
Historic Distribution and Challenges to Bison Recovery in the Northern Chihuahuan Desert

RURIK LIST,^{*††} GERARDO CEBALLOS,^{*} CHARLES CURTIN,[†] PETER J. P. GOGAN,[‡] JESÚS PACHECO,^{*} AND JOE TRUETT[§]

^{*}Instituto de Ecología, Universidad Nacional Autónoma de México, 3er Circuito Exterior Ciudad Universitaria, Coyoacán, 04510 México, D. F. México

[†]Arid Lands Project, P.O. Box 29, Animas, NM 88020

[‡]USGS – Northern Rocky Mountain Science Center, Forestry Sciences Laboratory, Montana State University, Bozeman, MT 59717, U.S.A.

[§]Turner Endangered Species Fund, P.O. Box 211, Glenwood, NM 88039, U.S.A.

Abstract: *Ecologists and conservationists have long assumed that large grazers, including bison (Bison bison), did not occur in post-Pleistocene southwestern North America. This perception has been influential in framing the debate over conservation and land use in the northern Chihuahuan Desert. The lack of an evolutionary history of large grazers is being used to challenge the validity of ranching as a conservation strategy and to limit the protection and reintroduction of bison as a significant component of desert grassland ecosystems. Archeological records and historical accounts from Mexican archives from AD 700 to the 19th century document that the historic range of the bison included northern Mexico and adjoining areas in the United States. The Janos-Hidalgo bison herd, one of the few free-ranging bison herds in North America, has moved between Chihuahua, Mexico, and New Mexico, United States, since at least the 1920s. The persistence of this cross-border bison herd in Chihuahuan Desert grasslands and shrublands demonstrates that the species can persist in desert landscapes. Additional lines of evidence include the existence of grazing-adapted grasslands and the results of experimental studies that document declines in vegetation density and diversity following the removal of large grazers. The Janos-Hidalgo herd was formed with animals from various sources at the turn of the 19th century. Yet the future of the herd is compromised by differing perceptions of the ecological and evolutionary role of bison in the Desert Grasslands of North America. In Mexico they are considered native and are protected by federal law, whereas in New Mexico, they are considered non-native livestock and therefore lack conservation status or federal protection. Evidence written in Spanish of the presence of bison south of the accepted range and evidence from the disciplines of archaeology and history illustrate how differences in language and academic disciplines, in addition to international boundaries, have acted as barriers in shaping comprehensive approaches to conservation. Bison recovery in the region depends on binational cooperation.*

Keywords: Arid grasslands, *Bison bison*, Chihuahuan Desert, historic distribution, large grazers

Distribución Histórica y Retos para la Recuperación del Bisonte en el norte del Desierto Chihuahuense

Resumen: *Los ecólogos y conservacionistas han supuesto por mucho tiempo que los herbívoros mayores, incluyendo el bisonte (Bison bison), no habitaron en el suroeste de Norte América durante el post Pleistoceno. Esta percepción ha influido en el debate sobre la conservación y uso de suelo en el norte del Desierto Chihuahuense. La falta de una historia evolutiva de herbívoros mayores está siendo usada para desafiar la validez de la ganadería como una estrategia de conservación y para limitar la protección y reintroducción del bisonte como un elemento significativo de los ecosistemas de pastizales áridos. Los registros arqueológicos y los relatos históricos, desde AD 700 hasta el siglo diecinueve, en archivos mexicanos documentan que la*

^{††}email rlist@ecologia.unam.mx

Paper submitted December 18, 2006; revised manuscript accepted June 28, 2007.

distribución histórica del bisonte incluía el norte de México y áreas contiguas en Estados Unidos. La manada de bisontes de Janos-Hidalgo, una de las pocas manadas de bisontes libres en Norte América, se ha movido entre Chihuahua, México y Nuevo México, Estados Unidos, desde los 1920s por lo menos. La persistencia de esta manada transfronteriza de bisontes en los pastizales y matorrales del Desierto C demuestra que la especie puede persistir en paisajes desérticos. Líneas de evidencia adicionales incluyen la existencia de pastizales adaptados al pastoreo y los resultados de estudios experimentales que documentan reducciones de la densidad y diversidad de la vegetación después de la remoción de herbívoros mayores. La manada Janos-Hidalgo se formó a principios del siglo XIX con animales provenientes de varias fuentes. Sin embargo, el futuro de la manada está comprometido por diferentes percepciones del papel ecológico y evolutivo del bisonte en los Pastizales áridos de Norte América. En México, el bisonte es considerado nativo y está protegido por la legislación federal, mientras que en Nuevo México es considerado ganado no nativo y por lo tanto carece de estatus de conservación o de protección federal. La evidencia, escrita en español, de la presencia de bisonte al sur de la distribución aceptada y las evidencias arqueológicas e históricas ilustran que las diferencias de idioma y de disciplinas académicas, además de los límites internacionales, han sido barreras para la definición de métodos integrales de conservación. La recuperación del bisonte en la región depende de la cooperación binacional.

