National Park Service
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Natural Resource Stewardship and Science

Restoration of Bison (*Bison bison*) to Agate Fossil Beds National Monument

A Feasibility Study

Natural Resource Report NPS/AGFO/NRR—2014/883

ON THE COVER
Agate Fossil Beds National Monument landscape and bison montage
Photographs by Daniel S. Licht

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Executive Summary

Agate Fossil Beds National Monument is a 3,057-acre park located in western Nebraska. The unit is comprised of northern mixed-grass prairie vegetation, typical of the Northern Great Plains. Weather, fire, and grazing are generally considered to be the ecological drivers of prairie ecosystems and critical for prairie health. However, grazing has essentially been absent since the 1960s. In 2014, a Department of the Interior report explicitly listed the park as a high priority for bison restoration. This report evaluates the feasibility, management options, benefits, and challenges of restoring bison to Agate Fossil Beds National Monument.

A potential bison pasture encompasses about 2,676 acres within the park, essentially the area east of Highway 29. Assuming 2,676 acres are available to bison, a forage intake rate of 2.667%, a natural sex and age structure for the herd, an average bison weight of 1,000 lbs, and an allocation of 33% of annual plant productivity to bison consumption, the park could support 166 bison in the fall in a normal-precipitation year including calves, or about 136 yearlings and adults. Using the same assumptions the dry year carrying capacity is 129 animals and the wet year carrying capacity is 219 animals (including calves). Changes in other assumptions and objectives result in different modeled carrying capacities ranging from 52 to 443 animals, demonstrating the latitude available to management. Using the assumptions listed above, if the portion of the park that encompasses the visitor center, park housing, and a private in-holding is excluded from the bison pasture (an area of about 300 acres) then the carrying capacity is reduced to about 147 bison in the fall.

If bison were restored to the park they would occur in a closed system absent of natural predation to affect population growth. Assuming a starting population of 40 yearlings (at a 50:50 sex ratio), the herd would reach carrying capacity about 9-11 years later. Numerous anthropogenic options are available to manage the herd size; however, the most conventional and feasible consists of the park periodically rounding up and transferring live animals to other entities such as Native American tribes. This approach is used by many NPS units with bison. Tradeoffs exist between the frequency of the removal operations and the quantity and age-sex classes of the animals removed in a cull. For example, assuming a goal of a long-term average population of 166 bison in the fall, an annual cull of 70% of the yearlings (about 23 animals) would maintain the herd at that level as would a cull conducted every third year that removed 40% of all age and sex classes (removing about 81 animals total). The greater the duration between culls the greater the variability in herd size, e.g., a cull every fifth year that removes 60% of the herd results in a population that fluctuates between 99 and 202 animals. Other considerations in selecting a culling strategy include ecological objectives, bison genetic goals, available funding and infrastructure, drought, and availability and desires of the recipients of the bison.

The conservation of bison genetics is a high priority within the NPS. Frequent smaller culls better conserve bison genetics as the population does not experience the deep nadirs caused by the removal of large numbers of animals necessitated by less frequent culls. The larger the herd the better genetic diversity is conserved, all else being equal. Genetic diversity could be better conserved if an Agate Fossil Beds herd was managed as a metapopulation with other NPS herds. The park could also choose to manage bison in partnership neighbors, one of whom owns about 5,000 acres. Such a partnership would greatly increase the size of the herd, ecological function, and genetic conservation.

The potential benefits of restoring bison to Agate Fossil Beds National Monument include:

1) restoring a native species to the park,
2) restoring an ecological process to the park that enhances the conservation of biodiversity,
3) improving visitor experience and understanding,
4) benefitting local communities via increased tourism,
5) restoring a Native American ethnographic and cultural resource,
6) contributing to meeting DOI and NPS bison goals,
7) establishing a metapopulation that contributes to agency and global conservation of bison genetic diversity,
8) establishing a genetically pure bison herd (assuming the needed technology is completed),
9) establishing a satellite herd that provides redundancy in case of a catastrophe to another NPS herd(s),
10) being a repository for Yellowstone National Park or other park bison, if needed.

The challenges to bison restoration at the park include the cost and potential impacts of bison-associated infrastructure and maintenance, the need to hire staff with natural resource expertise, and the need to foster support within the agency and with stakeholders. Depending on the location of the bison pastures the park may also need to address private inholdings within the park administrative boundary, impacts on paleontological resources, issues associated with a county road, and impacts to the park administrative areas and structures. The small size of the park makes a well-designed prescribed fire program and an active vegetation monitoring program especially important to assure park goals are being met.

This feasibility study primarily provides a scientific evaluation of restoring bison to Agate Fossil Beds National Monument. Ultimately a full evaluation that considers other concerns and impacts (e.g., cultural resources) would need to be conducted as part of an environmental assessment and management plan. This report tries to facilitate that process wherever possible by analyzing and presenting a range of values. An environmental assessment would also need to consider action alternatives that were not fully vetted here, such as introducing cattle in lieu of bison for purposes of restoring the grazing process. From an ecological and conservation perspective there would be many benefits to restoring bison to the park, and it would be very feasible.

