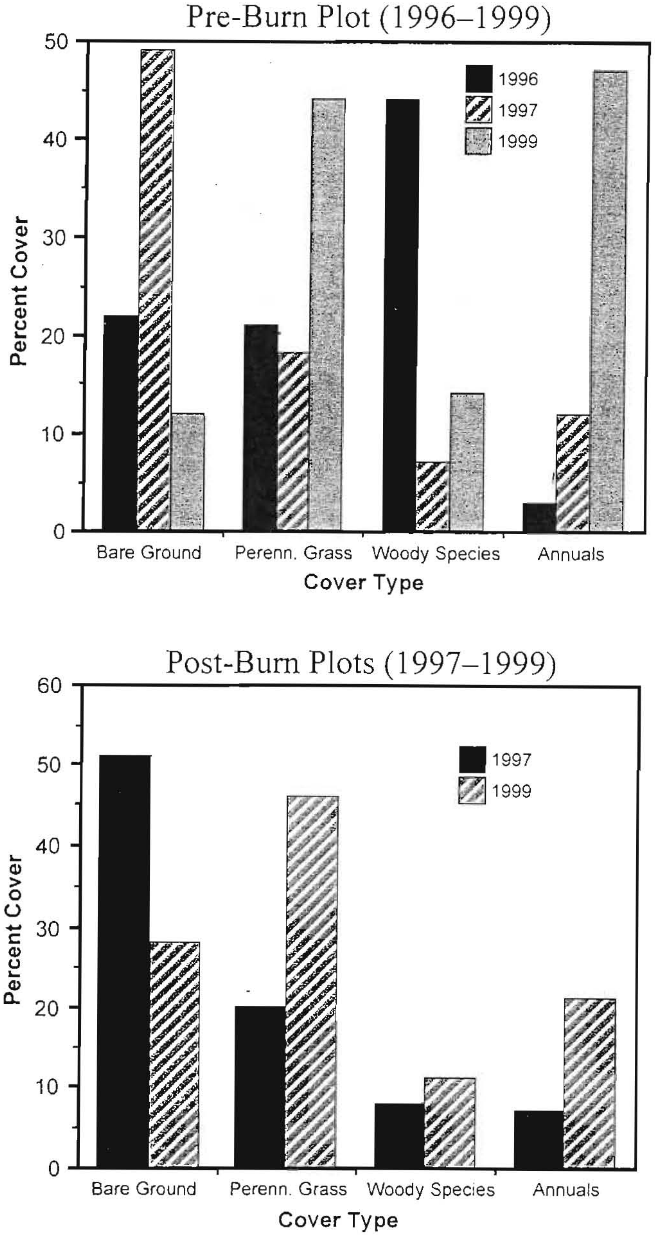

Fig. 4. Change in percent cover of bare ground, perennial grasses, woody species, and annual forbs 2 years following the 1997 Maverick prescribed burn, Peloncillo Mountains, Coronado National Forest, Arizona, 1996–1999.

Table 3. Pre- and post-burn small mammal diversity and biomass, McKinney Flats, Gray Ranch, New Mexico, 1998–2000. While current sampling entails three 3-day samples per year, the baseline data presented below represent one 3-day sample per year on 12 plots.

	Pre-burn	Post-burn	
Variable	1998	1999	2000
Species (average no. per plot)	5.0	3.3	5.0
Biomass (average grams per plot)	336.7	283.1	510.8

this species' response varied across the pasture in response to environmental conditions with increases on some sites, and declines in others. Blue grama did not show a significant increase following the fire. The percentage of open ground increased and the cover by broom snakeweed declined significantly; these patterns were consistent with previous monitoring data. Small mammals from 1998 through 2000 showed marked shifts in species composition in many plots with a decline in species biomass and diversity in the year following the fire that rebounded in the second year following the fire (Table 3). A shift in overall species composition occurred with fewer large species to greater numbers of small species. This appears to be a result of a number of large shrubland-adapted species such as packrats (*Neotoma* spp.) declining following the fire and being primarily replaced by pocket mice (*Perognathus* spp.) and harvest mice (*Reithrodontomys* spp.). This result suggests that the fire significantly altered the composition of resources in the system as reflected in the change in species composition.

An area of frequent debate and concern among biologists and land managers working in the Southwest is the long-held belief that because black grama grass has shown a negative response to fire in early studies (Reynolds and Bohning 1956, Cable 1965, McPherson 1995), black grama-dominated desert grasslands therefore did not have a history of fire and thus are not fire-adapted ecosystems. While black grama growing points are situated above ground level where they are more susceptible to fire than comparable species such as blue grama (McClaran and Van Devender 1995), these results show that with natural burns in healthy communities black grama is not necessarily negatively affected by fire. Many of the negative effects documented in previous studies were probably in response to drought conditions or occurred in degraded

Table 2. Pre- and post-burn plant species composition (of common and special interest species) and soil cover, McKinney Flats, Gray Ranch, New Mexico, 1998–1999.