Palabras Clave: *Bison bison*, Desierto Chihuahuense, distribución histórica, herbívoros mayores, pastizales áridos

Introduction

The plains bison (*Bison bison bison*), a keystone species of the North American grasslands, was a central figure for the First Nations and an important and controversial part of the history of the colonization of western North America (e.g., Coppedge & Shaw 1997; Knapp et al. 1999; Truett et al. 2001). Historically the plains bison ranged, east to west, from the Allegheny Mountains to north-eastern California, Oregon, and southeastern Washington (Meagher 1986; Boyd 2003; Reynolds et al. 2003). The species occurred, north to south, from the western tip of Lake Superior to central Manitoba, Saskatchewan, Alberta, and eastern British Columbia south to the panhandle of Florida along the coast of the Gulf of Mexico to all but the southern tip of Texas and westward into Coahuila and Chihuahua. Yet the southwestward limit of distribution in southeastern Arizona and southwestern New Mexico and northwestern Mexico has long been controversial (e.g., Reed 1952; Bailey 1971; Findley 1987).

We examined evidence from the archeological literature and Mexican archives that expands the historic range of bison in desert grasslands. Our findings suggest that the perception of the range of the bison may have as much to do with cultural, linguistic, and intellectual barriers among people as the fundamental ecological barriers to bison.

Extensive archeological and ecological evidence and records from Mexican archives show that bison did, can, and do survive in arid and semiarid ecosystems. These findings represent a fundamental challenge to the hypothesis that southwestern ecosystems in North America have no recent evolutionary history of large grazers. This issue is of importance to both the ecology and conservation of these vast landscapes because it plays a pivotal role in the debate over how best to conserve these ecosystems

(Curtin et al. 2002), as the protection and reintroduction of grazers may be fundamentally important to sustaining the diversity and function of southwestern desert grassland ecosystems (Curtin & Brown 2001; Milchunas 2006).

Literature Review and Surveys

We undertook an intensive review of literature pertaining to the archeological and historical records of bison in northern Mexico, paying particular attention to Spanish-language publications. Over the years we have opportunistically gathered sightings of bison from local people. We also met with the owners of or workers on the three ranches and one ejido (communally managed property) where bison were reported to have occurred in Mexico, to ask where within these properties they had seen bison. We assembled available information on habitat characteristics, movement patterns, and genetics of bison that inhabit the Janos region of Chihuahua, Mexico, and Hidalgo County, New Mexico, United States. To determine the locations of bison along the Chihuahua–New Mexico border, we conducted three aerial surveys during July 2003, April 2004, and February 2006. Surveys were conducted 200 m above ground level along parallel aerial transects (separated by 1.5 km) from a high-wing Cessna 182. The surveys were conducted in the Animas Valley, between the foothills of the Animas and San Luis mountains in the west to the Hatchet Mountains in the east and from the Phelps Dodge Mine in the north to the Buenavista Agricultural area in the south. We attempted to count all bison in the surveyed area. Bison groups are easily spotted in the valley, but detecting them in the foothills is more difficult and underestimating numbers in those areas is likely. We reviewed the conservation and legal status of bison on both sides of the international boundary.

