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Transformations of the Chihuahuan Borderlands: grazing, fragmentation, and biodiversity conservation in desert grasslands

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Abstract

Environmentalists, scientists, and land managers have long debated the role of ranching in landscape conservation with some contending that ranching represents the major threat to ecological systems, while others believe it is key to long-term conservation. We contrast the impacts of livestock grazing with those of the major alternative land use at this time, suburban and ex-urban development, on the semi-arid Chihuahuan Desert grasslands and savannas of southern Arizona and New Mexico, USA, and northern Chihuahua and Sonora, Mexico. Because landscape change has resulted from complex interactions among natural and anthropogenic disturbances, attempts to identify simple causal relationships resulting from livestock are of limited ecological significance. Far more important is long-term conservation of basic ecological processes at large spatial scales, which in turn requires that certain social conditions be maintained. In the face of rapid, extensive suburban and ex-urban development in the region, conservation of functioning ranch units represents the most viable means of sustaining ecological function. Examples of community-based adaptive management illustrate the potential of coalitions of ranchers, agencies, scientists, and environmentalists to conserve biodiversity of these landscapes, protecting a matrix of publicly and privately owned land through an extension of UNESCOs biosphere reserve model. © 2002 Published by Elsevier Science Ltd.

Keywords: Grasslands; Ranching; Community-based conservation; Landscape fragmentation; Biosphere reserve

1. Introduction

The North American desert grasslands, like their counterparts in Africa, Asia and Australia, have long been shaped by the activities of humans (Curtis, 1956; Manning, 1997; Pyne, 1997). The effects of some activities have been extreme, as in the case of the extermination of mega-fauna by early inhabitants (Martin, 1984). Others, such as the fire practices of native Americans, have been more subtle but equally profound (Dobyns, 1981; Pyne, 1982). Although these transformation processes have been ongoing since the first arrival of humans thousands of years ago, the pace of change has increased dramatically in the period since Anglo-American settlement of the region in the second half of the 19th century (Hastings and Turner, 1965; Bahre, 1991).

In this case study, we examine two human interventions of significance to the recent history of desert grasslands in the southwestern United States (and indeed much of the American West): (a) large-scale cattle ranching, including its associated range improvements and management techniques, and (b) conversion of rangelands into smaller parcels for suburban and ex-urban real estate development. Ranching is the most extensive land use in the western United States, with well documented historical impacts across hundreds of millions of acres of arid and semi-arid rangelands; these impacts have led some environmental advocates and conservation biologists to advocate curtailing or eliminating livestock grazing to preserve native biodiversity (Fleischner, 1994; Donahue, 1999). Although more limited spatially and more recent than ranching, subdivision/suburbanization is rapidly expanding, altering large areas of crop and range land throughout the US. As competing land uses, ranching and real estate development constitute something of a dilemma for conservationists, captured in the phrase “cows versus condos” (Jensen, 2001; Sheridan, 2001). While major conservation organizations, such as The Nature Conservancy have made ranch conservation a focus of their western conservation efforts, some have denied the trade-off implied by the phrase (Donahue, 1999), while others have argued that suburban development is environmentally preferable to agriculture (Wuerthner, 1994).

Regardless of the point of view, the full ecological impacts of ranching and suburban development have yet to be assessed. Understanding the relations between ranching

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and subdivision requires historical, economic, and ecological analysis sensitive to the particular conditions of specific landscapes (Sayre, 2002). Here, we explore the dynamics and impacts of these activities in the Chihuahuan Desert grasslands and savannas located in southern Arizona and New Mexico, USA, and northern Chihuahua and Sonora, Mexico—an area we term the Chihuahuan Borderlands (Fig. 1).

The conservation importance or biodiversity of an organism or landscape reflects not just its total abundance, but also its relative abundance (or rarity), and its biological and cultural importance (Wilson, 1988). We have chosen to focus on the Chihuahuan Borderlands for several reasons. First, it is a region of extraordinarily rich biodiversity, lying at the juncture of six major biomes. Second, it has experienced dramatic environmental change in the past 140 years, much of it related to livestock grazing. Third, it was the site of seminal research in range science and extraordinary efforts at range restoration. Finally, it is home to some of the most creative and successful efforts to integrate ranching with conservation (Western, 2000; Curtin, 2002a).

Following a brief description of the area, the case study is divided into three main sections. First, we examine the effects of cattle ranching on the biodiversity of the border-

