Interacting Effects of Landownership, Land Use, and Endangered Species on Conservation of Southwestern U.S. Rangelands

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Abstract: *The contemporary southwestern United States is characterized by fire-adapted ecosystems; large numbers of federally listed threatened and endangered species; a patchwork of federal, state, and private landownership; and a long history of livestock grazing as the predominant land use. I compared eight sites in southern Arizona and New Mexico to assess the interacting effects of these characteristics on conservation practices and outcomes. There was widespread interest and private-sector leadership in restoring fire to southwestern rangelands, and there is a shortage of predictive scientific knowledge about the effects of fire and livestock grazing on threatened and endangered species. It was easier to restore fire to lands that were either privately owned or not grazed, in part because of obstacles created by threatened and endangered species on grazed public lands. Collaborative management facilitated conservation practices and outcomes, and periodic removal of livestock may be necessary for conservation, but permanent livestock exclusion may be counterproductive because of interactions with land-use and landownership patterns.*

Key Words: collaborative management, Endangered Species Act, fire, livestock grazing, riparian areas, threatened species

Interacción de Efectos de la Propiedad de Tierras, Uso del Suelo y Especies en Peligro Sobre la Conservación de Llanuras del Suroeste

Resumen: *El suroeste contemporáneo de Estados Unidos se caracteriza por ecosistemas adaptados al fuego; numerosas especies enlistadas federalmente como amenazadas y en peligro; un mosaico de propiedad federal, estatal y privada de la tierra; y una larga historia de pastoreo por ganado como forma predominante de uso de suelo. Comparé ocho sitios en el sur de Arizona y Nuevo México para evaluar la interacción de los efectos de estas características sobre las prácticas y resultados de conservación. Hubo interés generalizado y liderazgo del sector privado en el restablecimiento de fuego en llanuras del suroeste, y hay una carencia de conocimiento científico predictivo en relación con los efectos del fuego y el pastoreo de ganado sobre especies amenazadas y en peligro. Fue más fácil restablecer fuego en terrenos de propiedad privada o no pastoreados, debido en parte a obstáculos creados por la presencia de especies amenazadas y en peligro en terrenos públicos, pastoreados. La gestión cooperativa facilitó las prácticas y resultados de conservación, y la remoción periódica de ganado puede ser necesaria para la conservación, pero la exclusión permanente de ganado puede ser contraproducente debido a las interacciones con los patrones de propiedad y uso de suelos.*

Palabras Clave: Acta de Especies en Peligro, áreas ribereñas, especies amenazadas, fuego, gestión cooperativa, pastoreo de ganado

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Introduction

Conservation of rangelands in the southwestern United States faces a complex tangle of social and ecological issues created by the interaction of four regional characteristics: (1) except for the lowest and driest deserts, the region's ecosystems are prone to burn and are adapted to fire (Ffolliott et al. 1996); (2) the region is home to large numbers of species protected as threatened or endangered under the U.S. Endangered Species Act (ESA) (Flather et al. 1994); (3) landownership is a patchwork of federal, state, and private holdings; and (4) livestock grazing is the dominant land use and has been for more than a century.

Successful conservation at any large scale must address these four factors in an integrated fashion, but the obstacles are considerable. Different landownership types have different constituencies, economic constraints, and legal mandates. The ecological interactions among fire, livestock grazing, and threatened and endangered species management are often poorly understood, and each topic has its own scientific literature and experts. Similarly, public debates about conservation and development tend to focus on a single species, land use, management issue, or landownership type.

Historical and contemporary factors make effective conservation action unusually urgent. A century of fire suppression, combined with periods of drought and heavy grazing, has resulted in widespread, persistent, and undesirable changes in the structure and function of southwestern rangelands (Archer 1994; McPherson & Weltzin 2000), making fire restoration an important conservation issue (McPherson 1995; Ffolliott et al. 1996). Various definitions of southwestern ecoregions have been offered, but recent reviews and assessments agree that the region harbors tremendous biological diversity, that conversion of grasslands to shrub dominance is a major and ongoing threat, that fire restoration is necessary (if not sufficient) to counter this trend, and that rapid residential development in rural areas poses an additional threat both directly and by foreclosing the option of restoring fire (Bogan et al. 1998; Olson & Dinerstein 1998; Dinerstein et al. 2000; McPherson & Weltzin 2000; Gori & Enquist 2003). Gori and Enquist (2003) found that 3.5 million ha (84.1%) of historical grasslands in the Arizona and New Mexico portion of the Apache Highlands Ecoregion have experienced significant shrub encroachment, of which approximately 1.4 million ha have potential for restoration through the use of fire. They also determined that 67.6% of intact native grasslands and 58.3% of restorable grasslands are not federally owned and are therefore subject to development. Here I address and try to better understand fire restoration in this complex landscape.