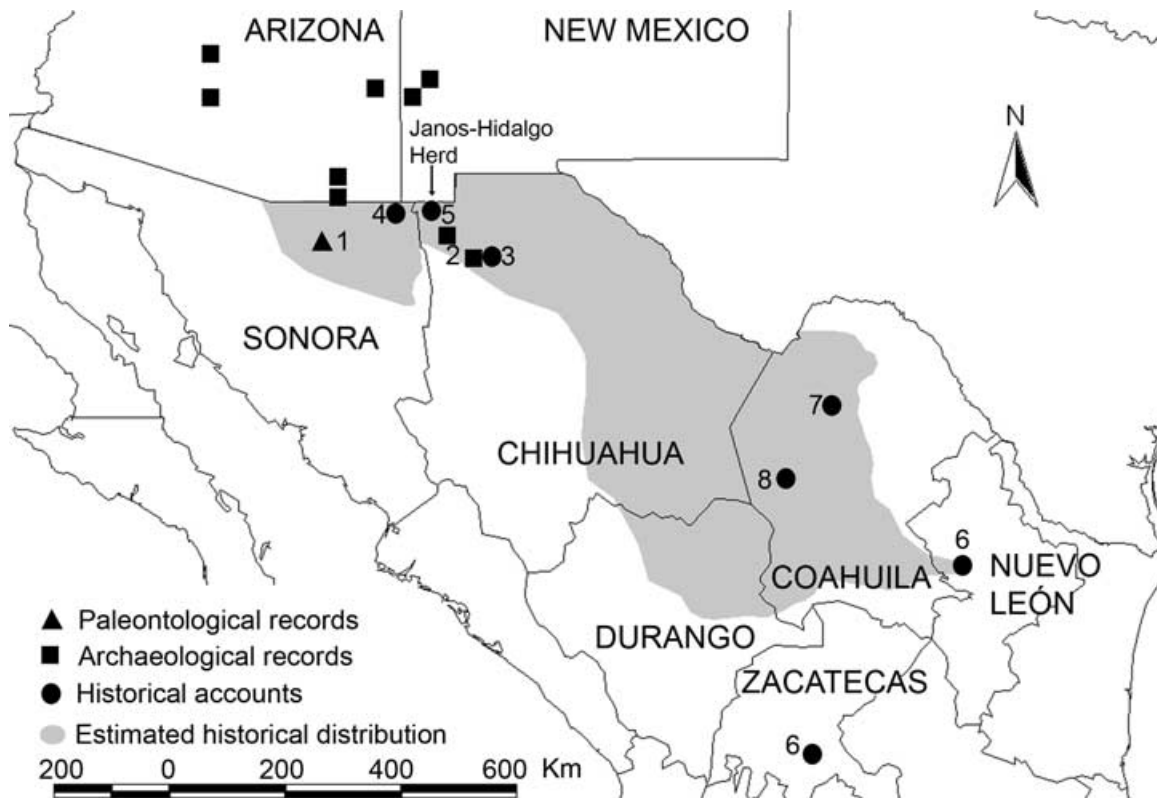


Figure 1. Locations of paleontological and archeological records, approximate location of sightings described in published historical accounts in Mexico, and estimated historical distribution of the bison (*Bison bison*) in Mexico. The estimated distribution does not include Zacatecas because the report was of domesticated bison. The locations of archeological records in the border region of the southwestern United States are from Truett (1996). Numbers indicate information sources: 1, Van Devender et al. (1985); 2, Di Peso et al. (1974); 3, Hammond and Rey (1928); 4, Treutlein (1949); 5, Bush Romero (1950); 6, Berlandier (1850); 7, Daugherty and López Elizondo (1997); 8, Wallace (1879).

Archeological Record

The archeological record we examined confirmed the late prehistoric and historic presence of bison in five states in northern Mexico. The oldest record (two molars and a phalange) from an individual of the genus *Bison* from this region came from Rancho La Brisca, Sonora, 180 km northeast of Hermosillo and 90 km south of the U.S. border at an elevation of 1000 m (Fig. 1). These specimens have not been identified to species or dated, but are believed to represent the presence of *Bison* <150,000 years ago (Van Devender et al. 1985). More recent records are from the municipality of Casas Grandes, Chihuahua, where remains of 6 modern bison of the Viejo Period (AD 700–1150) and 48 of the Medio Period (AD 1150–1450) were found in the Paquime archeological site (Di Peso et al. 1974; Fig. 1). Numerous bison bones were collected by E.B. Sayles from the neighboring municipality of Janos, 1.6 km east of Ejido Tres Alamos (Di Peso et al. 1974; site CH D:3:11 Gila Pueblo Archeological Survey, lot GP 39961; M. Jacobs, personal communication; Fig. 1). Archeological evidence of bison in southeastern Arizona and southwestern New Mexico, 200–300 km north

and northwest of Janos, during AD 0–1700 (Agenbroad & Haynes 1975; Truett 1996; Fig. 1) add to the evidence for the late prehistoric and early historic occurrence of bison in this borderland region.

Historical Record

We found only one report of bison in central Mexico. Berlandier (1850) mentions that two bison were used to pull a cart in the city of Zacatecas in the 17th century (Fig. 1), which suggests that bison ranged far south occasionally. In northwestern Mexico the first written accounts of bison date from the mid-16th century. In 1565 Baltazar de Obregón observed hides, bones, and bison droppings in the Paquimé ruins of Casas Grandes, Chihuahua, during an expedition with Francisco de Ibarra (Hammond & Rey 1928; Fig. 1). José Agustín Escudero (in Di Peso et al. 1974), who was Vocal of the Mexican Society of Geography and Statistics, visited the Casas Grandes region in 1819, where he saw and described bison. Escudero (1834) often mentioned the presence of bison in Chihuahua and described bison hunting and the use of

bison-leather pouches as Apache hair ornaments. A detailed report from Sonora, by Ignaz Pfefferkon, who lived for 11 years in Sonora as a missionary (~1756–1767) wrote, “In northeastern Sonora, in the uninhabited regions which border with the mountains of the Apaches [Fig. 1], there is a kind of wild cattle, called forest oxen by some, but known generally in Sonora and in the New Spain as *cibulos* or *ciboros* [*cíbolos*]. These animals have a fine, thick, curly hair rather like sheep’s wool but reddish-brown in color” (Treutlein 1949). In his account of Sonora, J. Escudero (1849) mentions bison as one of the game animals of Sonora.