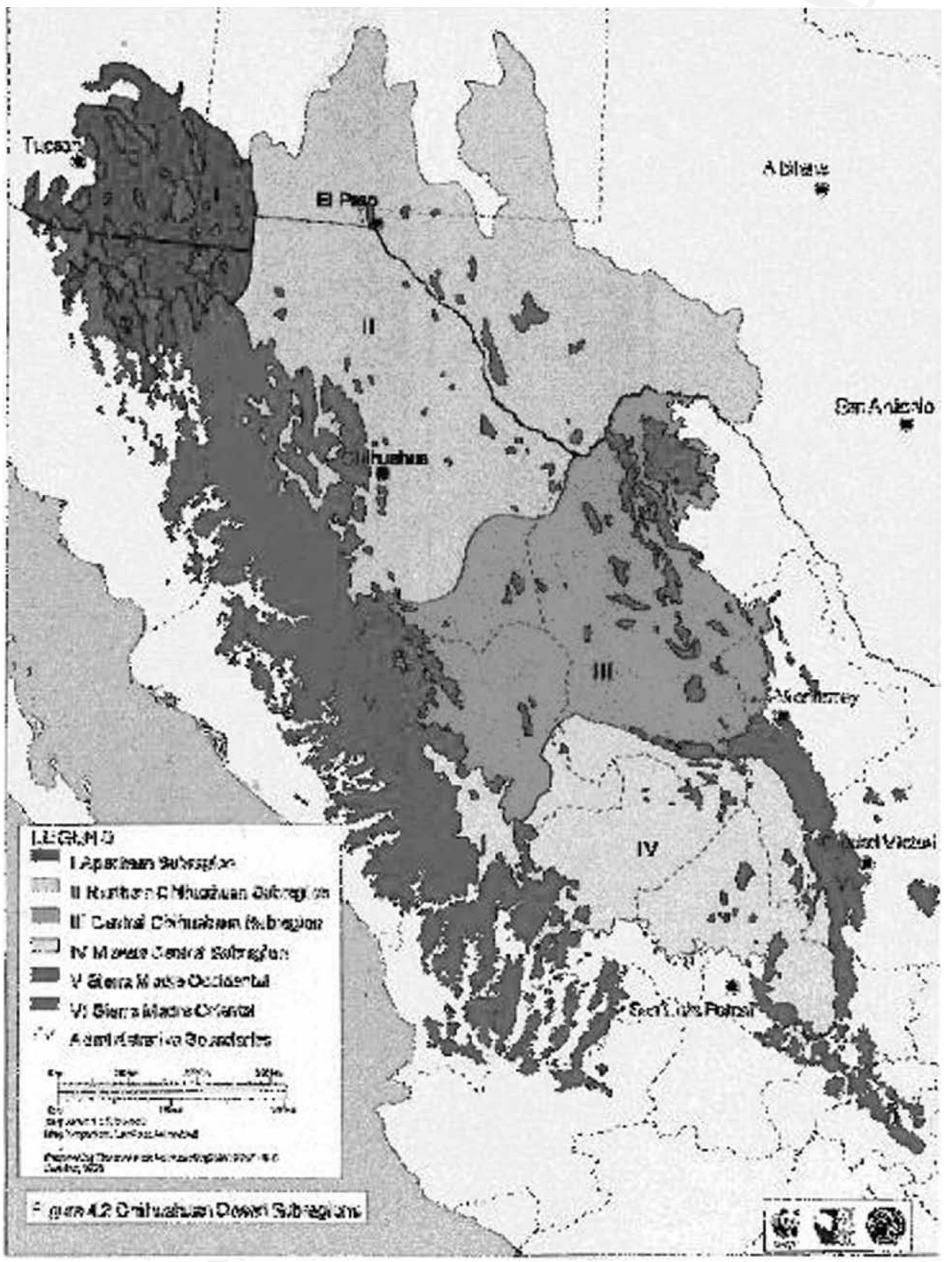

Fig. 1. This study focuses on the Mexico–US Borderlands between El Paso, Texas and Tucson, Arizona. The area encompasses the upper elevation Apachean subregion that includes mountains and adjoining grasslands and the lower elevation grasslands and shrublands within the northern portions of the northern Chihuahuan subregion (after Dinerstein et al., 2000).

lands, with particular attention to grazing, ranch management, and the evolution of scientific understanding of the area's ecosystems. Next, we consider the accelerating process of conversion of ranch lands to residential uses, focusing on underlying economic dynamics and ecological and cultural implications. The third section is devoted to initiatives and strategies employed by local communities to conserve both the biodiversity and the traditional ranching culture of the region. The case study concludes with a brief consideration of the environmental and social implications of the Chihuahuan Borderlands case for UNESCOs biosphere reserve concept. We suggest that the work being done by community conservation initiatives in the region is consistent with this approach and may serve as an example for biodiversity conservation beyond the network of formally recognized areas.

2. The setting

As defined by the World Wildlife Fund's Biological Assessment (Dinerstein et al., 2000), the Chihuahuan Desert covers 629,000 km^2 (243,000 square miles) in Mexico and USA. Though historically described as covering a smaller area (e.g. Brown and Lowe, 1980), according to the most recent analysis by Dinerstein et al. (2000), the Chihuahuan Desert ecoregion is a complex landscape matrix composed of a series of basins and ranges with a central highland extending from Zacatecas, Mexico, north to the southern edge of Albuquerque, New Mexico, USA, and from roughly El Paso, Texas, west to the valleys just above Tucson and Arizona (Fig. 1). The area contains not just desert shrublands, but also grasslands, cienegas and other riparian habitats, and montane woodlands. The Chihuahuan Desert is a high-elevation desert with typical elevations ranging from 600 to 1680 m (2000–5500 ft).

The Chihuahuan is one of the most diverse desert ecosystems in the world, rivaled only by the Great Sandy—Tanami Deserts in Australia and the Namib—Karoo of southern Africa (Olson and Dinerstein, 1998). It is world renowned as a center of diversity of cacti (family Cactaceae); many desert plants, fish, and reptile species show localized patterns of endemism and exhibit high turnover of species with distance (Dinerstein et al., 2000). The complexity of the freshwater fish assemblages is such that the Chihuahuan is the only desert ecoregion recognized for both freshwater and terrestrial biodiversity; this fact contributed to its being selected as a global priority conservation site in the World Wildlife Fund's Global 2000 analysis (Olson and Dinerstein, 1998). While the grasslands have a high affinity with the North American great plains, two-thirds of the grass species in Chihuahuan Desert grasslands are endemic (Burquez et al., 1998). A survey of Chihuahuan Desert flora and fauna is not complete, yet substantial inventories of the US portion of the desert (less than one-third of the deserts area) have documented approximately 2263 species of vascular plants, over 100 species of mammals and reptiles, 250 bird species, 20–25 amphibian species, and 250 species of butterflies (Dinerstein et al., 2000).

The grasslands and savannas of the Chihuahuan Desert, like arid and semi-arid ecosystems worldwide, have been disproportionately disturbed and/or destroyed by human activities and desertification (Sears, 1935; Curtis, 1956; Reisner, 1986; Manning, 1997). Between 25 and 50% of current shrublands (40% of the landscape) may have been grasslands as recently as 200 years ago. At present, approximately 20% of the landscape contains grasslands, but much of this area has a strong shrub component (Dinerstein et al., 2000).

We focus on the grasslands and savannas (including those that have converted to shrublands) of the northern Chihuahuan Desert, in southeastern Arizona and southwestern New Mexico. The diversity of this portion of the borderlands is arguably the highest on the continent (Brown and Kodric-Brown, 1995), because it lies at a biogeographic crossroads: the intersection of the Chihuahuan and Sonoran deserts, Sierra Madre and Rocky Mountains, and Great Plains and Great Basin grasslands and shrublands. In addition to being highly biodiverse, it also serves as a crucial corridor between the North and South American continents, and between some of these continents' major biomes (Gehlbach, 1981). As such, its conservation is essential to preserving dynamic evolutionary processes at a continental scale.