Introduction

Agate Fossil Beds National Monument is a 3,057-acre park located in a remote and rural region of western Nebraska. The prairie ecosystem within the park is typical of the Northern Great Plains biome, with relatively flat topography, a mixed-grass plant community, few trees, and a meandering shallow prairie stream (Figure 1). Prairie ecosystems are the result of the interaction of weather, fire, and grazing, the three ecological drivers of the system. Park management conducts prescribed fires in an effort to restore that driver and maintain prairie health. However, grazing has been essentially absent from the park for many decades. The primary native grazer in the biome—and a keystone species of prairie ecosystems (Knapp et al. 1999)—is the Plains bison (*Bison bison bison*). Bison exist in some National Park Service (NPS) units in the Northern Great Plains (Dratch and Gogan 2008), but the species remains one of conservation concern due to harmful management practices, degraded genetics, and other concerns (Redford and Fearn 2007, Sanderson et al. 2008, Gates et al. 2010).

Figure 1. Agate Fossil Beds National Monument west entrance.

National Park Service policies call for the conservation of native species and natural processes (National Park Service 2006b). Where these elements are missing the park should consider and evaluate restoring them. Discussions about restoring bison to the park occurred in the 1990s; however, lack of funding, insufficient staff resources, and other priorities prevented a detailed analysis and commitment to the effort.

At the beginning of the 21st Century the conservation of bison became a high priority within the conservation community, the NPS, and the U. S. Department of the Interior (DOI). In 2007 the Wildlife Conservation Society raised questions and concerns about the ecological future of bison (Redford and Fearn 2007). In 2008 the U. S. Department of the Interior (2008) published the *Bison Conservation Initiative* that called for establishing new federal bison herds or metapopulations, among other objectives. The National Park Service (2011) published the *Call to Action* that made bison restoration an explicit goal and agency priority. Other reports (Sanderson et al. 2008, Gates et al. 2010) also elevated the global conservation priority of bison. Some reports called for establishing new satellite herds or using metapopulation principles as a means to effectively increase population size and better conserve bison genetics on NPS lands (Dratch and Gogan 2008). In 2014 an analysis was conducted by the DOI Bison Working Group (in prep) to identify sites where quarantine bison from Yellowstone National Park (NP) could be relocated: Agate Fossil Beds National Monument ranked in the top category of potential relocation sites (Department of the Interior 2014). All of these reports, initiatives, and recommendations, in combination with renewed interest by park staff, elevated the need to conduct a feasibility study of restoring bison to Agate Fossil Beds National Monument.

The main objective of this feasibility study is to evaluate and document the scientific and ecologic feasibility of reintroducing bison (Figure 2) to Agate Fossil Beds National Monument. This report also develops a preliminary list of benefits and challenges to such a restoration. This report should not be construed as an action plan or decision document. A full analysis of all the ramifications and issues of a reintroduction would be conducted through a management plan and associated environmental assessment. That administrative process and those documents would constitute a record of decision.

Figure 2. Bison restoration and establishment of new herds is a high priority in the NPS.

Study Area

General Setting

Agate Fossil Beds National Monument is located in northwestern Nebraska, in a remote and sparsely populated region approximately midway between the towns of Harrison and Mitchell, Nebraska (Figure 3). The 3,057-acre park is comprised primarily of native mixed-grass prairie. Gentle slopes and geologic outcroppings flank the north and south boundaries of the park, otherwise the land is relatively flat, characteristic of the vast Great Plains biome. A meandering prairie stream (the upper reach of the Niobrara River) traverses the park from west to east. The relatively flat topography, the mostly tree-less landscape, and the native mixed-grass prairie make the park arguably more representative of the once vast Northern Great Plains ecosystem than any other unit in the National Park System.