Methods

I compared eight sites in southern Arizona and New Mexico, where different combinations of four conservation practices are taking place. The practices were fire restoration, threatened and endangered species management, long-term livestock exclusion, and periodic livestock exclusion. Sites were selected to reflect the major permutations of landownership (private, state, federal) in the region, along with a range of different combinations of practices (Table 1). The resulting sample was skewed toward areas where fire is an actual or contemplated practice. In common with the region as a whole, all sites had a history of livestock grazing. Beginning in the 1980s, long-term livestock exclusion (>5 years) occurred on all of

Table 1. Landownership, conservation practices, and endangered species at eight southwestern sites.[a]

Site	*Landownership*	*Fire*	*Livestock exclusion*	*Threatened or endangered species*
U Bar Ranch	Pr	no	P, L	Southwestern Willow Flycatcher
Muleshoe Ranch	Pr, F	yes	L	Gila chub
Empire Ranch	S, F	no	P, L	Gila topminnow
				Gila chub[b]
				Chiricahua leopard frog
				Southwestern Willow Flycatcher
Gray Ranch	Pr	yes	P	New Mexico ridgenose rattlesnake
Malpai Borderlands	Pr, S, F	yes	P	New Mexico ridgenose rattlesnake
				Lesser long-nosed bat
Altar Valley ranches	Pr, S	yes	P	Pima pineapple cactus
				Cactus Ferruginous Pygmy Owl
Buenos Aires National Wildlife Refuge	F	yes	L	Pima pineapple cactus
				Cactus Ferruginous Pygmy Owl
				Masked Bobwhite
San Pedro Riparian National Conservation Area	F	no	L	Southwestern Willow Flycatcher

[a] *Abbreviations: Pr, private; S, state; F, federal; P, periodic; L, long term.*
[b] *Proposed endangered but not currently listed.*

three sites and on portions of two others. Periodic livestock exclusion was practiced at six sites for periods of several weeks to a year under rotational grazing systems and up to 5 years in conjunction with prescribed burning. The nine threatened and endangered species considered spanned a range of taxa and included five species common to two or more sites.

I gathered information for each site from published literature, public and private reports, interviews, and site visits. Complete case studies of every site were not possible because of data limitations. The quantity and quality of available data were not the same across sites or across all threatened and endangered species present at some sites. Although regrettable from a strict methodological perspective, this accurately reflected the conditions that conservation practitioners face on the ground: uneven availability of data (especially across landownership types) and significant scientific uncertainty about ecological interactions and generalizability of results across sites.

Results

U Bar Ranch

The U Bar Ranch, located in southwestern New Mexico, includes ~13 km of the Gila River where it first leaves national forest land. The ranch encompasses ~75,000 ha, of which ~18,000 ha are privately owned by the Phelps Dodge mining corporation and leased to the U Bar. The manager of U Bar, David Ogilvie, advocates fire restoration in upland areas of the ranch but not in the ~650-ha riparian corridor, which was the focus here.

The species in question was the Southwestern Willow Flycatcher (*Empidonax traillii extimus*), petitioned for listing in 1993 and listed as endangered in 1995. The largest known breeding population of the flycatcher occupies patches of mature riparian woodland on private U Bar land along the Gila River and adjacent irrigation return ditches (Sogge & Marshall 2000). The surrounding fields have long been cultivated, and most of them serve as pasture for cattle.

In 1994 U Bar and Phelps Dodge began monitoring the Southwestern Willow Flycatcher on this land. Concurrently, Ogilvie implemented a management program involving complete livestock exclusion from some flycatcher sites, rapid rotation of grazing in other sites during the growing season, and no grazing or farming in or around all sites during the flycatcher nesting season.