3. Transformation of the Chihuahuan Borderlands I: cattle ranching

Livestock grazing has been the most extensive land use in the Chihuahuan Borderlands region since the arrival of Europeans some 400 years ago. Yet the impacts of grazing have varied dramatically, depending on larger socio-economic and political circumstances. Haciendas established in the Spanish and Mexican periods were recurrently abandoned due to warfare with the Apaches; some historians have argued that there were large herds of cattle circa 1790–1830 (Morrisey, 1950), but more recent scholars dispute the claim (Sheridan, personal communication, 1998). In any case, while livestock have been documented to have had severe long-term impacts in areas with consistent long-term Spanish settlement, such as central Mexico and northern New Mexico (Melville, 1994), in most of the borderlands Spanish settlement was more ephemeral and livestock appear to have been restricted to areas near natural water sources with little evidence of widespread severe or enduring impacts (Morrisey, 1950; Bahre, 1991). In northern Mexico and the US where livestock production was not wholly for subsistence purposes, it remained a local commerce, usually associated with mining settlements.

3.1. The cattle boom

Following the Gadsden Purchase in 1854, construction of railroads into the area, and defeat of the Apaches, Anglo settlement increased rapidly in the 1870s and 1880s. A conjuncture of national and international factors resulted in a flood of livestock into the area, part of the "cattle boom" which spread north and west from Texas following the civil war (Osgood, 1929; Webb, 1931). Surpluses of investment capital in Great Britain and New England rushed to take advantage of free grass on the public domain; early profits of >25% per annum fueled a speculative bubble that overwhelmed native rangelands (Jackson, 1956; Atherton, 1961). Integrated into national and international markets, the livestock industry mushroomed: numbers in New Mexico increased from 41,000 cattle and 619,000 sheep in 1870 to around 800,000 cattle and 5 million sheep in 1885 (Fredrickson et al., 1998). Cattle in Arizona numbered approximately 38,000 in 1870; by 1891, there were roughly 1.5 million (Sayre, 1999).

The boom resulted in the paradigmatic tragedy of the commons (Hardin, 1968). Homesteading laws did not allow for claims large enough to support a household from livestock, and fencing of public domain was illegal. Consequently, settlers claimed areas around water sources and relied on adjacent, unregulated public range for grazing. Drought drastically reduced forage production in 1885 and again in the early 1890s, and market prices for cattle collapsed. Heavily indebted operators were reluctant to sell on the sagging market, and up to 75% of herds perished on the range during the great drought of 1891–1893 (Wagoner, 1961; Bahre and Shelton, 1996; Abruzzi, 1995). Photographs from the time show large areas, previously dominated by perennial grasses, reduced to bare ground. The cycle repeated two decades later: high prices during World War I sparked expansion, followed by drought and severe post-war agricultural depression, resulting again in severe overgrazing. Regulated leases for grazing were implemented on forest reserves after 1905; the desert grassland valleys remained open range until after 1912 (for State Trust Lands) and 1934 (for unclaimed federal lands, managed today by the Bureau of Land Management).

3.2. Range science

The discipline of range science was born in the aftermath of the cattle boom, as government agencies scrambled to mitigate the damage and put livestock production on a more stable foundation. The southwest was judged to be the most severely impacted region of the country, and much of the earliest research was conducted in the area (Chapline, 1944). Early studies estimated that carrying capacities had declined by >40% in Texas, and even more in Arizona and New Mexico (Smith, 1899; Griffiths, 1901; Wooton, 1908). Seminal work in these states (Bentley, 1898, 1902; Smith, 1899; Griffiths, 1901, 1904, 1907, 1910; Jardine, 1917) established the basic framework of range research and management for decades to come. The goal was invariably, and understandably, to restore rangelands to their "original capacity" (Bentley, 1902).

The paradigm that emerged from this work reflected two prior judgments. First, the researchers believed that removing livestock would reverse the damage that excessive grazing had occasioned. Short-term observations were generalized to conclude that recovery would occur in as little as 3 years of complete rest (Bentley, 1902; Griffiths, 1910). Recognizing that complete destocking was economically infeasible for ranchers, however, researchers sought ways of managing livestock that would permit ongoing recovery of forage species. The second judgment held that the cornerstone of reform would be exclusive grazing leases, which would enable investment in improvements and reward long-term stewardship while maintaining public ownership (Potter and Coville, 1905). Observations and measurements were used to determine fixed carrying capacities for specific range types, so that equitable and economical allotments could be assigned and administered. In this paradigm, "original" capacity represented a range's potential, while actual capacity served as a guide to prevent overgrazing; in theory, the two would converge over time as recovery proceeded.

These two judgments rested, in turn, on a set of assumptions that went more or less unchallenged in the emerging discipline: (1) that rangelands would never find a "higher" use than livestock production; (2) that spatial and temporal variability in forage production was of secondary importance, as much as it could be abstracted away in carrying capacity calculations and/or mitigated by improvements; (3) that the intensity of livestock grazing was the principal independent variable determining vegetation response on rangelands; and (4) that livestock exclusion would cause vegetation to revert to its earlier composition and density. The exact origins of these assumptions are obscure, but it is clear that they were imported to desert grasslands from elsewhere. The first was debated at the national level, among policy makers. It was advanced in the name of the Jeffersonian ideal of independent, democratic, family-scale producers (Potter and Coville, 1905). Adapting this vision to non-arable rangelands, where much larger areas of land were required to support a family, was problematic and grazing leases afforded a compromise with those who feared the creation of a quasi-aristocratic class of large property owners (Stegner, 1954). The other three derived from a venerable ideal (common to both oriental and western traditions) of the "balance of nature", which strongly colored scholarship in natural history and ecology (Worster, 1977; Wu and Loucks, 1995).

Early researchers in the southwest observed numerous phenomena that conflicted with assumptions (2–4). David Griffiths, for example, remarked on the role of fire in suppressing shrubs Griffiths (1910, p. 22), and on the temporal irregularity of perennial grass establishment Griffiths (1910, p. 12). Both Griffiths (1904) and Bentley (1902) noted the extreme variability of rainfall and biogeography in the region, which made calculating carrying capacities extremely difficult. Bentley (1902) and Jardine (1917) stressed the importance of timing (rest periods) for forage recovery. But researchers lacked a theoretical framework to explain these phenomena.