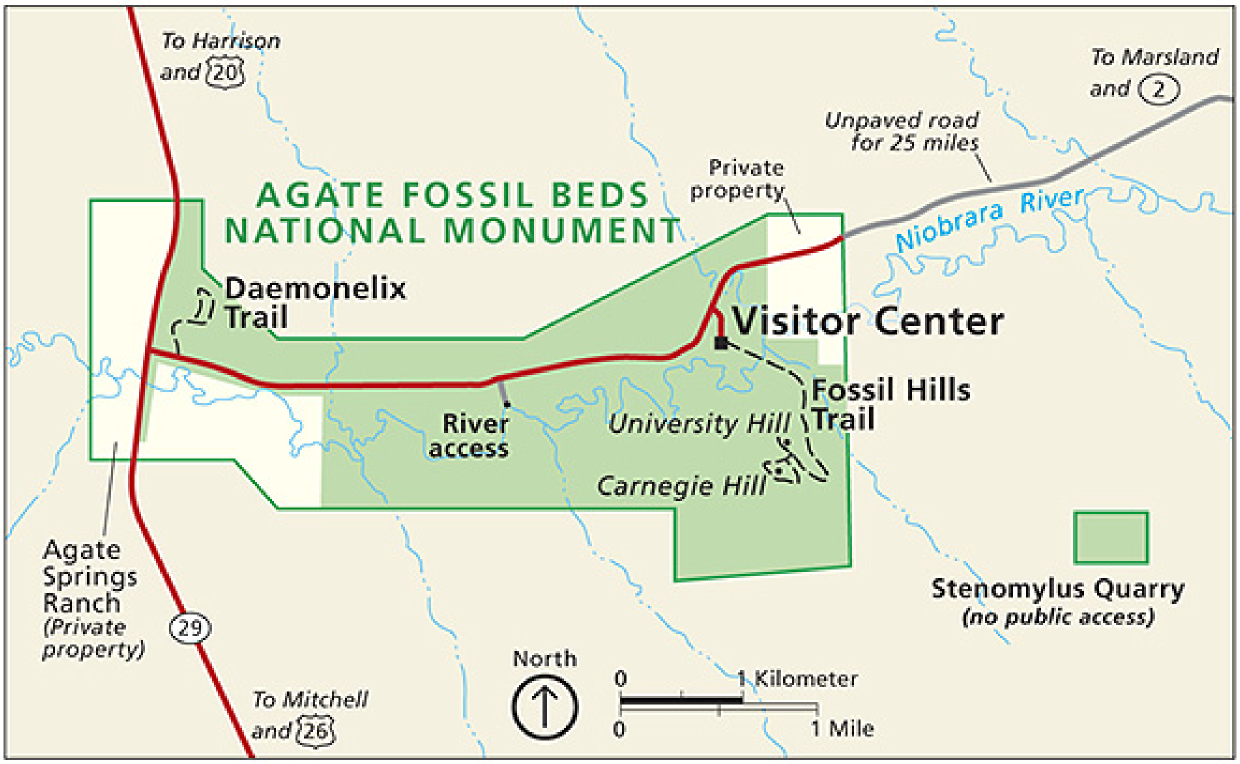

Figure 3. General map of Agate Fossil Beds National Monument.

Agate Fossil Beds National Monument was authorized on June 5, 1965, by Public Law 89-33 (79 Stat. 123). The legislation explicitly stated that the reason for establishing the park was

> *"to preserve for the benefit and enjoyment of present and future generations the outstanding paleontological sites known as the Agate Springs Fossil Quarries, and nearby related geological phenomena, to provide a center for continuing paleontological research and for the display and interpretation of the scientific specimens uncovered at such sites, and to facilitate the protection and exhibition of a valuable collection of Indian artifacts and relics that are representative of an important phase of Indian history."*

These paleontological and cultural resources make the park regionally, nationally, and internationally significant. The park's prairie ecosystem, although not listed as a fundamental resource, is identified in park management plans as an important resource worthy of conservation and management (National Park Service 2012). Furthermore, the park is part of the NPS system and therefore should be managed according to agency policies, regulations, and mission. Those directives call for the restoration and conservation of the park's natural resources including the restoration of native species and ecological processes (National Park Service 2006b).

The park's administrative boundary encompasses 3,057 acres; however, only 2,270 acres are fee acres (Figure 3). Of the remainder, 24 acres are in other public ownership, 460 acres are private lands protected under an easement, and the remaining 303 acres consist of a private in-holding not under easement. State Highway 29 runs north-south through the western end of the park, effectively isolating about 350 acres from the main unit (Figure 3). For purposes of this bison reintroduction feasibility study the land to the west of Highway 29 and the stand-alone Stenomylus Quarry site located to the southeast of the main unit (Figure 3) will not be considered available to bison. The area that will be considered available to bison amounts to 2,676 acres. However, those acres include a portion of the private inholdings and the park's administrative area and visitor center (Figure 4), and the park may subsequently decide to make those acres unavailable to bison, so analyses will also be conducted for a bison pasture that excludes those 300 acres (see the Methods and Results sections).

The park has a strong relationship with Native American tribes and actively consults with 31 federally-recognized tribes that are culturally affiliated with the upper Niobrara landscape. For all of these tribes the Plains bison is a central element of their history and culture. Many of the tribes now own and manage bison herds. These herds were often established with founder animals from National Park Service units in the Northern Great Plains.

Figure 4. The park visitor center and headquarters.

Visitation to the park is very light. Approximately 12,000 visitors came to the park in 2012. This modest visitation is due in part to the remote location and small size of the park. Wildlife observation, which is a popular activity in many NPS units (Vequist and Licht 2013), is comparatively limited at the park. This is probably due in part to the absence of charismatic and iconic species such as bison. Furthermore, much of the wildlife that occurs at the park and are sought by visitors, such as the songbirds, are only seasonal residents. Conversely, bison could be year-round residents. The layout of the park, specifically, the wide open vistas and east-west road, would make bison readily viewable in all seasons and on all days.

Natural Resources

Agate Fossil Beds National Monument lies within a region that is commonly referred to as the Northern Great Plains biome, ecoregion, or province. The park is generally considered to be within the mixed-grass prairie physiographic zone or sub-unit of the Great Plains. Geographically, the park's location is near, if not at, the center of the Plains bison's historic range, which stretched from southern Canada down to northern Mexico and from the Rocky Mountains to the deciduous forest of the eastern United States (Reynolds et al. 2003).

The park's administrative boundary includes 3,057 acres; however, for logistical and other reasons the land to the west of State Highway 29 and the stand-alone Stenomylus Quarry site are assumed to be not available to bison. For purposes of this feasibility study the area assumed available to bison amounts to 2,676 acres (Figure 5). The park could subsequently choose to make unavailable to bison the northeast corner of the park that includes the headquarters and visitor center, park housing, and private land, effectively reducing the bison pasture to 2,350 acres; these considerations are discussed later in this report.

Soils are the foundation for the mixed-grass prairie. The park's soils are generally categorized as mixed coarse-loamy units (Figure 6, Table 1). Soils in the Niobrara River floodplain are often more loamy and moister than those in the uplands. Bare ground is present in the uplands, including the presence of rocky outcroppings. The park's soil types are typical of the region and well suited for use as rangeland. The soil types and the associated U.S.D.A. Natural Resources Conservation Service (USDA-NRCS) data can be used to estimate plant productivity and bison carrying capacity (see the Methods section).