When initial surveys found large numbers of flycatchers and outsiders questioned the data, Ogilvie recruited partners. The Rocky Mountain Research Station, The Nature Conservancy (TNC), and Western New Mexico University helped develop a research program that included detailed sampling of 27 occupied habitat patches: 15 grazed and 12 ungrazed. To date, researchers (Stoleson & Finch 2000, 2003) have found that (1) the population increased from roughly 60 to 210 breeding pairs in the first 6 years of monitoring; (2) U Bar has the highest density of breeding birds (of all species) ever recorded in North America (>1200 pairs/40 ha in all measured patches and a maximum of 1430 pairs/40 ha [Stoleson 2003]); (3) nest success is higher along stringers of habitat created by irrigation return ditches than in larger patches next to the river; (4) grazed habitat patches support significantly higher densities of flycatcher nests than ungrazed ones and nest success is unaffected by grazing; and (5) brood parasitism by Brown-headed Cowbirds (*Molothrus ater*) is low (unlike at other major flycatcher sites), even though cowbirds are not trapped at U Bar.

Livestock grazing and irrigated agriculture are two causes of endangerment to the flycatcher (USFWS [U.S. Fish and Wildlife Service] 1995*c*, 2002*b*). Several studies have documented increased numbers of Willow Flycatchers following reduction or elimination of grazing (Marshall & Stoleson 2000). Periodic livestock exclusion has not been examined as a strategy for flycatcher habitat conservation, however. Research at U Bar indicates that livestock grazing as currently managed is not detrimental to the flycatcher and may even be beneficial, and that irrigation ditches have created high-quality habitat. Ogilvie's management has probably contributed to the quality of the habitat (Stoleson 2003). Cattle have been permanently excluded from riparian areas on the Gila National Forest upstream and downstream of U Bar since 1998, principally because of litigation filed on behalf of the flycatcher (Raish 2000). To date, exclusion has not resulted in increased numbers of flycatchers at those sites (S. Stoleson, personal communication).

Muleshoe Ranch Preserve

The Muleshoe Ranch Preserve is located on the southwestern flank of the Galiuro Mountains in Arizona. After a century as a cattle ranch, it was acquired by TNC in the early 1980s to preserve intact populations of rare (but not listed) native fishes in four small perennial streams. The preserve formally includes a retired U.S. Forest Service grazing allotment and a small area of state land, but I considered only the private (2500 ha) and Bureau of Land Management (BLM) (10,750 ha) lands because they are where the fish and the fires occur.

The Muleshoe is an early example of collaborative rangeland management in the region. Through a consensus-based planning process, the BLM and TNC defused controversy surrounding the removal of livestock from the ranch and focused management on restoring grasslands through prescribed burning (Conley 2003). The rare fish species, vegetation, water quality and quantity, and stream morphology were monitored before and after four prescribed fires, which were ignited between 1995

and 2000 and burned 8300 ha. Despite severe drought conditions and declining water flows, habitat conditions for the fish showed marked improvement from 1994 to 2001 (Brunson et al. 2001).

Empire Ranch

The Empire Ranch is in the Sonoita Valley of southeastern Arizona. Its ~30,000 ha are divided almost equally between state and BLM ownership. Dominated by native perennial grasses, Empire includes the upper 22 km of Cienega Creek, a riparian area inhabited by three listed threatened or endangered species: the Gila topminnow (*Poeciliopsis occidentalis occidentalis*), the Chiricahua leopard frog (*Rana chiricahuensis*), and the Southwestern Willow Flycatcher. Natural and accidental fires occur, but the use of fire as a management tool is ruled out by the proximity of several hundred residences in adjacent areas (BLM 2001).

John and Mac Donaldson have leased the Empire Ranch since 1975, stocking it with cattle at 20–50 ha/animal unit (Sayre 2001). They rotate their livestock frequently during the growing season and vary their stocking rates widely to track forage production. Most of Cienega Creek is fenced to exclude livestock, pursuant to a 1996 biological opinion, although 2.5 km of the creek and numerous crossing lanes are periodically grazed (BLM 2001).