The earliest historical report we found from bison in northeastern Mexico was from the 17th century, when Franciscan friars found bison in the valley of Monterrey (Berlandier 1850; Fig. 1). All other reports for this region are from the 19th century. The first account (Dobie 1953) indicated that bison hunting was common in Coahuila in 1806. From 1827 to 1829 Jean Louis Berlandier (1850) a physician-botanist of the Mexico–United States Border Survey, saw and hunted bison in Coahuila, Mexico, and reported their seasonal movement patterns. Escudero (1834) reported that wars among Apaches, Comanches, Mezcaleros, Faraones, Llaneros, and Lipanes were fought over control of the bison herds, which abounded in the territorial limits of these tribes in eastern Chihuahua and Coahuila. He also noted seasonality in the bison movements. General L. A. Guajardo (Daugherty & López Elizondo 1997) reported that a Lipan Indian from a party that attacked the Hacienda La Mota, Coahuila (Fig. 1), in 1848 was wearing a well-prepared bison pelt. Lew Wallace, Governor of New Mexico, killed a bison from a herd while taking part in a hunt near the town of Pararas, Coahuila, Mexico, in 1866 (Wallace 1879; Fig. 1).

History of the Borderlands Bison Herd

Apparently bison were extirpated from Coahuila toward the second half of the 19th century, but whether they persisted that long in the Janos-Casas Grandes region in Chihuahua is less clear. We think it most likely that bison disappeared from the Janos region after 1820 and that the present herd is derived from reintroduced animals. Nevertheless, the origin of these contemporary bison is unclear. On the one hand, there are verbal reports from a U.S. Immigration Officer stationed at the Antelope Wells Border Crossing, local Mexican people, and the New Mexico Fish and Game Department (J. Montoya, personal communication) that Mormons reintroduced bison to Janos at the beginning of the 20th century. On the other hand, bison from the House Rock Ranch in northern Arizona appear to have been moved to Chihuahua on two occasions, and it is presumed that some of those animals were the founders of the Janos-Hidalgo herd. The first movement of bison took place in 1924, when the Grand Canyon Cattle Company shipped about a dozen bison calves (Di

Peso et al. 1974; D.E. Brown, personal communication) to their affiliate ranch in Mexico. In 1949 bison from the House Rock Ranch were sent to Fort Huachuca, Arizona. When the fort was reactivated in 1955, the Arizona Game and Fish Department either gave 20 bison to the state of Chihuahua (Danz 1997; Arizona Game and Fish Department 2004) or sold them to a private individual. These bison could have been released at Janos (Anderson 1972; Arizona Game and Fish Department 2004). There is, however, one discrepancy: these 20 bison were reported as shipped to the state of Sonora (Dary 1989).

The information available on the bison at the House Rock Ranch and Fort Huachuca indicates that the herd was formed from individuals from different parts of the Great Plains. The bison herd from the House Rock Ranch came from animals captured in Kansas, Manitoba, Montana, and Texas by Charles Jesse “Buffalo” Jones in the late 19th century, who also did some experimental hybridization with cattle (e.g., Coder 1975; Gates et al. 2005). In 1941, 15 bison from Wichita Mountain, Oklahoma (herd formed from New York Zoological Society stock), were added to the herd, and 18 more were added in 1945 (Dary 1989). Fifteen bison, 1 and 2 years of age, from House Rock Ranch were donated to Fort Huachuca in 1949 (Arizona Game and Fish Department 2004; L. C. Jones, personal communication).

The lack of evidence for bison being moved to the Janos area by Mormons suggests that the origin of the Janos herd is from the House Rock Ranch bison brought to the region in the 1920s. Support for this idea comes from a published report of a bison hunt in Janos in the 1930s (Bush-Romero 1950; Fig. 1). It is also likely that the bison given to the state of Chihuahua in the 1950s were incorporated into the Janos herd (Anderson 1972; Arizona Game and Fish Department 2004; D. E. Brown, personal communication). Nevertheless, Dary (1989) mentions that the animals (20) were sent to Sonora, reinforcing the idea that the Janos bison were the result of the 1920s reintroduction. By 1957 the Janos bison were well established. At that time S. Anderson (1972) observed around 40 bison close to the headquarters of Rancho San Francisco in the Janos region and was told that the bison had been reintroduced a few years earlier. It is remotely possible that some individuals from ancestors present at European contact survived in the area and provided additional genetic variability to the herd. It is fundamental to conduct more genetic analyses of individuals in the herd as a basis for future management.