Almost all of the park is considered native prairie, although there are some human-disturbed sites (Figure 7). With the exception of the administrative areas, the disturbed sites have many of the characteristics of native prairie, albeit a higher percentage of herbaceous vegetation. Within the potential bison pasture (Figure 5) about 44% of the area is classified as a Prairie Sandreed-Sandhills Bluestem vegetative community with Needle-and-Thread associations also being abundant (Table 2). The vegetation along the Niobrara River includes wetland plants such as rushes and cattails (*Typhus* sp.). The moist-soil communities along the river tend to have higher productivity (Figure 8) and diversity, although some of the plant species may be less palatable to grazers (e.g., cattails). About a half a dozen aging cottonwood (*Populus deltoides*) trees occur along the river. The park includes a mixture of comparatively arid uplands and moist riparian lowlands, which should benefit grazing animals in a year-round grazing regime. Ashton et al. (2013) stated that vegetation plots at the park had moderately low diversity of native plants compared to other mixed prairies. This could be due in part to the absence of grazing. A long-term vegetation monitoring program is being conducted at the park (Ashton et al. 2013).

Exotic plants are an issue at the park, especially in the lowland areas. One of the more noteworthy species is the pale yellow iris (*Iris pseudacorus*), an emergent aquatic species that grows in dense stands within the Niobrara River (Ashton et al. 2013). The plant may be impairing riverine hydrology. Park staff have observed that the noxious plant is less common and even absent from neighboring lands that have cattle grazing. Kentucky bluegrass (*Poa pratensis*) is also abundant in the riparian area (Ashton et al. 2013). The species is palatable to grazing animals.

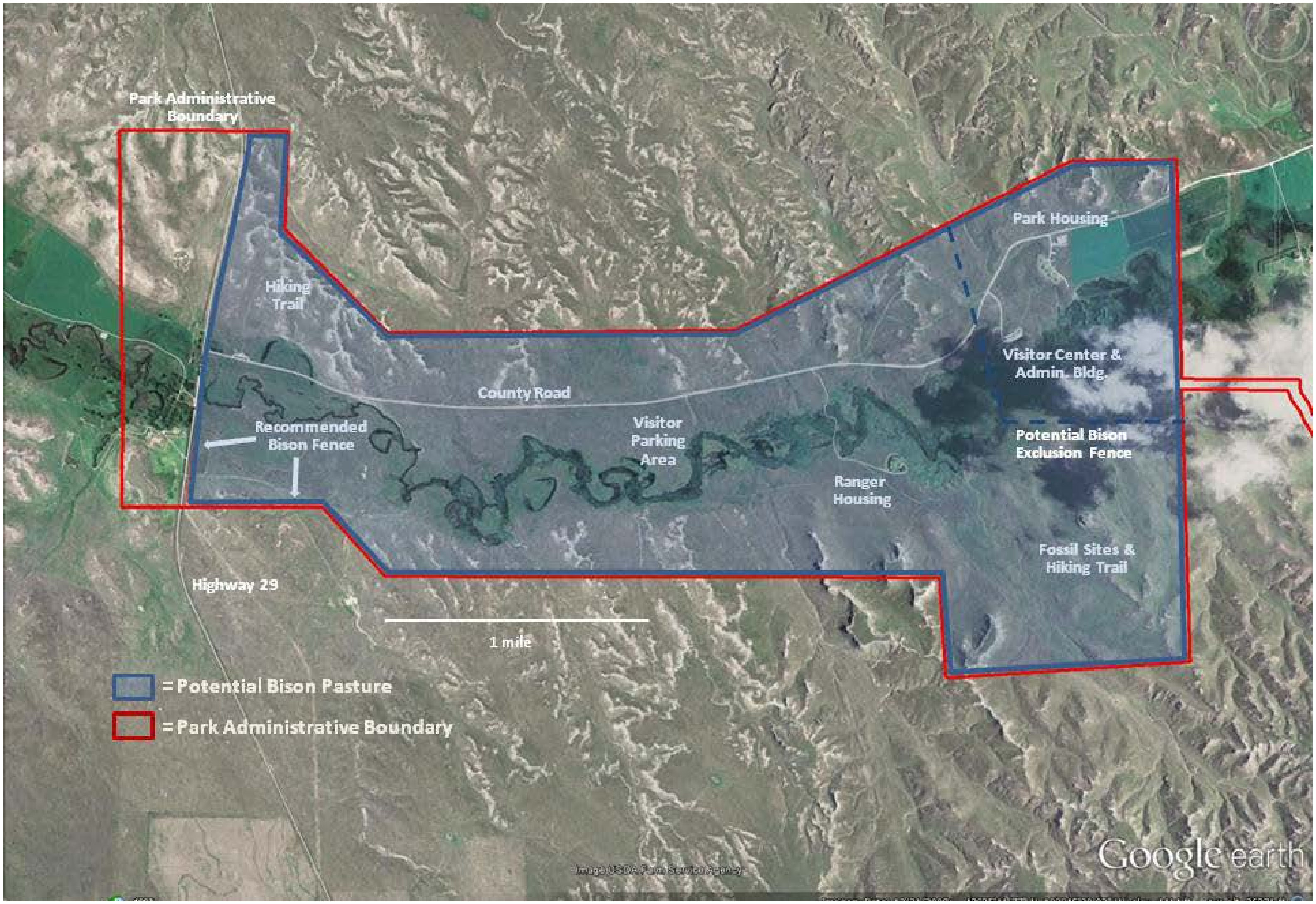

Figure 5. Features relevant to bison management.