Since 1994, the Donaldsons' management has been overseen by a biological planning team, which includes representatives from the local community, environmental groups, and state and federal agencies (Conley 2003). Detailed monitoring of vegetation, riparian conditions, and threatened and endangered species has enabled the team to resolve management issues and document stable or improving conditions for listed species (BLM 2001).

Gray Ranch

The 130,000-ha Gray Ranch is located in extreme southwestern New Mexico and contains one of the largest, intact, native, semidesert grasslands in the Southwest. It is owned by the Animas Foundation, a nonprofit organization established in 1993 to buy the ranch from TNC and manage it for conservation values. The Gray Ranch harbors several threatened and endangered species, including the New Mexico ridgenose rattlesnake (*Crotalus willardi obscurus*). The second-largest known population of this threatened subspecies inhabits the Animas Mountains, which are contained entirely within the ranch. The Gray Ranch forms the southeastern portion of the larger Malpai Borderlands Group (MBG) planning area. The biological issues surrounding the rattlesnake are discussed in the next section.

Since 1994 more than 80,000 ha of the Gray Ranch have burned. Most of these fires have ignited naturally from lightning strikes, although numerous human-caused fires (both prescribed and accidental) have also occurred, some ignited for research purposes. Monitoring data indicate that fire has had a positive effect on native grass abundance and diversity, and that 85% of variability is attributable to rainfall patterns rather than livestock grazing (Sundt 1996, 1999). Stocking rates have been conservative (generally 30–50 ha/animal unit) and all pastures receive a period of rest after grazing. In 1997 the Animas Foundation completed a fire management plan with the New Mexico State Forester's Office implementing a "least-cost suppression" policy, under which natural fires are generally allowed to burn themselves out within widely spaced existing fire breaks. This strategy has resulted in fire suppression costs of about $3/ha.

Malpai Borderlands

Composed of 32 ranches in extreme southwestern New Mexico and southeastern Arizona, the Malpai Borderlands (~324,000 ha) is a patchwork of national forest and BLM, USFWS, state (New Mexico and Arizona), and privately owned lands. Nearly the entire area is rotationally grazed under systems that vary from ranch to ranch. The area harbors numerous threatened and endangered species, including the New Mexico ridgenose rattlesnake and the lesser long-nosed bat (*Leptonycteris curasoae yerbabuenae*).

The name for the area derives from the MBG, a nonprofit organization of ranchers, scientists, and environmentalists that works to restore fire, protect threatened and endangered species, and prevent subdivision of private lands (Curtin 2002). The MBG spearheaded three large prescribed fires in the Peloncillo Mountains along the Arizona–New Mexico border: Baker I in 1995, Maverick in 1997, and Baker II in 2003. The burned areas were rested from grazing for 1–3 growing seasons before and after the fires. The latter two fires were delayed by consultations with the USFWS about the rattlesnake and the bat.

Consultations about the bat focused on the possibility that fires and grazing could have a negative impact on populations of Palmer's agave (*Agave palmeri* Engelm.), whose flowers are a major food source for the bat when it is in the area in late spring and early summer. The flowers are found at the tops of tall stalks, which each plant produces once before dying. Cattle can prevent flowering by browsing the stalks when they are bolting, and fire can kill entire plants. Whether these impacts were actually occurring (or would occur in the case of fires) and whether they could affect the bat were matters of anecdote and speculation in 1996. With significant input from the MBG and TNC, the USFWS issued an incidental take statement that allowed no more than 20% fire-related agave mortality (USFWS 1997).

Scientific research subsequently indicated that these concerns were unwarranted. As part of the MBG's scientific program, a study was conducted to measure the

effects of the Maverick fire and another, accidental fire on the Gray Ranch on the reproduction of agaves (Slauson 2002). The study found <4% fire-related mortality and no effect on nectar and pollen production. It also suggested that fire may increase germination and establishment, resulting in a longer-term benefit to agaves. The more fundamental question—whether the bat is food limited in the region—remained unanswered until Ober (2000) studied the bat's foraging ecology and analyzed population data on both bats and agaves. She found that there were 5–20 times as many agaves as the bats needed, depending on annual fluctuations in flowering.