	Pre-burn			Post-burn	
Variable	Percent cover	SE		Percent cover	SE
Black grama (*Bouteloua eriopoda*)	4.8	1.0	>	4.0	1.0
Blue grama (*B. gracilis*)	16.9	2.4	<	18.8	3.2
Hairy grama (*B. hirsuta*)*	2.3	0.3	<	4.0	0.6
Sideoats grama (*B. curtipendula*)	2.7	0.6	>	2.2	0.4
Broom snakeweed (*Gutierrezia sarothrae*)*	5.2	1.2	>	1.8	0.4
Soil cover*	34.3	2.75	<	41.9	3.3

* Significant difference at $P < 0.05$.

communities undergoing other environmental stresses. A number of the studies cited above (e.g., Reynolds and Bohning 1956, Cable 1965) that documented black grama declines following fire were conducted in the Santa Rita Experimental Range near Tucson, Arizona, which is in degraded rangeland and substantially lower and drier than most Chihuahuan Desert sites. The frequent fire events in grasslands on the Gray Ranch across numerous grassland communities indicate that with adequate rainfall to build fine fuels, even with livestock grazing, fire has a place in Chihuahua Desert grasslands.

MANAGEMENT IMPLICATIONS

While there has been a long-term interest in the effect of rainfall on desert grasslands (Cable 1975, McClaran and Van Devender 1995), the impact of rainfall for influencing vegetation response to fire has not been widely addressed. The key message that researchers and land managers should take away from these results across a wide array of sampling regimes is that while some trends such as declines in short-term shrub and woody vegetation and increases in soil cover are consistent across ecological systems, the response of most grasses appear to be largely climatically driven with response to fire by key species such as black grama largely influenced by rainfall. Therefore, researchers and land managers should carefully document rainfall before and after fire events. Especially important is soil moisture (Wright 1974), not just recent rainfall patterns, for measurement of soil moisture allows researchers and land managers to determine if plants are drought-stressed prior to burning, and the water availability in the soil in the weeks and months following the burn.

In the Keynote Address of Fire Conference 2000, former Forest Service Chief Jack Ward Thomas (*this volume*) made a plea for increased research on the effects of fire, particularly the implications of fire for wildlife. This experience in the borderlands supports Thomas's statements. The single biggest impediment to implementing landscape-level reintroduction of fire in the Malpai Borderlands was concern for the potential negative effects of fire on rare and endangered species by environmental groups and agency biologists, and on rangeland health by some neighboring ranchers. The MBG monitoring and research program was undertaken to document the effects of fire. The initial results to date indicate that fire has a minimal effect on species of concern, with the primary constraint being the need to pre-burn or reduce stand-replacing fire in upper-elevation wooded canyons, which are key to survival for a number of rare and endangered species including the ridgenosed rattlesnake and Gould's wild turkey (*Meleagris gallopavo mexicana*). At the same time, long-term repeat photographic studies (Curtin and Brown 2001) have documented that this landscape is undergoing a significant increase in woody species, and that to effectively reintroduce fire and preserve montane savanna habitats, fire must be reintroduced into this system within the next decade.

These studies demonstrate that partnerships of local communities, federal and state agencies, and researchers have an important role to play both in restoring fire to western landscapes and in documenting the role of fire to maintain and sustain grassland and savanna ecosystems. Such partnerships can result in research and restoration programs unobtainable through traditional federal or university-oriented research programs (Curtin 2002). Federal agencies should be urged to sustain and expand private research and restoration initiatives; there is the hope that federal agencies will move away from fire suppression programs and extensive research on fire suppression and will increasingly move toward supporting the use of fire as a restoration tool with increased research on the ecological implications of active fire management.

ACKNOWLEDGMENTS

I thank the conference organizers for the opportunity to present these materials. The Animas Foundation, Arid Lands Project, Arizona Game and Fish, Bureau of Land Management, the Coronado National Forest, Claiborne-Ortenberg Foundation, the Forest Service Rocky Mountain Research Station, McCune Foundation, National Fish and Wildlife Foundation, National Interagency Fire Center, National Science Foundation, New Mexico Bureau of Land Management, New Mexico Game and Fish, Helwett Foundation, Thaw Charitable Trust, the Wallace Research Foundation, and World Wildlife Fund have supported research in the Malpai Borderlands.

LITERATURE CITED

Allen, L. 1998. Grazing and fire management. Pages 97–100 *in* B. Tellman, D.M. Finch, C. Edminster, and R. Hamre (eds.). The future of arid grasslands: identifying issues, seeking solutions. Proceedings RMRS-P-3, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Allen, L.S. 1995. Fire management in the sky islands. Pages 386–388 *in* L.F. DeBano, P.F. Ffolliott, A. Ortega-Rubio, G.J. Gottfried, R.H. Hamre, and C.B. Edminster (technical coordinators). Biodiversity and management of the Madrean Archipelago: the sky islands of southwestern United States and northwestern Mexico. General Technical Report RM-GTR-264, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Allen, L.S. 1999. Fire management in the Borderlands: the Peloncillo Programmatic Fire Plan. Pages 74–76 *in* G.J. Gottfried, L.G. Eskew, C.G. Curtin, and C.B. Edminster (compilers). Toward integrated research, land management, and ecosystem protection in the Malpai Borderlands. Proceedings RMRS-P-10, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Bahre, C.J. 1991. A legacy of change: historic human impact on vegetation of the Arizona Borderlands. University of Arizona Press, Tucson.