The framework that was available, and which was subsequently applied throughout the west, relegated these observations to the status of anomalies. It was developed by Clements and his colleagues at the University of Nebraska, based on work in the Great Plains (Tobey, 1981; National Research Council, 1994). Clements (1916) postulated a singular "climax community" of vegetation for any given site, determined by climatic and abiotic factors which were taken as static. As adapted for range management on National Forests by Arthur Sampson (1919), a student of the Nebraska school, the climax theory understood grazing as a counter-successional or retrogressive force, which pushed vegetation back along a linear series of potential communities. Most importantly for the present discussion, the Clements–Sampson model constructed grazing intensity as the key independent variable determining vegetation composition. It followed that livestock exclusion would result in a return to climax conditions. Mobilized through the administration of federal agencies and later quantified by Dyksterhuis (1949) (another Nebraska student), the Clements–Sampson model dominated range research and public lands administration for most of the 20th century. Its influence is best seen in the common practice of using livestock exclosures as controls, and/or contrasting different grazing intensities (light, moderate and heavy), in range science "experiments".

Within limits, the Clements–Sampson model did work in desert grasslands. Following overgrazing, native perennial grass species were often replaced by annual grasses, forbs, and unpalatable shrubs. Removing livestock allowed perennials to reassert themselves, a pattern that was slowed but not reversed—in the short-run, at least—where livestock numbers were reduced and carefully controlled (Griffiths, 1910). The failure of efforts to cultivate or otherwise reestablish native perennial grasses on Chihuahuan Desert grasslands may have added to the appeal of the Clements–Sampson model, which promised "natural" recovery of palatable species under proper management. Subsequent applied research focused on calculating carrying capacities and developing improvements, especially fencing, water sources, and methods of cultivating and/or stockpiling non-native cultivars for use in drought periods (Griffiths, 1910; Jardine, 1917; Thornber, 1910; Wooton, 1916).

Biodiversity was not a concern of early range scientists, and even today, research linking different range management strategies and measurements of biodiversity is lacking (Havstad and Coffin Peters, 1999). [1] Nevertheless, with the benefit of hindsight, it is clear that the Clements–Sampson model had a profound influence on southwestern rangelands. The construction of fences, for example—a necessary precondition for implementing the entire paradigm—gave ranchers direct financial incentive to suppress grassland wildfires, since early fence posts were made of wood (Sayre, 2002). The development of artificial water sources, distributed as evenly as the land and budgets would permit, affected both the distribution of grazing pressure and the distribution of other organisms on the landscape (Landsberg et al., 1997; McAuliffe, 1998). As greater regulatory control was established on federal lands after World War I (and later on state lands), grazing impacts became less locally severe, but more homogeneous and extensive. Stocking rates generally declined, partially counterbalanced by improvements that enabled grazing in previously unutilized areas (McAuliffe, 1998). "Improved" breeds were likewise promoted as a means of earning equal or greater returns from smaller herds.

The limits of the model were defined by other factors, however, which interacted with grazing in complex, unforeseen ways. Fixed carrying capacities were necessary for ranchers seeking credit from lending institutions, but they were highly misleading given the natural variability of forage production on desert grasslands. The same grazing intensity could have radically different impacts depending on the timing and quantity of precipitation. And some impacts—arroyo formation and shrub encroachment, for example—were non-linear in relation to grazing: reducing or removing livestock would not necessarily cause the damage to "heal". By mid-century, the model's shortcomings were obvious to ranchers and researchers familiar with southwestern desert grasslands. Encroachment by woody species (especially mesquite (*Prosopis* spp.), creosote (*Larrea* spp.), and acacia) was well advanced in much of the Chihuahuan Borderlands, by this time, even in areas excluded from livestock for many years. The need for fire to maintain desert grasslands was voiced (Humphrey, 1958), but it ran afoul of public sentiments and policies crafted for managing timber. Efforts to remove shrubs with bulldozers and chemicals implicitly challenged the prevailing paradigm, but a theoretical alternative would not emerge for several decades (Westoby et al., 1989).

3.3. *Consequences of grazing*

Clearly livestock grazing has the potential to damage desert grasslands. There is no disputing the historic contribution of overgrazing to arroyo formation, soil erosion, and vegetation change (Hastings and Turner, 1965; Cooke and Reeves, 1976; Bahre, 1991). Yet from the perspective of current conservation and management, the question must be how to conserve existing biological values and—if possible—restore those that have been degraded. What are the consequences of current grazing? What can be expected to happen if it is curtailed or eliminated?

Over the last decade, a number of efforts have been made to answer these questions using existing research and in-

[1] The intermediate disturbance hypothesis (Connell, 1978; Hobbs and Huenneke, 1992) would suggest that moderate grazing enhances biodiversity (Laycock, 1994). Research to test this is being conducted in short- to mid-grass prairies in Wyoming (Havstad, 2001, personal communication) and on the Gray Ranch in the Chihuahuan desert grasslands (Jensen, 2001; Curtin, 2002a), yet it remains largely untested.

formation. A committee of the National Research Council (1994) concluded that no rigorous, systematic assessment of range conditions in the US was possible, due to inconsistent methods and inadequate data. The data that do exist suggest that conditions have generally improved over the past 60 years, but that many rangelands remain degraded relative to their pre-settlement conditions (USDI BLM, 1997). Working from a global data set, Milchunas and Lauenroth (1993) found a pattern of increased sensitivity to grazing with increased aridity and/or lack of an evolutionary history of grazing, but no simple correlations between grazing and basic ecological indicators. Stohlgren et al. (1999) analyzed data from multiscale plots in and adjacent to 26 long-term grazing exclosures in central Rocky Mountain grasslands. They found no significant differences in species diversity, evenness, cover of different life-forms, soil texture, or soil percentage of N and C between grazed and ungrazed sites when examined at large scales (1000 m^2 plots). The effects of current grazing, they concluded, are highly variable, inconsistent, and probably minor compared to other disturbances. In a quantitative review of the literature, Jones (2000) found that grazing is most likely to impact soil related variables, followed by litter cover and biomass and rodent diversity and richness. More importantly, however, she found that most grazing studies did not follow basic experimental design requirements, or carefully document a range of different use and rest intensities, making it impossible to identify consistent responses to grazing even when statistically significant results occurred.