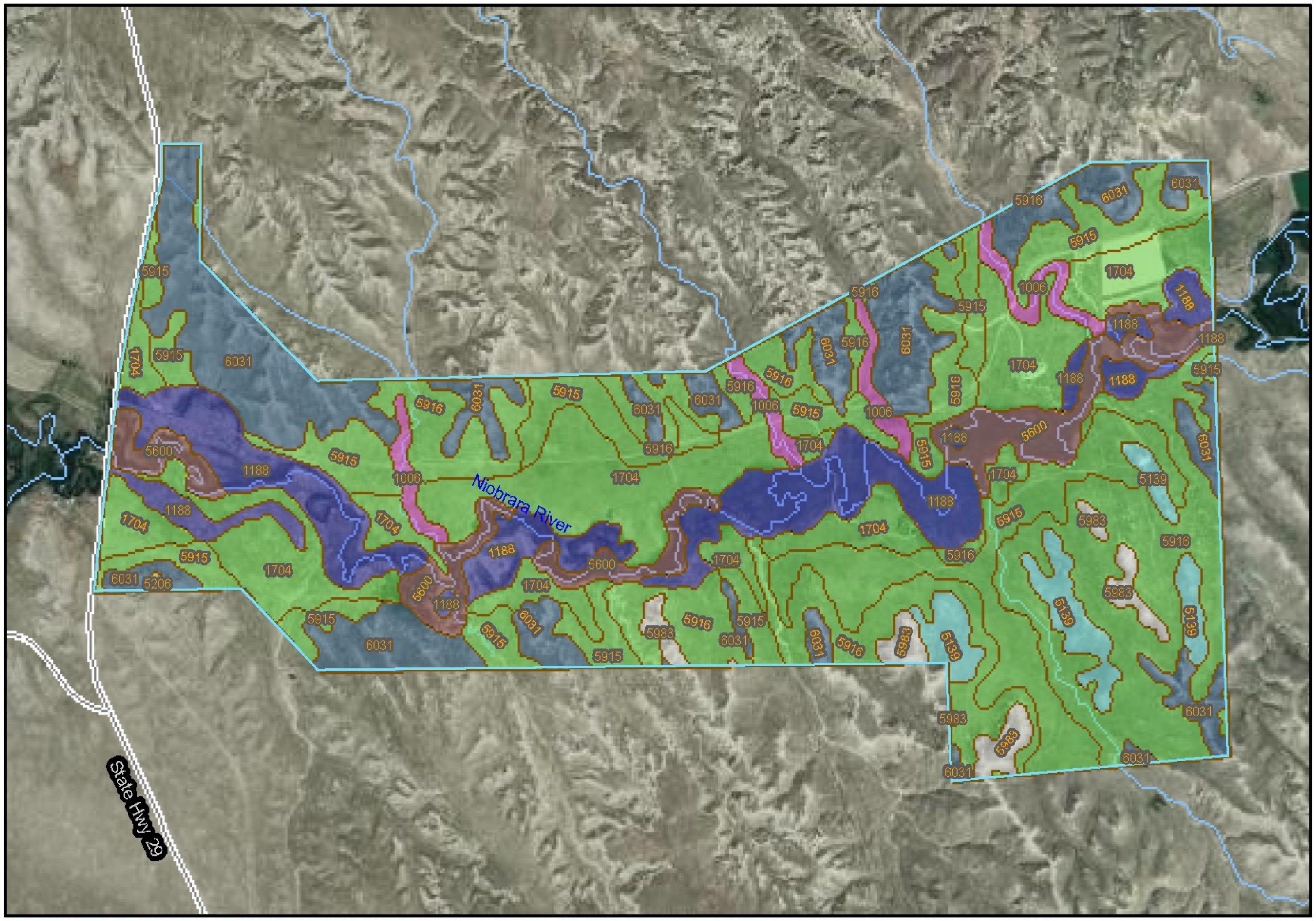

Figure 6. Potential bison pasture and soil types.

MAP LEGEND

- Coarse-loamy, mixed (calcareous), mesic Aeric Fluvaquents
- Coarse-loamy, mixed (calcareous), mesic Aridic Ustorthents
- Coarse-loamy, mixed (calcareous), mesic Typic Fluvaquents
- Coarse-loamy, mixed, mesic Aridic Haplustolls
- Coarse-silty, mixed, mesic Aridic Haplustolls
- Loamy, mixed (calcareous), mesic, shallow Ustic Torriorthents
- Sandy, mixed, mesic Ustic Torrifluvents
- Not rated or not available

MAP INFORMATION

Source of Map:

Natural Resources Conservation Service Web Soil Survey 2013

URL: http://websoilsurvey.nrcs.usda.gov

Coordinate System: UTM Zone 13N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Sioux County, Nebraska

Survey Area Data: Version 14, Jul 30, 2012

Date(s) aerial images were photographed: 7/7/2006

Table 1. Soil types and acreages at park.