Although the Maverick fire helped resolve the bat issue, it also contributed to subsequent difficulties surrounding the New Mexico ridgenose rattlesnake and delays in implementing the Baker II fire. The snake is found in only three disjunct locations: the Sierra San Luis in Mexico, the Animas Mountains of the Gray Ranch, and the Peloncillo Mountains. It inhabits rocky wash bottoms with abundant plant litter and an overstory of trees (Holycross & Painter 2001). The Peloncillo population is by far the smallest—too small to permit replicated experiments or statistically meaningful sampling.

To evaluate direct mortality from fires, 13 snakes (most of them not ridgenose rattlesnakes, which could not be found in sufficient numbers) were radiotagged before the Maverick fire, and only one (not a ridgenose) perished. The fire escaped its primary boundaries, however, and burned very hot in a canyon with occupied habitat. Whether this incident killed any snakes is unknown, but it created distrust among some snake biologists for the MBG's fire restoration efforts (A. Holycross, personal communication). The biologists feared that fires would be more intense than in the past because of fuel buildup from decades of fire suppression and that crown fires could destroy the trees, thereby affecting habitat quality for the rattlesnake.

There is little empirical evidence to support this hypothesis (Mushinsky & McCoy 2003). Snakes are found in a canyon in the Sierra San Luis that experienced a crown fire in 1989. Much of the research on the subspecies has been conducted in an area of the Animas Mountains that also experienced a stand-replacing fire that year. Additionally, the hypothesis cannot be tested experimentally because the Peloncillo population is so small and habitat conditions in the other ranges are very different. After numerous rewrites of fire plans, draft biological opinions, and an expensive habitat-mapping effort, the Baker II fire was ignited in June 2003. Covering 19,290 ha of private, BLM, national forest, and Arizona state lands, the Baker II fire is reportedly the largest prescribed fire ever conducted successfully in the Western United States. The cost—not accounting for planning—was $124,467 ($6.74/ha), of which the MBG paid $20,000 (Bemis 2003).

Altar Valley Ranches

The Altar Valley is a ~250,000-ha watershed southwest of Tucson, Arizona, composed of 12 ranches and the Buenos Aires National Wildlife Refuge (NWR). I treat the refuge separately in the discussion that follows because it is federal land and ungrazed. The ranches are grazed under various rotational grazing systems, and pastures where prescribed fires occurred were rested for 1–2 growing seasons before and after burning. The species in question were the Pima pineapple cactus (*Coryphantha sheeri* var. *robustispina* Benson) and the Cactus Ferruginous Pygmy Owl (*Glaucidium brasilianum cactorum*). Both have restricted ranges in the United States, and both are being negatively affected by residential development around Tucson (USFWS 2002*a*).

Similar to the MBG, the Altar Valley Conservation Alliance is a nonprofit organization of area ranchers who want to restore fire to slow or reverse the conversion of grasslands to shrublands. In the late 1980s and early 1990s the alliance developed a fire plan for the valley, gathered agency support, identified areas where natural fires could be allowed to burn, and conducted several prescribed burns. Prescribed burning on Altar Valley ranches stopped in 1993 following the listing of the Pima pineapple cactus as endangered. Further obstacles were created in 1997 by the listing of the Cactus Ferruginous Pygmy Owl as endangered.

The Pima pineapple cactus occurs over a large portion of the valley, but its sparse distribution (2–8 ha/plant) and small size (4.5–46 cm in height) make locating specimens expensive, and <20% of its estimated range has been surveyed (USFWS 2002*a*). Little is known scientifically about grazing and fire effects on the cactus (Roller 1996; Roller & Halvorson 1997), and it is a relatively minor research priority compared with more charismatic or controversial threatened and endangered species in the state. In the meantime, inferences from observations and natural history are inconsistent.

Presumably, the cactus is adapted either to recover from fire effects or to avoid them by utilizing microhabitats of lower grass cover (Roller 1996). Historical fire suppression and grazing may have benefited the cactus by reducing fire mortality and herbaceous competition, respectively. But the introduction of a non-native perennial grass, Lehmann lovegrass (*Eragrostis lehmanniana* Nees), into the area (beginning in the 1940s) may have altered potential fire intensities and thereby increased fire risks to the cactus (Roller & Halvorson 1997). The first supposition cannot be tested for lack of longitudinal data. The second rests on only a single study with a very small sample size and is complicated by observations made following one prescribed fire in the early 1990s, which included low postfire mortality but high mortality in a subsequent drought (D. Robinett, personal communication).