Current Range and Habitat Use of the Borderlands Herd

In our July 2003 aerial surveys we counted 94 individuals, 80 adults and juveniles, and 14 calves in three groups ranging from 12 to 57 animals, all on a private ranch in New Mexico. In April 2004 the bison were much more scattered. We recorded 128 bison in 10 groups, ranging

from 2 to 37 animals; 6 and 65 on the two private ranches in New Mexico, respectively, and 57 on a private ranch in Chihuahua. More recently, in February 2006 we counted 136 individuals, 97 adults, and 39 juveniles (yearlings and calves). Over 200 bison have been reported in recent years. The bison are hunted on both sides of the border, which suggests these numbers are not a reflection of ecological constraints but rather of hunting pressure.

Based on the aerial surveys, ground-based surveys, and on reports from local residents, we believe the area inhabited by contemporary bison extends in the United States from the eastern foothills of the Animas Mountains to the western and southern foothills of the Hatcher Mountains in New Mexico. In Mexico the range includes the foothills and adjacent grasslands of the Sierra Madre Occidental of northwestern Chihuahua and extreme northeastern Sonora. The entire range lies between approximately 31° and 31°40'N and 108°15' and 108°40'W at an elevational range of 1350–1550 m.

The habitat occupied by the bison is a large plain with a mosaic of vegetation types, mainly grasslands, characterized by blue grama (*Bouteloua gracilis*), sideoats grama (*B. curtipendula*), hairy grama (*B. hirsuta*), poverty threeawn (*Aristida bamulosa*), toboso (*Hilaria mutica*), and fescue (*Festuca* sp.). The historically expanding shrub component is dominated by mesquite (*Prosopis glandulosa*) and includes Mormon tea (*Ephedra trifurca*), cholla (*Opuntia imbricata*), and broom snake-

weed (*Gutierrezia sarothrae*) (Brown 1994; Ceballos et al. 2005). In the foothills and in the ecotone between grasslands and oak forests, the primarily seasonal streams are framed by riparian vegetation dominated by sycamore (*Platanus wrightii*), walnut (*Juglans major*), willows (*Salix* spp.), oaks (*Quercus* spp.), and alligator juniper (*Juniperus deppeana*) (Ceballos et al. 2005). Agricultural lands currently cover a small part of the area but are expanding rapidly, particularly in the southwestern portion.

The land in the United States is privately owned. In Mexico the lands are a mixture of private and ejido (communal) land. The dominant economic activity on both sides of the border is cattle ranching, and Mennonite communities control some lands in Mexico that are predominantly devoted to agriculture. The private ranchers in the United States and Mexico do not like bison moving across their lands because bison knock down fences (including the international border fence) and are thought to compete with cattle for grass. In Mexico the bison are occasionally shot or trapped illegally despite their protected status (SEMARNAT 2002). In New Mexico bison are legally classified as livestock and are hunted to provide additional ranch income. The owners of one of the two ranches in the United States used by the bison pays agricultural taxes for and thus claims ownership of some of the bison, but the New Mexico Highway Department suggests that free-ranging bison are common enough to justify multiple highway signs (Fig. 2). In 1998 part of the



Figure 2. Evidence that the New Mexico Highway Department recognizes that there are free-ranging bison in the borderlands between New Mexico and Mexico (even if New Mexico Department of Fish and Game does not).

Janos-Hidalgo herd, largely composed of cows and calves, was held within an electrified enclosure on a ranch on the U.S. side of the border. By 2002 the animals appeared to be moving freely again, but the present treatment of bison on this ranch is unknown. Because of the bison's status as an endangered species in Mexico and the cross-border migratory patterns of this herd, the Institute of Ecology of the National University of Mexico (UNAM) are advocating for legal protection of the herd in both countries, including protection under the international treaties on migratory wildlife species between Mexico and the United States.

Grazing and Grazers in Northern Mexico and the Southwestern United States

The evolutionary history of grazing is a prime determinant of the impact of grazing on vegetation composition (Milchunas & Lauenroth 1993; Milchunas 2006). The primary vegetation type in the areas where the Janos-Hidalgo herd roams is *Bouteloua* (grama grass), which is part of a family that is adapted to herbivory (Milchunas 2006). This family in general and grazing-adapted blue grama (*Bouteloua gracilis*) in particular (e.g., Milchunas 2006) are widespread throughout much of the borderlands (P. Sundt, unpublished data). Therefore the vegetation composition of the region suggests a long coevolution with large grazers and an ecological affinity with herbivory-adapted plains ecosystems (e.g., Brown & Lowe 1980; Milchunas 2006). The response of vegetation to grazing in controlled experiments further supports this evidence that southwestern ecosystems are adapted to large grazers. An experimental study on rangelands 10 km west of areas currently inhabited by the Janos-Hidalgo bison herd (C. Curtin, unpublished data) documented significantly lower diversity of native species and a lower rebounding of biomass following drought in areas protected from grazing by enclosure compared with grazed areas ($p < 0.05$). Recent studies in northern Arizona (Loeser et al. 2007) also document negative responses of vegetation following removal of large grazers (e.g., cattle). The results of both these studies are especially striking because the studies were conducted during a drought, when the negative impacts of herbivory would be most pronounced (e.g., Milchunas & Laurenroth 1993).