Taken together, these studies indicate that there are no consistent impacts associated with livestock grazing per se; that climate, substrate, evolutionary history, and other disturbance factors are often more important in determining vegetation response than the number—or presence—of livestock (Curtin, 2002b). In short, the ecology of rangelands cannot be comprehended through the tacitly Clementsian lens of grazing versus no grazing.

3.4. Consequences of dynamic interactions in the borderlands

In light of these findings, conservationists, land managers, and scientists need to focus their efforts not on the presence or absence of livestock, but on the interaction of grazing with other dynamic processes (Curtin, 2002b). The structure and composition of grasslands are outcomes of complex interactions among a finite set of variables including background factors (biological diversity, ecosystem resistance and resilience, geology, geography, and substrate) and dynamic driving forces including climate, fire, and herbivory (by both cattle and native species) (Frank et al., 1998; McPherson and Weltzin, 2000; Curtin and Brown, 2001). Conversion of grasslands to shrub-dominated communities through dynamic, non-linear processes exemplifies this newer understanding.

Comparisons of surveyor records and current vegetation (Kelt and Valone, 1995; Rich et al., 1999), and analysis of repeat photography and long-term data sets indicate that woody vegetation has expanded into grasslands over the last century (Glendening, 1952; Hastings and Turner, 1965; Buffington and Herbel, 1965; Grover and Musick, 1990; Schlesinger et al., 1990; Curtin and Brown, 2001). This trend is not limited to the late 1800s and early 1900s, but may have increased in many locations in the borderlands since the mid 1970s (Brown et al., 1997; Curtin and Brown, 2001)(Fig. 2). While researchers from the Jornada experimental range near Las Cruces, New Mexico, attribute increases there to growth of existing mesquite (Havstad, personal communication, 2001), vegetation transects from a site near Portal, Arizona, indicate an increase in shrub and sub-shrub number, not just shrub size (Quo et al., 1995). The data indicates that there are no consistent problems or solutions, but that numerous factors are involved that vary spatially and temporally.

3.4.1. Climate

Shrub increases and declines in grasses have occurred in both grazed and ungrazed sites, and are correlated with climatic shifts, suggesting that recent “desertification” (defined as increases in shrubs and declines in grasses) is not simply a result of grazing (by itself or in combination with drought). Rather, higher levels of winter rain, coupled with dry summers, appear to have favored shrub growth over grasses (Brown et al., 1997). Analysis of historical ground photography back to the 1880s in the Chiricahua Mountains documents an additional epoch of woody species increase in the 1920s and 1930s (Curtin, unpublished). This supports work by Neilson (1986) and Swetnam and Betancourt (1998), which indicates that these climatically driven vegetation patterns are cyclic and a pervasive part of southwestern ecosystems. Tree ring chronologies indicate that the recent high levels of rainfall have not occurred in nearly 2000 years (Swetnam and Betancourt, 1998) and thus represent an important perturbation within this system.

3.4.2. Fire

Fire was historically prevalent in most grasslands and woodlands in the borderlands region, and changes in vegetation are undoubtedly also associated with many decades of fire suppression (McPherson and Weltzin, 2000; Webster and Bahre, 2001). In the early 20th century, Griffiths (1910) observed that mesquite trees increased in grasslands after fire ceased to be common. Overgrazing in that period reduced fine fuels and thereby retarded fire spread. Later, fire suppression efforts and woody species encroachment had a similar effect, regardless of grazing pressure. In Mexico, by contrast, natural fire ignitions remained common in remote upland areas (grazed or ungrazed) (Swetnam et al., 2001). Today, however, the opposite pattern is beginning to emerge: greater fire suppression in Mexico (through direct

Faraway Ranch 1912. Arizona Historical Society # 63653.Photographer unknown

Faraway Ranch 1999. Photo by Charles Curtin

Fig. 2. Though the Chihuahua grasslands and associated montane ecosystems were dramatically altered in the late 1800s, this pattern of change has continued or even increased through the 20th century. For example, in the Chiricahua mountains sites, such as at Faraway ranch depicted above have undergone several epochs of vegetation change through the 19th and 20th centuries, with 28% cover by woody species in 1912, 35% in 1935, and 55% in 1999 (Curtin, unpublished). These cycles of vegetation change create the need for continual management to sustain borderlands ecosystems including restoration of fire, which requires open, unfragmented landscapes.

intervention or indirectly, through higher levels of grazing), while increasing efforts are made to restore fire to some US ecosystems.

While fire is considered essential to the survival of most grasslands (Manning, 1997; Pyne, 1997), the role of fire in desert grasslands has been questioned due to data indicating negative effects on black grama (*Bouteloua eriopoda*), a major desert grassland species (Reynolds and Bohning, 1956; Cable, 1965; McPherson, 1995; McClaran and Van Devender, 1995). Recent data from the Gray Ranch in New Mexico contradict this finding, and suggest that the negative effects documented in previous studies probably resulted from coincident drought conditions. Numerous vegetation transects in the Malpai Borderlands of southeastern Arizona and southwestern New Mexico indicate that vegetation response to burns is largely climatically driven, mediated by the timing and intensity of precipitation as much as by the fire itself. Grasses showed a strong positive response to fire when accompanied by relatively high soil moisture, and a neutral response or short-term declines during drought (Curtin, 2002c). These results are consistent with recent findings at the Jornada experimental range (Drewa, personal communication, 2001).

3.4.3. *Herbivory*

While the impact of cattle on vegetation composition has long been appreciated, recent studies have documented that native species may actually be more important in structuring desert ecosystems. Birds, insects, and small mammals have all been found to have major effects on vegetation and the biological diversity of arid lands (Crawford, 1986; Chew and Whitford, 1992; Hawkins and Nicoletto, 1992; Gibbons et al., 1993; Guo et al., 1995; Weltzin et al., 1997; Brown, 1998; Bock and Bock, 2000; Curtin and Brown, 2001).