Large numbers of the cactus are on the site today, including in patches of Lehmann lovegrass.

The knowledge base is also limited for the Cactus Ferruginous Pygmy Owl. Long considered a riparian species in Arizona, its discovery in the Altar Valley in the late 1990s was unexpected. How long it has been there and whether it is increasing or decreasing is unknown. Substantial numbers occur just south of the valley, in Mexico. Although the largest concentration of owls in the valley occupies a pasture that was burned in 1991, the USFWS is concerned that fires may destroy existing or potential nesting habitat along dry washes that dissect the valley's broad alluvial fans (USFWS 2002*a*).

Buenos Aires National Wildlife Refuge

The Buenos Aires NWR, located in the Altar Valley, is a ~47,000-ha site created by USFWS acquisition of the Buenos Aires Ranch in 1985. The refuge was created principally to preserve habitat for the endangered Masked Bobwhite (*Colinus virginianus ridgwayi*), and it also supports populations of the Pima pineapple cactus and the Cactus Ferruginous Pygmy Owl. I have treated the history and management of the Buenos Aires in detail elsewhere (Sayre 2002).

In the 12-year period from 1988 to 1999, the refuge conducted 84 prescribed fires, burning a total of 33,158 ha. Seven wildfires also occurred, burning 2332 ha. These figures represent areas actually burned, according to refuge records. The refuge fire plan calls for much larger areas to be burned (6000–8000 ha/year), and some USFWS publications (e.g., USFWS 2000) erroneously state that these plans have been implemented. The number of prescribed fires per year declined in 1993–1994 after the pineapple cactus was listed but subsequently increased above 1992 levels; no decline occurred after listing of the pygmy owl in 1997. The size of prescribed fires has increased since 1999 (S. Gall, personal communication). The refuge fire budget (1990–1995) averaged $191,000/year (USFWS 1995*a*), suggesting that refuge fires have cost ~$65/ha. (This figure includes overhead costs, which are not reflected in the costs for fires on Gray Ranch and the Malpai Borderlands.)

The potential effects of fire on threatened and endangered species have prompted a series of consultations between the refuge and the Arizona Ecological Services Office (AESO) of USFWS, which have resulted in several intraservice biological assessments and three biological opinions (USFWS 1994, 1995*b,* 2002*a*). The latter have all stipulated that burn units be surveyed for pineapple cactus and that individual cacti be protected by burning or mowing fire breaks around them before ignition. Surveys, however, have proved extremely labor intensive (>60 hours of staff time/located cactus in 1995 [USFWS 1995*a*]), feeding an ongoing dispute about the adequacy of actual survey efforts and of possible sampling techniques. Contrary to the refuge fire plan and the 1995 biological opinion, fire effects on the cactus and on Lehmann lovegrass were not monitored, or at least the AESO received no results (USFWS 2003).

The rationale for burning on the refuge is based on natural history. Because the semidesert grassland evolved with fire, it is presumed that fire is beneficial to native grasses, the Masked Bobwhite, and other native organisms. Livestock exclusion is premised on the same logic. Only anecdotal evidence has been presented to support these claims (USFWS 2000), however. "The effects of a decade of prescribed fire on the spread of Lehmann lovegrass has [sic] yet to be evaluated" on the refuge (USFWS 2003:9). Substantial experimental evidence from comparable sites indicates that fire benefits Lehmann lovegrass (Cable 1971; Ruyle et al. 1988; Sumrall et al. 1991; Anable et al. 1992), which is more widespread on the refuge than anywhere else in the valley.

Empirical evidence from the refuge either fails to support or contradicts natural historical inferences about fire, livestock grazing, native grasses, and listed species. Vegetation monitoring on the refuge has been insufficient to assess management effects with any confidence (Simms 1989), and the data that have been collected indicate no significant change in composition or density since 1985 (E. Geiger & G. McPherson, unpublished data). Surprisingly, researchers have found that captive-bred Masked Bobwhites released on the refuge disproportionately utilize Lehmann lovegrass and mesquite sites (King 1998; Guthery et al. 2000), suggesting that the fire program benefits the endangered bird only if it fails in its other stated objectives. Finally, two historical analyses concluded that large arroyos, which formed early in the twentieth century, altered the vegetation and microclimate of key breeding habitat (King 1998; Sayre 2002). The arroyos have not responded to livestock exclusion.