Soil ID	Soil Unit Name	Soil Rating	Acres in AOI	Percent of AOI
1006	Bankard loamy fine sand, channeled, frequently flooded	Sandy, mixed, mesic Ustic Torrifluvents	68.9	2.6%
1188	Las Animas-Lisco complex, occasionally flooded	Coarse-loamy, mixed (calcareous), mesic Typic Fluvaquents	337.6	12.6%
1704	Otero loamy very fine sand, 0 to 3 percent slopes	Coarse-loamy, mixed (calcareous), mesic Aridic Ustorthents	474.9	17.7%
5139	Busher-Tassel complex, 6 to 30 percent slopes	Coarse-loamy, mixed, mesic Aridic Haplustolls	85.2	3.2%
5206	Oglala-Canyon complex, 3 to 9 percent slopes	Coarse-silty, mixed, mesic Aridic Haplustolls	1.7	0.1%
5600	Bigwinder fine sandy loam, frequently flooded	Coarse-loamy, mixed (calcareous), mesic Aeric Fluvaquents	168.1	6.3%
5915	Ashollow loamy very fine sand, 3 to 9 percent slopes	Coarse-loamy, mixed (calcareous), mesic Aridic Ustorthents	460.8	17.2%
5916	Ashollow loamy very fine sand, 9 to 20 percent slopes	Coarse-loamy, mixed (calcareous), mesic Aridic Ustorthents	554.6	20.7%
5983	Rock outcrop-Tassel complex, 9 to 70 percent slopes	n/a	54.0	2.0%
6031	Tassel-Ashollow-Rock outcrop complex, 9 to 60 percent slopes	Loamy, mixed (calcareous), mesic, shallow Ustic Torriorthents	470.7	17.6%
Totals for Area of Interest			**2,676.4**	**100.0%**

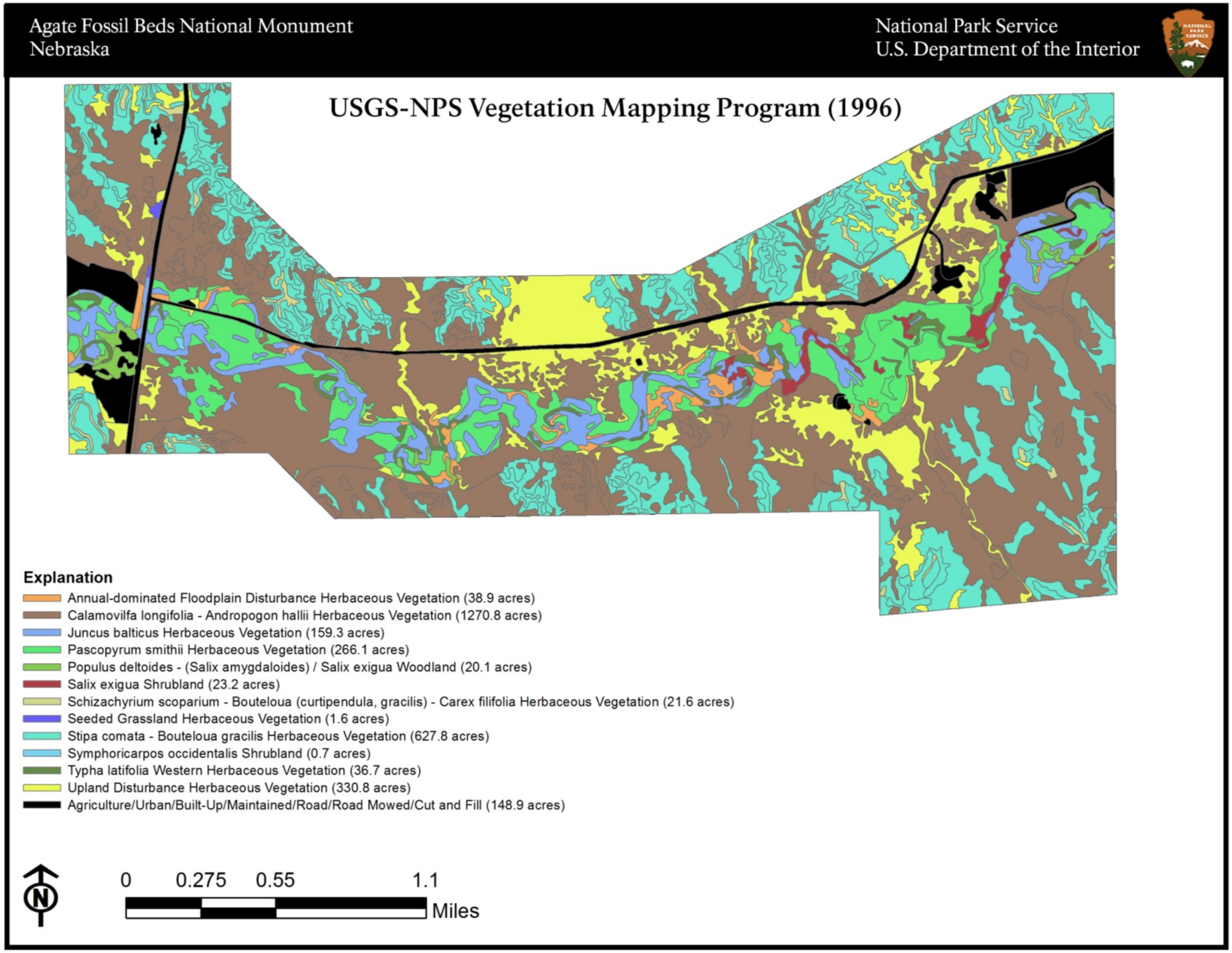

Figure 7. Vegetation cover map of the park.