Long-term studies by Curtin et al. (2000) indicate that small mammals are important in dampening the effects of recent climatically driven vegetation change. Increases in woody vegetation were much higher in small mammal exclosure plots than in adjoining control areas. This led Curtin and Brown (2001) to hypothesize that livestock grazing might have a similar effect. In a comparison of winter grazed rangeland near Rodeo, New Mexico, with an adjoining ranch ungrazed since the late 1960s, increases in woody vegetation were two-fold in the grazed habitat, and six-fold in the absence of grazing. This suggests that cattle grazing, like that of native species, may have served to mitigate vegetation change in the face of recent climatic patterns.

Livestock numbers in the Chihuahuan Borderlands during the cattle boom were sufficiently high that their impacts appear to have overshadowed (or overwhelmed) some of the other factors. But this is no longer the case. Today, ecologists recognize that the interactions among climate, fire, herbivory, and vegetation are neither linear nor deterministic, and that the precise outcome of a given interaction may never be precisely predictable. What is clear is that simply removing livestock will not, by itself, result in restoration of earlier conditions at most sites (Curtin, 2002b). As a recent state-of-the-knowledge review specific to the US–Mexico Borderlands concluded, "although livestock grazing (particularly in combination with other factors) played an important role in vegetation change shortly after Anglo settlement, excluding livestock from most sites now will have little or no impact on abundance of woody plants or non-native herbs during the next several decades" (McPherson and Weltzin, 2000, p. 4).

4. Transformation of the Chihuahuan Borderlands II: urbanization

If assumptions (2–4) were mistaken in desert grasslands from the beginning, assumption (1) held true until approximately 1970: arid and semi-arid rangelands had no "higher" value, economically speaking, than for livestock production. Since that time, however, another value has eclipsed livestock: real estate development. Today, the value of land for development can be 4–100 times its value for livestock production, even in remote areas. The consequences of land use conversion for biodiversity are not known in detail, but they are potentially severe and far less reparable than those associated with present livestock grazing (Havstad and Coffin Peters, 1999, p. 635).

4.1. Socio-economic causes of ranch conversions

The Chihuahuan Borderlands are undergoing unprecedented population growth. Between 1990 and 1995, border counties in Arizona, New Mexico, and west Texas had population growth rates of 2.5–13%. Arizona and New Mexico are among the fastest growing states in the US, with annual population growth rates in the 1990s of 11.2% (doubling time: 5.8 years) and 9.1% (doubling time: 7.9 years), respectively. This growth is disproportionately concentrated outside of existing urban boundaries (Atlas of the New West, 1997). In Chihuahua and Sonora, Mexico, meanwhile, border cities are rapidly expanding, a process accelerated by the North American Free Trade Agreement (NAFTA). Tens of thousands of Mexicans are migrating to these cities for industrial work as international competition and declining state subsidies render their previous agricultural livelihoods untenable.

Demographic growth alone cannot explain the urban boom, however. Even as the population of US metropolitan areas has increased, their population densities have generally declined, due to the enlarged home and lot sizes associated with suburban development ("sprawl"). A wide range of government policies—from highway construction and mortgage insurance to zoning and taxation—has enabled and/or encouraged this spatial pattern (McKenzie, 1994). As evidenced in marketing materials that promote a "ranching lifestyle", suburban development places a premium on physical isolation, views, wildlife, and other "amenity values" symbolically linked to the famous mythology of ranching (Sayre, 2002). Ironically, the development of "ranchettes" has come at the expense of actual working ranches, which declined by more than 100,000 (more than 10%) nation-wide between 1980 and 1996 (The Nature Conservancy, unpublished).

Ranches in the US are typically comprised of a patchwork of deeded land and leases to graze on state and/or federal lands. It is the deeded land that is immediately subject to subdivision and development; this is usually a minority of a ranch, though it may amount to tens of thousands of acres. Most deeded parcels were originally claimed under the various homesteading laws in effect between 1862 and 1934. As a result, they tend to be scattered across the landscape, wherever water could be found at that time. This means, moreover, that deeded acres tend to correspond with the areas of greatest ecological value or potential: riparian areas, springs and seeps, and floodplains. Larger ranches usually contain many old homesteads, consolidated over the years and managed as a unit within a matrix of state and federal lands (Sheridan, 2001).

Leases to graze on state or federal lands usually transfer when the deeded lands are sold. Their value at sale is determined by the productive capacity that they contribute to the ranch, calculated in animal units. In this way, leases form part of the equity value of the ranch even though the land remains publicly owned. When the number of animal units permitted under a lease decreases, this equity value diminishes proportionately.

Over the last four decades, ranches in the desert grasslands of southern Arizona and New Mexico have performed rather poorly when viewed as businesses. Cattle prices have steadily declined in real terms, meaning that returns have stagnated. Costs for labor, equipment, insurance, taxes, fuel and other inputs have increased. Meanwhile, the market value of ranches has increased, sometimes dramatically, in response to the area's growing population and demand for housing. The value of deeded acres for actual or potential development has come to define the market price of most ranches, especially near urban areas and along highway corridors. The combined result of these trends is that the rate of return-on-investment for ranching has dwindled to well below market norms (Martin and Jefferies, 1966; Starrs, 1998). Rates of return of less than 3% are common; in years of low rainfall and/or low market prices, many ranches lose money. A recent analysis of federal grazing permittees, based on a random sample survey, found that 50.4% of public land ranches depend on non-ranching income and can thus be classified as "hobby ranches" (Gentner, 1999).

Viewed as investments, however, ranches have been good long-term investments over the past 40 years. As cities have grown and expanded, land values have increased. Ranchers have become "land rich and money poor", and many have sold out at high prices, willingly or under pressure of debts or estate tax obligations. The majority of ranchers' equity now derives from the possibility of subdivision and development—in other words, terminating the ranch operation and converting to another land use.

Research conducted elsewhere in the west indicates that as landscapes become more suburbanized, increasing difficulties with ranching combine with growing expectations of lucrative land sales to make the ranching community more hostile to land use control. Escalating land prices increase the costs of incentive-based land conservation programs, and attrition of the ranching community threatens the economic and social viability of ranching. "There comes a point when the landscape begins to be widely recognized as 'urban' in character, rather than rural. At this threshold, ranchers shift from thinking about ranching as a long-term part of the landscape to a phenomenon moribund in their locale. Committed to ranching as a lifeway, they look elsewhere to continue it, less concerned with the future of the functionally compromised land they now occupy, and more concerned for the short haul with maintaining their opportunity to liquidate" (Liffmann et al., 2000).