San Pedro Riparian National Conservation Area

The San Pedro Riparian National Conservation Area (NCA) is a ~23,000-ha site on the upper San Pedro River in southeastern Arizona. The NCA was continuously and heavily grazed before its acquisition by the BLM in 1987, and it is frequently cited as a paradigmatic case of the benefits of livestock exclusion for southwestern riparian areas and associated wildlife (Ohmart 1996). The Southwestern Willow Flycatcher is present in the area.

The effects of livestock exclusion on vegetation and avian species at the NCA were carefully monitored and recently analyzed (Krueper et al. 2003). The overall number of birds detected in surveys more than doubled from 1986 to 1990, and the density of herbaceous vegetation increased significantly in the riparian area and on adjacent mesquite-grassland terraces from 1986 to 1992. Shrubs and trees showed small (nonsignificant) increases in the

riparian area, as did low trees on the terraces. Unfortunately, more recent data are not available.

Vegetation in the surrounding uplands—which form the majority of the NCA—showed no significant response during the study period, with the density of small herbs actually declining and shrubs increasing. Detections of Brown-headed Cowbirds more than doubled. Meanwhile, the major threat to conservation of the upper San Pedro is now judged to be groundwater depletion caused by rapid residential population growth in the vicinity of the NCA (Rojo et al. 1998).

Discussion

The eight sites I examined are not representative of the Southwest as a whole, mainly because the sample was strongly skewed toward areas where fire is being investigated or implemented as a management tool. A complete survey would consider areas where fire restoration is impossible or unlikely because of inadequate herbaceous fuel loads, dangerously high woody fuel loads, or the presence of homes and other property. Nevertheless, the sites I reviewed suggest a number of provisional conclusions about the effects of landownership, land use, and threatened and endangered species on conservation practices and outcomes in the region.

First, there is significant interest and private-sector leadership in restoring fire to southwestern rangelands, except in major riparian areas and near houses. Ranchers and TNC appear particularly important in leading these efforts, with government agencies making uneven but significant progress in building the capacity to implement and permit prescribed fires. The lack of interest in burning major riparian areas is understandable given the risks involved and the ecological and aesthetic values of canopy cottonwood-willow forests in a desert environment. It may warrant reconsideration from a biodiversity conservation perspective, however. Canopy cottonwood-willow forests are not resilient to fire in the short term, but the riparian systems they inhabit did evolve with fire (Davis et al. 2002). Analysis of paired photographs indicates that the biomass of cottonwood and willow in southern Arizona more than doubled from 1890 to 1994 (Turner et al. 2003). There are other kinds of riparian habitat (e.g., sacaton [*Sporobolus wrightii* Munro ex Scribn.] flats and marshlands [Hendrickson & Minckley 1984; Davis et al. 2002]) that may deserve greater conservation attention and that are eminently adapted to fire.

Second, there is a pronounced shortage of predictive scientific knowledge about the effects of fire and livestock grazing on threatened and endangered species. That grazing replaced fire as a widespread disturbance for more than a century confounds simple inferences about their effects on threatened and endangered species. We cannot know a priori whether current populations are adapted to the twentieth-century disturbance regime, dependent on it, or threatened by it. Nor can we know, without careful research, if partial restoration of the earlier regime (i.e., restoring fire and continuing grazing) will help, hurt, or have no effect.

These problems can be overcome through carefully focused research efforts, for which private-sector leadership from conservation groups and landowners appears critical. Where populations of threatened and endangered species are very small or difficult to study, the need for cooperation among public and private stakeholders is especially great because predictive knowledge cannot be obtained through experimentation. Instead, adaptive management must be employed, meaning that actions must be taken based on available information and impacts determined after the fact (Walters & Hilborn 1978; Walters & Holling 1990).

Third, fire restoration is easier on lands that are either privately owned or not grazed; conversely, the presence of threatened and endangered species is more likely to interfere with fire restoration on grazed public lands. There are three likely explanations for this—less regulatory scrutiny of actions taken on private lands, greater herbaceous fuel loads on ungrazed lands, and greater confidence among regulators in the motives and expertise of nonranching landowners such as TNC or the USFWS. It is possible that legal challenges to livestock grazing on public lands have created an atmosphere in which fire restoration is scrutinized more critically when proposed by ranchers than by other parties. The majority of the region's land is public or grazed, however, and there is no obvious reason why ranchers who wish to use fire should be held to higher standards of ecological justification or regulatory compliance.