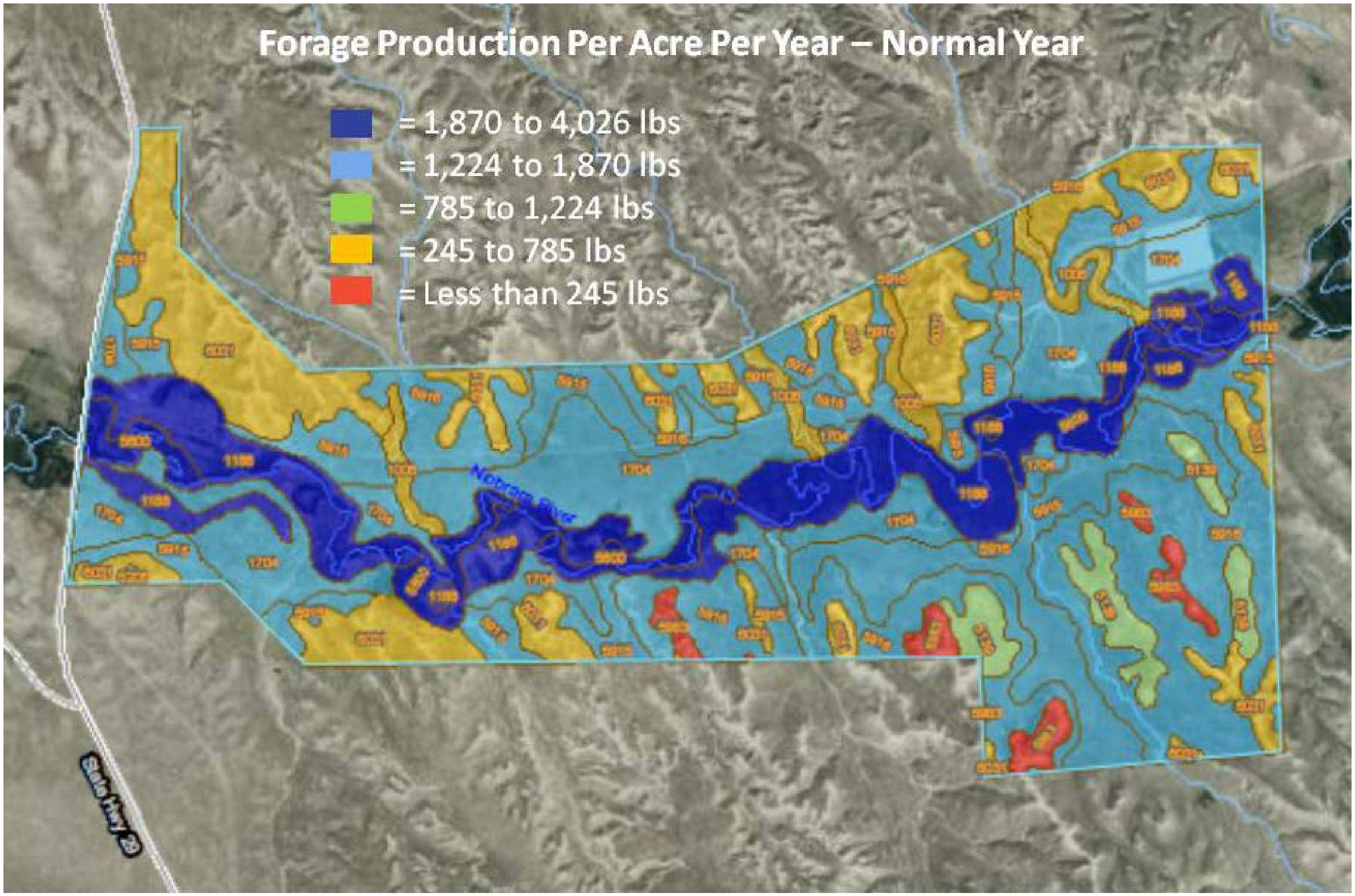

Figure 8. Annual plant productivity in the park.

Table 2. Plant community types in the potential bison pasture and forage attributes[1].

Plant Community	**Acres**	**Percent**	**Forage Attributes of Dominant Species**
Annual-dominated Floodplain Disturbance Herbaceous	35	1.3%	May have some summer value for bison.
Prairie Sandreed – Sandhills Bluestem Herbaceous	1183	44.2%	Prairie sandreed is a fair forage plant in spring and early summer; however, it cures well and is important for late-fall and winter grazing. Sandhills bluestem is an excellent forage plant because of its palatability and yield.
Baltic Rush Herbaceous	146	5.5%	Negligible forage value for bison.
Western Wheatgrass Herbaceous	257	9.6%	High forage quality and grazing resistant. Palatable year-round although quality lowest in late summer. Can tolerate 40-50% grazing.
Eastern Cottonwood – Narrowleaf Willow Woodland	8	0.3%	Forage for deer and cattle, but ignored by bison as forage.
Narrowleaf Willow Shrubland	23	0.9%	Can be an aggressive spreading plant. Could be browsed by deer and cattle, but mostly ignored by bison as forage.
Little Bluestem – Grama – Threadleaf Sedge Herbaceous	17	0.6%	Fair to good forage species. Bluestem and grama are warm season grasses that grow during hot summer months until first frost; they provide good forage in winter. Sedge is good early spring forage.
Needle-and-thread – Blue Grama – Threadleaf Sedge Herbaceous	486	18.2%	Needle-and-thread is a cool season grass that provides good spring and fall forage. Cures well and provides good winter forage. Sedge is good early spring forage.
Needle-and-thread – Blue Grama – Mosaic Herbaceous	76	2.8%	Needle-and-thread is a cool season grass that provides good spring and fall forage. Cures well and provides good winter forage.
Needle-and-thread – Blue Grama – Gravel Herbaceous	2	0.1%	Needle-and-thread is a cool season grass that provides good spring and fall forage. Cures well and provides good winter forage.
Western Snowberry Shrubland	1	0.0%	Forage for deer and other wildlife, negligible for bison.
Common Cattail Herbaceous	32	1.2%	Cattails can outcompete other plants creating monocultures. The unpalatable pale yellow iris is dominating much of the plant community.
Upland Disturbance Herbaceous	306	11.4%	May have some summer forage value for bison.
Urban/Built Up/Maintained/Road	104	3.9%	No value.
Total	2,676	100%	

[1] Forage attributes from USDA plant fact sheets (Natural Resources Conservation Service 2014a), consultation with others, and professional judgment.