Long-held ideas about the role of bison in the southwest appear to be, at least in part, a reflection of interdisciplinary and linguistic barriers. Although not widely cited in the English-speaking literature, there are Spanish-language accounts of bison, and not all have English translations. Within the books printed in Spanish before 1900 at the National Institute of Anthropology's Library in Mexico City that make reference to northern Mexico, we found two volumes without English translations that give important and recent information on the bison in northwestern Mexico (Escudero 1849, 1934). In addition, the

people we interviewed at three of the four properties in Mexico where bison occur spoke only Spanish. Much of the archeological evidence is not widely cited in the biological literature, despite representing scientifically accepted records of the presence of species. In addition, many historic documents translated into English that report the presence of bison in northern Mexico are also not cited. This has led to widely differing perceptions of the role of bison in desert grasslands. In Mexico bison are extended full protection as a rare and ecologically significant species, whereas north of the border, bison are essentially considered an exotic species and afforded the same status as livestock. Because bison are not considered wildlife in New Mexico they could be removed by landowners, which would eliminate nearly a century of bison movements in the area.

The loss of bison has much broader significance for the restoration and maintenance of desert grasslands in general for several reasons. First, livestock ranching continues to be one of the most controversial land uses in the southwest, with proponents identifying it as key to preserving landscapes and critics citing it as a major threat (Curtin et al. 2002). The evolutionary-history argument frequently appears as a major justification for the elimination of ranching in the southwest. Just as often, it is argued that bison did not exist in desert grasslands and thus should not be "restored." This argument has important implications for the overall restoration of southwestern grasslands because the presence of bison would significantly affect the structure of grasslands (Knapp et al. 1999). Although the foraging impacts of bison and cattle are similar (Milchunas 2006), except for that on riparian areas (Trimble & Mendel 1995; Belsky et al. 1999), one aspect of bison's impact on landscape composition may be different. Buffalo wallows were a ubiquitous landscape feature described by many early travelers of the plains. Although some differences in plant diversity exist, these areas do hold water and create ephemeral pools during the wet season (Collins & Uno 1983; Polley & Collins 1984; Knapp et al. 1999). Thus, it is plausible that this additional water-holding capacity could be an ecologically significant feature in arid and semiarid landscapes.

Four lines of evidence strongly support the idea that bison had a significant presence in the desert grasslands that are now part of northern Mexico and the southwestern United States west of the Pecos River. First, archeological evidence and historical records extensively document bison in desert grasslands extending as far west as central Arizona. Especially detailed archeological evidence is associated with the Casas Grandes culture of northern Mexico. Second, despite hunting pressure, bison have persisted in the region of northern Chihuahua, Mexico, and southern New Mexico, United States, for at least 80 years. Third, the vegetation of the region encompassing Chihuahua and Sonora, Mexico, and Arizona and New Mexico, United States, contains dominant vegetation

types that are considered to have coevolved with large grazers. Finally, replicated experiments of large grazers, even in periods of extreme drought, document a significant positive response to grazing and a negative response to the removal of large herbivores. Taken together these lines of evidence strongly support the contention that bison were once an integral part of southwestern grasslands.

Conclusions

The World Conservation Union Bison Specialist Group recognizes the Janos-Hidalgo herd as within the historical range of the bison (<http://www.notitia.com/bison/AboutBison.htm>), and bison specialists have extended their definition of the southwestern range of bison west to the San Pedro River in Arizona, adding millions of acres of potential bison habitat (Sanderson et al. 2007). The addition of bison to desert grasslands has immense potential to add to the cultural and ecological richness of the southwest. The Janos-Hidalgo herd has the potential to provide some of the necessary genetic material and the associated physical adaptations that could help bison survive and flourish at the southwestern edge of their range. A broader view of the range of bison is key to restoring this cultural and ecological keystone species and the ecosystem it inhabits. The above discussion highlights the importance of developing more effective cross-boundary conservation and argues that conservationists and researchers need to collaborate more broadly and work across disciplines. In the case of this paper, international cooperation between the authors lead to a much broader understanding than would have been possible under conventional approaches drawn along institutional or international boundaries.

Provided adequate protection and sound conservation strategies, large mammals can survive across international borders, as exemplified by migrations of wildebeest (*Connochaetes taurinus*) across the international boundary between Tanzania's Serengeti National Park and Kenya's Masai Mara National Reserve and the Porcupine caribou (*Rangifer tarandus*) herd of Alaska and the Yukon, Canada. Transboundary protected areas and peace parks are being considered as an alternative for wildlife conservation for African wildlife, where neighboring countries are trying to eliminate fences and link the protected areas to be managed as a unit (Hanks & Charlton 2003). A joint fact-finding process (e.g., Karl et al. 2007) to develop a comprehensive conservation plan on both sides of the border that protects the bison and the livelihoods of people within the range of the Janos-Hidalgo herd could be an impetus for the necessary cooperative work that would ensure the recovery of the bison across the neighboring nations.