Fourth, collaborative management facilitates implementation of conservation practices, especially where landownership is mixed. The ecological and regulatory complexity of implementing conservation practices necessitates cooperation among diverse stakeholders. Where trust has developed, scientific uncertainty has been met with adaptive management and has resulted in generally satisfactory outcomes. Where trust and cooperation are lacking, opportunities to learn from management actions have been lost, perpetuating the problem of inadequate scientific information.

Fifth, permanent livestock exclusion is neither necessary nor sufficient for protecting threatened and endangered species. It is not necessary because periodic or temporary exclusion can suffice to allow vegetation to recover from grazing, including in riparian areas (Briggs 1996). It is not sufficient because in many cases other factors—arroyo formation, shrub encroachment, invasive species, or urbanization—have altered habitats in ways that will not respond to livestock exclusion. In the words

of Aldo Leopold (1924:7), "Wholesale exclusion of grazing is neither skill nor administration, and should be used only as a last resort."

Conclusion

The sites I examined can be arrayed along gradients of biophysical and social conditions that impede or facilitate successful fire restoration. The Gray Ranch sustains a predominantly natural fire regime at very low cost, made possible by its large size, isolation from human habitations, proactive management, private ownership, and a 50-year history of relatively frequent fires that have kept the vegetation resilient to burning. The other sites diverge from one or more of these conditions. Altered vegetation, public or fragmented landownership, threatened and endangered species, and livestock grazing make fire more difficult and costly to restore. Even if biophysical conditions are favorable, as at Empire Ranch, proximity to houses can make fire restoration effectively impossible.

The alignment of certain social factors helps enable fire restoration. Where landownership is mixed, cooperation and trust are critical even if threatened and endangered species are absent. Where threatened and endangered species are present, collaboration is needed even on single, private properties such as the U Bar to gather credible information, craft and support scientific research, and resolve management issues. The U Bar Ranch, Empire Ranch, Gray Ranch, and Malpai Borderlands demonstrate that fire, livestock grazing, and threatened and endangered species can be managed together successfully. To achieve results at a regional scale, however, planning and implementing fires will need to become more efficient and less expensive for such groups.

Historically, fire and commercial livestock grazing have been mutually exclusive on southwestern rangelands. With the arrival of ranching in the 1880s, fire frequencies dropped abruptly because of diminished fine fuels (Bahre 1991). The lack of fire, in turn, caused or contributed to widespread rangeland degradation (Bahre 1991; Swetnam & Betancourt 1998). At most sites, removing livestock for 1–2 growing seasons is necessary to accumulate fuel for fires. These considerations all suggest a conservation strategy based on livestock exclusion to enable fire restoration.

Because of interactions with land use and landownership, however, fire restoration may actually depend on continued livestock grazing combined with periodic exclusion. If livestock exclusion is permanent, it may result in subdivision and development of private ranch lands, foreclosing the option of fire there and on adjacent state and federal lands (Knight 2003). Periodic and carefully timed rest from grazing, rather than outright livestock exclusion, thus appears critical for long-term, large-scale conservation of southwestern rangelands.

Conversion of ranch lands to ungrazed conservation areas or refuges is not likely to occur on more than a fraction of the region. Even if it did occur more widely, conservation outcomes on nonriparian lands (which constitute >95% of the region) might be quite limited, judging from the San Pedro Riparian NCA and the Buenos Aires NWR. In any event, the claim that removing livestock will "heal" the damage of historical overgrazing in the Southwest is theoretically and empirically flawed. Grazing has been occurring for more than a century. During most of that period stocking rates were significantly higher than at present (Fredrickson et al. 1998) and grazing was generally year-round and continuous. The ESA does not apply retroactively to events that predate its passage, and it does not mandate restoration of presettlement disturbance regimes. If a listed species is found on grazed land and population trends at that site are unknown, abruptly excluding livestock may violate rather than uphold the precautionary principle.

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