Almost all ranches of any size in southeast Arizona and southwest New Mexico depend on state and/or federal grazing leases for their viability. The deeded lands are too small (and in many cases too fragmented) to sustain enough livestock to support a household. If the leases are lost or severely cut, the ranch's deeded acres are rendered valueless for ranching purposes. In most cases this leaves ranch owners little choice but to subdivide their private lands—or sell to someone who intends to subdivide—to secure their equity. Thus, stocking rate cuts—often imposed as a result of litigation by environmental groups—may actually accelerate the trend towards ex-urban development, especially in areas highly valued for their scenic beauty or recreational opportunities (Rowe et al., 2001).

4.2. Ecological consequences of ranch conversions

The subdivision of the grasslands into ranchettes affects biodiversity at two scales. At a local scale it changes species composition within a few hundred meters of a home. Odell and Knight (2001) studied the effects of ex-urban development in short-grass steppe of eastern Colorado, a grassland of comparable structure to many desert grasslands. They found that birds near ranchettes were of the same generalist species (e.g. robins, black-billed magpies, and brown-headed cowbirds) as found near higher density urban environments. Songbirds, such as blue-gray gnatcatchers, orange-crowned warblers and dusky flycatchers, were usually not present until hundreds of meters away from developments. Carnivores exhibited similar patterns, with domesticated species near homes and coyotes and foxes farther away. The effects of urbanization thus ramify beyond the boundaries of developed areas. Moreover, the species associated with ranchettes have been documented to depress populations of native species and overall biodiversity. Maestas and Knight are currently undertaking a study contrasting birds, carnivores, and plants in protected areas, ranches, and ranchettes. The initial results indicate that protected areas and ranches have comparable biodiversity and species composition, while in the vicinity of ranchettes the usual suite of generalist or domesticated species were documented (Knight et al., 2002). In short-grass prairie in eastern Colorado, Bock and Bock found reduced plant species diversity even in protected areas adjoining subdivisions (Bock, personal communication, 2000).

At a larger scale, and perhaps more importantly, ex-urban development tends to eliminate the possibility of restoring natural processes. While fire has been the dominant ecological process in many grassland and savanna ecosystems (McClaran and Van Devender, 1995; McPherson and Weltzin, 2000; Swetnam et al., 2001), under existing institutional arrangements it takes only a small number of homes to render fire management effectively impossible at the landscape level. Similarly, housing developments in former floodplains—where much deeded land is concentrated—frequently eliminate the option of healing arroyos and restoring pre-entrenchment hydrological regimes.

4.3. Strategies to slow fragmentation

At the regional level, the conversion of ranch lands to suburban uses is fundamentally driven by a decline in returns to livestock production relative to rising land values. Even lands remote from urban areas carry investment backed expectations of potential residential development, whether or not the present owner seeks to capitalize on them. On an individual or local level, these structural incentives are countered by a suite of personal, cultural, and environmental values that resist economic "rationality" (Gentner, 1999). Numerous studies have found that profit is not high among ranchers' motivations to continue ranching (Smith and Martin, 1972; Gentner, 1999; Liffmann et al., 2000; Rowe et al., 2001).

Effective strategies to slow fragmentation must address, and connect, both levels. Three strategies that have been employed in the Chihuahuan Borderlands are: (a) conservation easements and purchase of development rights (PDR) programs, (b) community-based conservation, restoration and science, and (c) grassbanking.

4.3.1. Conservation easements and PDR programs

Conservation easements and PDR programs are legal tools that remove development potential from a ranch's private lands in exchange for money and/or other consideration. Economically, this allows ranch owners to liquidate the speculative portion of their property values while retaining the agricultural value and the right to continue ranching. The value of an easement is generally understood as the difference between the present market value and the value of the land encumbered by the easement. This can range from 20 to 90% of the present market value of a ranch (Veslany, 2001).

Once the right to subdivide has been extinguished, the ranch's value rests on its productivity for livestock (and, potentially, other values not yet marketable, such as functioning watersheds, wildlife, etc.). This gives the ranch owner strong incentive to preserve and improve range conditions. In other words, these legal tools restore the incentive structure on which pre-World War II range policies were premised (see assumption (1) above).

Conservation easement and PDR programs have been established by a variety of private and public entities in the Chihuahuan Borderlands, although they are more recent and less well funded than their precursors in the eastern United States (Veslany, 2001). Aside from funding, the biggest obstacle these efforts face is that they can only cover ranchers' deeded acres. The state and federal lands that constitute the majority of most ranches cannot be so encumbered. Conservation of deeded ranchlands cannot succeed in the long-term unless public lands tenure issues are also resolved because ranchers are unlikely to sell or donate conservation easements on their deeded property if there is a reasonable chance of losing access to adjacent public lands. In that event, the deeded land would lose most or all of its value for livestock production, and its value for other purposes would be reduced or eliminated by the easement. Meanwhile, state trust lands must, by law, generate maximum revenue for beneficiaries and are thus subject to commercial or residential development. At present, the only solution to this dilemma is to do what the Malpai Borderlands Group has done: include an escape clause in the conservation easement, under which the easement terminates automatically in the event of loss of associated grazing leases.

4.3.2. Community-based conservation, restoration, and science

Community-based conservation focuses on local residents' roles and interest in maintaining the landscapes on which their livelihoods and values depend. It has been widely accepted and applied in developing countries (Western et al., 1994), but rarely employed in North America (Western, personal communication, 2000). A notable exception is the Malpai Borderlands Group, an organization dedicated to conservation of an 780,000 acre ecosystem in the Arizona–New Mexico Borderlands.