Acknowledgments

S. Lanham from Environmental Flying Services flew us in her plane for the aerial surveys. K. Pelz, E. Ponce, and R. Sierra participated on the aerial surveys. J. Arroyo Cabrales, D. E. Brown, M. Jacobs, and J. Montoya provided useful information for the manuscript. I. Salazar helped with the map. E. Main and two anonymous reviewers provided useful comments that improved the manuscript. Funding came from The J. M. Kaplan Fund, Denver Zoological Foundation, Wildlife Conservation Society, Dirección General de Apoyo al Personal Académico-Universidad Nacional Autónoma de México, and the Turner Foundation.

Literature Cited

- Agenbroad, L. D., and C. V. Haynes. 1975. *Bison bison* remains at Murray Springs, Arizona. *Kiva* 40:309-313.
- Anderson, S. 1972. Mammals of Chihuahua. *Bulletin of the American Museum of Natural History* 148:149-410.
- Arizona Game and Fish Department (AGFD). 2004. Game buffalo. AGFD, Phoenix. Available from http://www.azgfd.gov/h_f/game_buffalo.shtml (accessed February 2007).
- Bailey, V. 1971. Mammals of the southwestern United States (with special reference to New Mexico). Dover Publications, New York.
- Belsky, A. J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. *Journal of Soil and Water Conservation* 54:419-431.
- Berlandier, J. L. 1850. Journey to Mexico during the Years 1826 to 1834. S. M. Ohlendorf, J. M. Bigelow, and M. M. Standifer, translators. 1980. **Volume 2**. Texas State Historical Association, Austin.
- Brown, D. E. 1994. Grasslands. Pages 107-141 in D. E. Brown, editor. *Biotic communities. Southwestern United States and northwestern Mexico*. University of Utah Press, Salt Lake City.
- Brown, D. E., and C. H. Lowe. 1980. *Biotic communities of the Southwest*. General technical report RM-70. U.S. Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station, Ogden, Utah.
- Boyd, D. 2003. Conservation of North American bison: status and recommendations. M.S. thesis. University of Calgary, Alberta.
- Bush-Romero, P. 1950. México y África desde la mira de mi rifle. (No Press data printed on book.) In the collection of Naturalia A.C., Mexico, D.F.
- Ceballos, G. R. List, J. Pacheco, P. Manzano, G. Santos, and M. Royo. 2005. Prairie dogs, cattle and crops: diversity and conservation of the grassland-shrubland habitat mosaic in northwestern Chihuahua. Pages 424-438 in J. L. E. Cartron, G. Ceballos, and R. S. Felger, editors. *Biodiversity, ecosystems, and conservation in northern Mexico*. Oxford University Press, Oxford, United Kingdom.
- Coder, G. D. 1975. The national movement to preserve the American buffalo in the United States and Canada between 1880 and 1920. Ph.D. thesis. The Ohio State University, Columbus.
- Collins, S. L., and G. E. Uno. 1983. The effect of early spring burning on vegetation in buffalo wallows. *Bulletin of the Torrey Botanical Club* 110:474-481.
- Coppedge, B. R., and J. H. Shaw. 1997. Effects of horning and rubbing behavior by bison (*Bison bison*) on woody vegetation in a tall-grass prairie landscape. *American Midland Naturalist* 138:189-196.
- Curtin, C. G., and J. H. Brown. 2001. Climate and herbivory in structuring vegetation of the Malpai borderlands. Pages 84-94 in C. J. Bahre and G. Webster, editors. *Changing plant life of La Frontera: observations of vegetation change in the United States/Mexico borderlands*. University of New Mexico Press, Albuquerque.