Cable, D.R. 1965. Damage to mesquite, Lehmann lovegrass, and black grama by a hot June fire. Journal of Range Management 24:170–176.

Cable, D.R. 1975. Influence of precipitation on perennial grass production in the semidesert Southwest. Ecology 56:981–986.

Curtin, C.G. 2002. Integration of science and community-based conservation in the Mexico/U.S. borderlands. Conservation Biology 16:880–886.

Curtin, C.G., and J.H. Brown. 2001. Climate and herbivory in structuring the vegetation of the Malpai Borderlands. Pages 84–94 in C.J. Bahre and G.L. Webster (eds.). Vegetation and flora of *La Frontera*: vegetation change along the United States–Mexico boundary. University of New Mexico Press, Albuquerque.

Hastings, R.J., and R.M. Turner. 1965. The changing mile: an ecological study of vegetation change with time in the lower mile of an arid and semiarid region. University of Arizona Press, Tucson.

Holycross, A.T., L.J. Smith, C.W. Painter, and M.E. Douglas. 1999. Effects of prescribed fire on montane rattlesnakes: endangered species and ecosystem restoration. Pages 109–111 *in* G.J. Gottfried, L.G. Eskew, C.G. Curtin, and C.B. Edminster (compilers). Toward integrated research, land management, and ecosystem protection in the Malpai Borderlands. Proceedings RMRS-P-10, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

McDonald, B. 1995. The formation and history of the Malpai Borderlands Group. Pages 483–486 *in* L.F. DeBano, P.F. Ffolliott, A. Ortega-Rubio, G.J. Gottfried, R.H. Hamre, and C.B. Edminster (technical coordinators). Biodiversity and management of the Madrean Archipelago: the sky islands of southwestern United States and northwestern Mexico. General Technical Report RM-GTR-264, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

McDonald, B. 1996. Fire and the Malpai Borderlands Group: one rancher's perspective. Pages 175–177 *in* P.F. Ffolliott, L.F. DeBano, M.B. Baker, G.J. Gottfried, G. Solis-Garza, C.B. Edminster, D. Neary, L. Allen, and R.H. Hamre (technical coordinators). Effects of fire on Madrean Province ecosystems. General Technical Report RM-GTR-289, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

McClaran, M.P., and T.R. Van Devender, eds. 1995. The desert grassland. University of Arizona Press, Tucson.

McPherson, G.R. 1995. The role of fire in desert grasslands. Pages 130–151 *in* M.P. McClaran and T.R. Van Devender (eds.). The desert grassland. University of Arizona Press, Tucson.

Reynolds, H.G., and J.W. Bohning. 1956. Effects of burning on a desert grass–shrub range in southern Arizona. Ecology 37: 769–777.

Scott, P.E. 1999. Effects of a prescribed burn on vegetation and birds in a semi-desert shrub–grassland. Pages 115–116 *in* G.J. Gottfried, L.G. Eskew, C.G. Curtin, and C.B. Edminster (compilers). Toward integrated research, land management, and ecosystem protection in the Malpai Borderlands. Proceedings RMRS-P-10, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Slauson, L., V. Dalton, and D. Dalton. 1999. Effects of prescribed burning on the Palmer agave and lesser long-nosed bat. Pages 111–114 *in* G.J. Gottfried, L.G. Eskew, C.G. Curtin, and C.B. Edminster (compilers). Toward integrated research, land management, and ecosystem protection in the Malpai Borderlands. Proceedings RMRS-P-10, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Smith, L.J., A.T. Holycross, C.W. Painter, and M.E. Douglas. 2001. Montane rattlesnakes and prescribed fire. Southwestern Naturalist 46:54–61.

Sundt, P. 1996. Effects of wildfires on grassland vegetation at the Gray Ranch. Unpublished report to the Animas Foundation, Animas, New Mexico.

Sundt, P. 1999*a*. Vegetation monitoring on the Gray Ranch, 1993 to 1998. Unpublished report to the Animas Foundation, Animas, New Mexico.

Sundt, P. 1999*b*. Vegetation monitoring of the Maverick burn, 1996 to 1999. Unpublished report to the Malpai Borderlands Group, Douglas, Arizona.

Swetnam, T.W., C.H. Baison, and J.M. Kaib. 2001. Forest fire histories of the sky islands of *La Frontera*. Pages 95–119 *in* G.L. Webster and C.J. Bahre (eds.). Changing plant life of *La Frontera*. University of New Mexico Press, Albuquerque.

Wright, H.A. 1974. Range burning. Journal of Range Management 27:5–11.