Incorporated as a non-profit in 1994, the Malpai Borderlands Group is an outgrowth of the traditional grazing association which worked to sustain the local community through cooperative land management and livestock marketing (Remley, 2000). Malpai ranchers had noticed a steady decline in grasslands relative to shrublands in their area and they determined that the reintroduction of fire was essential to preserving their landscape and a viable ranching economy (McDonald, 1996). What was new about the Malpai Borderlands Group was that its goals revolved around sustaining natural processes, in addition to the traditional goals of sustaining rural livelihoods. To achieve these goals they realized they needed the involvement of members of the scientific and conservation communities (Curtin, 2002a). The resulting emphasis on peer reviewed science and constructive interaction between local people and researchers is unprecedented in community-based conservation efforts (Western, personal communication, 2000). The Malpai Borderlands Group has demonstrated that collaboration can achieve conservation goals unobtainable by any of these groups working alone (Curtin, 2002a).

Numerous other community-based groups have emerged in recent years to address various dimensions of the ranching-conservation-subdivision situation in the Chihuahuan Borderlands region. Many are focused on particular landscapes (like the Malpai Borderlands Group) or watersheds: the Altar Valley Conservation Alliance, the Upper Gila Watershed Alliance, and the Catron County Citizens Group, for example. The Quivira Coalition, a non-profit based in Santa Fe, New Mexico, takes another approach. This cooperative organization of environmentalists, ranchers, and scientists, works to advance what it terms "The New Ranch" through meetings, publications, projects and workshops across the southwest. The New Ranch (Sayre, 2001) synthesizes recent models in range ecology with successful management practices developed by ranchers on the ground. Like the Malpai Group's efforts, The New Ranch is based on replacing confrontation with cooperation, and focuses on restoring ecological processes to sustain rural communities and open space (Winder, 1999). Quivira Coalition projects include reclamation of old mine tailings piles, riparian restoration, monitoring, drought management workshops, and efforts to resolve disputes between ranchers and government agencies.

4.3.3. Grassbanking

Communal management of rangelands and sharing of grazing rights has been a part of ranching cultures for hundreds of years (Starrs, 1998), while landscape rest and restoration programs have been a hallmark of progressive farm and rangeland policy since at least the 1930s (Sears, 1935; Manning, 1997). A recent integration of communal and government land management is the grassbank concept developed by the Malpai Borderlands Group. The grassbank is an area of rangeland (or a quantity of forage) set aside for community use; ranchers are encouraged to utilize the grassbank while their home range undergoes rest, fire, or other restoration treatments. In exchange, the rancher donates development rights, conservation easements, or in-kind conservation actions of equal value to the forage “withdrawn”. In addition to its direct value for range restoration, grassbanking is a first step toward landscape level adaptive management. Implicitly, it recognizes that many ranches are too small to be viable given the patchiness of rainfall and the variability of other resources in semi-arid and arid landscapes. The high cost of land makes it difficult or impossible for many ranches to expand; grassbanking allows for a flexible rescaling of social and economic systems to better accommodate the inherent dynamics of ecological systems.

5. Conclusion: the Chihuahuan Borderlands and the biosphere reserve concept

The goal of restoring degraded rangelands in the Chihuahuan Desert to their pre-Anglo-settlement conditions is as old as range science, and almost as old as commercial ranching itself. For most of the 20th century, the prevailing model in range science postulated that livestock exclusion would effect such a restoration; management practices and federal policies reflected this assumption, albeit constrained by economic and political imperatives. Decades of observations to the contrary have, in recent years, led to radically new models—as yet incompletely refined—which recognize domestic livestock grazing as only one, relatively minor factor in determining the vegetation, habitat conditions, and biodiversity of arid and semi-arid range ecosystems.

Today’s advocates of curtailing or eliminating livestock grazing have inherited the assumptions of the Clements–Sampson model, apparently without critical examination of its origins and limitations. Implicitly or explicitly, they call for the creation of more “protected” areas where human impacts would seemingly be excluded, in the belief that this would restore pre-settlement conditions and/or preserve biodiversity. While this may be true in some areas, it would not likely have the desired ecological effects in southwestern grasslands where current climatic conditions appear to be driving extensive vegetation change (Brown et al., 1997; Swetnam and Betancourt, 1998; Curtin and Brown, 2001). Its economic and cultural impacts, meanwhile, would be dramatic because subdivision of private lands would increase the level of fragmentation by orders of magnitude, effectively eliminating the use of tools that are critical to grassland and savanna conservation and ecological restoration. Finally, some argue that ranching should be terminated due to subsidization by the federal government. While certainly present, these subsidies amount to a fraction of those provided to other forms of agriculture in the US (Starrs, 1998). Industrialized countries have by-en-large determined that subsidizing agriculture to preserve open space in an appropriate use of public funds. Ironically, the creation of parks and restoration areas is perhaps the most expensive use of public dollars. For example, initial estimates from the borderlands indicate even if the Malpai Borderlands Group acquired conservation easements on all private lands within their working area, that perpetuating current public/private partnerships costs approximately a twentieth of the expense of removing local paroralists and instituting public lands management in the form of parks or wilderness areas (Western, personal communication, 2000).

On a more philosophical level, the oppositions posited between “protected” and “unprotected”, “natural” and “unnatural” warrant critical scrutiny in and of themselves. Chihuahuan Desert ecosystems, like other arid and semi-arid ecosystems worldwide, are sustained by climate and its interaction with fire and herbivory (Manning, 1997; McPherson and Weltzin, 2000; Curtin and Brown, 2001). None of these factors is purely “natural”; today we know that even climate is in some measure an artifact of human culture, and the structure and composition of grassland and savanna ecosystems at the time of European settlement were partially the result of burning and grazing practices by indigenous peoples (Curtis, 1956; Pyne, 1997). The key to preservation of grassland ecosystems lies not in creating more parks, but in preserving the semi-natural matrix that sustains landscapes and human cultural dynamics (Brown and Curtin, 2002). The laudable goals of conservationists cannot be achieved with fences and proscriptions but only with active, adaptive, collaborative management.

The Chihuahuan Borderlands case suggests that advocates of ecosystem conservation must move away from asking how small an area is sufficient to preserve populations of special interest species or their habitats, and instead ask how big an area is needed to preserve the dynamic interaction of natural processes that sustain a functioning ecosystem, including its human inhabitants. This approach to conservation is similar to UNESCOs biosphere reserves in that a diverse set of landscapes and cultures are protected within the context of a matrix of different land ownerships, rather than a single government controlled preserve. Community-based efforts in the borderlands area are demonstrating the viability of the biosphere approach in a social, political, and economic setting where it has not been deployed previously.

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