- Curtin, C. G., N. F. Sayre, and B. D. Lane. 2002. Transformations of the Chihuahuan borderlands: grazing, fragmentation, and biodiversity conservation in desert grasslands. *Environmental Science and Policy* **5**:55–68.
- Danz, H. P. 1997. *Of bison and man*. University Press of Colorado, Boulder.
- Dary, D. A. 1989. *The buffalo book: the full saga of the American animal*. 2nd edition. Swallow Press, Ohio University Press, Athens.
- Daugherty, F. W., and L. López Elizondo. 1997. New light on Chisos Apache Indian Chief Alsate. *The Journal of Big Bend Studies* **8**:33–49.
- Di Peso, C. C., J. B. Rinaldo, and G. J. Fenner. 1974. Casas Grandes, a fallen trading center of the Grand Chichimeca. Volume 8. Northland Press, Flagstaff, Arizona.
- Dobie, J. Frank. 1953. Bison in Mexico. *Journal of Mammalogy* **34**:150–151.
- Escudero, J. A. 1834. Noticias estadísticas del Estado de Chihuahua. Reimpresión por orden del supremo gobierno, Mexico.
- Escudero, J. A. 1849. Noticias estadísticas del estado de Sonora y Sinaloa. Tipografía de R. Rafael, Mexico.
- Findley, J. S. 1987. The natural history of New Mexican mammals. New Mexico Natural History Series, University of New Mexico Press, Albuquerque.
- Flores, D. 1991. Bison ecology and bison diplomacy: the southern plains from 1880 to 1850. *Journal of American History* **78**:465–485.
- Gates, C. C., B. Stelfox, T. Muhly, T. Chown, and R. J. Hudson. 2005. The ecology of bison movements and distribution in and beyond Yellowstone National Park. University of Calgary, Calgary, Alberta.
- Isenberg, A. C. 2000. *The destruction of the bison: an environmental history, 1750–1920*. Cambridge University Press, Cambridge, United Kingdom.
- Hammond, G. P., and A. Ray, translators and editors. 1928. *Obregon's history of 16th century explorations in western America: chronicle, commentary, or relation of the ancient and modern discoveries in New Spain and New Mexico, 1584*. Wetzel Publishing, Los Angeles, California.
- Hanks, J., and S. Charlton. 2003. Fauna de las praderas africanas. Pages 111–116 in R. A. Mittermeier, P. Robles Gil, C. A. Mittermeier, M. Hoffmann, W. R. Konstant, G. A. B. Da Fonseca, and Y. R. B. Mast, editors. *Grandes espectáculos del reino animal*. CEMEX-Agrupación Sierra Madre, Mexico City.
- Karl, H., L. E. Susskind, and K. H. Wallace. 2007. A dialogue not a diatribe: effective integration of science and policy through joint fact finding. *Environment* **49**:20–34.
- Knapp, A. K., J. M. Blair, J. M. Briggs, S. L. Collins, D. C. Hartnerr, L. C. Johnson, and E. G. Towne. 1999. The keystone role of bison in North American Tallgrass Prairie. *BioScience* **49**:39–50.
- Loeser, M. R., T. D. Sisk, and T. E. Crews. 2007. Interactions of drought and cattle grazing intensity affect plant diversity in an Arizona grassland. *Conservation Biology* **21**:87–97.
- Meagher, M. 1986. *Bison bison*. *Mammalian Species* **266**:1–8.
- Milchunas, D. G. 2006. Responses of grazing communities to grazing in the southwestern United States. General technical report RMRS-GTR-169. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado.
- Milchunas, D. G., and W. K. Laurenroth. 1993. Quantitative effects of grazing on vegetation and soils over a global range of environments. *Ecological Monographs* **63**:327–366.
- Polley, W. H., and S. L. Collins. 1984. Relationships of vegetation and environment in buffalo wallows. *American Midland Naturalist* **112**:178–186.
- Reed, E. K. 1952. The myth of Montezuma's bison and the type locality of species. *Journal of Mammalogy* **33**:390–393.
- Reynolds, H. W., C. C. Gates, and R. D. Glahot. 2003. Bison. Pages 1009–1059 in G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. *Wild mammals of North America*. 2nd edition. The John Hopkins University Press, Baltimore, Maryland.
- Sanderson, E. W., et al. 2007. *The Ecological Future of the North American Bison: Conceiving Long-term, Large-scale Conservation of Wildlife*. *Conservation Biology*: In press.
- SEMARNAT (Secretaría del Medio Ambiente y Recursos Naturales). 2002. Norma Oficial Mexicana NOM-059-ECOL-2001, Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo. *Diario Oficial de la Federación* **582**:1–80.
- Treutlein, T. E. 1949. *Ignaz Pfefferkorn Sonora a description of the province*. The University of New Mexico Press, Albuquerque.
- Trimble, S. W., and A. C. Mendel. 1995. The cows as a geomorphic agent—a critical review. *Geomorphology* **13**:233–253.
- Truett, J. C. 1996. Bison and elk in the American Southwest: in search of the pristine. *Environmental Management* **20**:195–206.
- Truett, J. C., M. Phillips, K. Kunkel, and R. Miller. 2001. Managing bison to restore biodiversity. *Great Plains Research* **11**:123–144.
- Van Devender, T. R., A. M. Rea, and M. L. Smith. 1985. The Sangamon interglacial vertebrate fauna from Rancho la Brisca, Sonora, Mexico. *Transactions of the San Diego Society of Natural History* **21**: 23–55.
- Wallace, L. 1879. A buffalo hunt in Northern Mexico. *Scribner's Monthly* **17**:713–724.