Table 3. Forage productivity per year by soil type.

Soil ID	NRCS Soil Unit Name	Acres in AOI	Percent of AOI	Dry Year lbs per ac	Normal Year lbs per ac	Wet Year lbs per ac
1006	Bankard loamy fine sand, channeled, frequently flooded	68.9	2.6%	400	700	900
1188	Las Animas-Lisco complex, occasionally flooded	337.6	12.6%	3,120	4,026	4,482
1704	Otero loamy very fine sand, 0 to 3 percent slopes	474.9	17.7%	1,200	1,500	2,300
5139	Busher-Tassel complex, 6 to 30 percent slopes	85.2	3.2%	908	1,224	1,757
5206	Oglala-Canyon complex, 3 to 9 percent slopes	1.7	0.1%	1,280	1,870	2,495
5600	Bigwinder fine sandy loam, frequently flooded	168.1	6.3%	3,500	4,000	4,500
5915	Ashollow loamy very fine sand, 3 to 9 percent slopes	460.8	17.2%	1,200	1,600	2,300
5916	Ashollow loamy very fine sand, 9 to 20 percent slopes	554.6	20.7%	1,200	1,600	2,300
5983	Rock outcrop-Tassel complex, 9 to 70 percent slopes	54.0	2.0%	175	245	350
6031	Tassel-Ashollow-Rock outcrop complex, 9 to 60 percent slopes	470.7	17.6%	575	785	1,125
	Weighted Totals	**2,676**		**3,817,222**	**4,906,991**	**6,461,649**

Wildlife at the park includes many species typical and representative of the Northern Great Plains and mixed-grass prairies. However, some ecologically significant species are absent and other species appear to be less common than expected, as discussed in the following paragraphs.

The bird community is comprised primarily of a handful of species. Powell (2000) found the most abundant species to be western meadowlark (*Sturnella neglecta*), lark bunting (*Calamospiza melanocorys*), grasshopper sparrow (*Ammodramus savannarum*), red-winged blackbird (*Agelaius phoeniceus*), and lark sparrow (*Chondestes grammacus*), in descending order. Some of these species, such as grasshopper and lark sparrows have shown significant long-term range-wide declines in the Great Plains (McCracken 2005). It remains unknown as to whether the impacts are due to habitat changes on the summer breeding grounds, changes in the wintering grounds, or due to other factors. Sharp-tailed grouse (*Tympanuchus phasianellus*) are observed, although park staff indicate that they are not common. A long-term monitoring program tracks the composition, distribution, and abundance of the park's summer-time bird community (Stenger et al. 2011).

White-tailed (*Odocoileus virginianus*) and mule (*Odocoileus hemionus*) deer are the largest mammals observed, with the former often being found near the stand of cottonwood trees and the latter being only infrequently observed. Pronghorn antelope (*Antilocapra americana*) are occasionally observed in and near the park. However, observations are less frequent than expected. The reasons for this are not known. It is possible that the absence of grazing by bison or livestock has increased graminoids which have crowded out forbs to the detriment of pronghorn. Swift fox (*Vulpes velox*) are also observed less than expected. Swift fox are strongly associated with habitats that have short vegetation structure. In western Nebraska such conditions are best created by grazing. Swift fox are a species of conservation concern in the Northern Great Plains. In the 1990s they were proposed for listing as endangered or threatened; however, there have been several reintroductions in places such as South Dakota and Montana. Coyotes (*Canis latrans*) are present in the park and the largest carnivore (although no threat to bison). Pocket gopher (*Geomys* sp.) mounds and burrows are found throughout the park. A diversity of other mammals are also found in the park (Schmidt et al. 2004). The most notable and ecologically significant missing mammals at the park are bison, elk (*Cervus canadensis*), and wolves (*Canis lupus*). Although the park is within the range of the black-tailed prairie dog (*Cynomys ludovicianus*), it is unclear if the soils and terrain within the park would have been hospitable to the species.

Figure 9. A hispid pocket mouse. Grazing may increase small mammal diversity.

The amphibian and reptile communities are generally typical of the Great Plains. Prairie rattlesnakes (*Crotalus viridis*) are common and are often observed by visitors. Snapping (*Chelydra serpentina*) and painted turtles (*Chrysemys picta*) are often observed in and near the river and at road shoulders where they sometimes dig a depression and lay their eggs. Bullfrogs (*Lithobates catesbeiana*) are found in the park; they are considered by some scholars to be non-native to the region (McKercher and Gregoire 2013).

Little is known about the upland insect and invertebrate community at the park outside of butterflies. Lawson (2004) recorded 23 butterfly species; however, he noted that the year was characterized by drought and may therefore be an under-representation.

It is reasonable to conclude that most of the park's indigenous upland wildlife evolved with fire and grazing and are influenced by these disturbances. The fire-return interval at the park is believed to be five years or less (Dodd and Smith 1994). If the interaction of fire and grazing creates a mosaic of habitat conditions on the landscape (e.g., patches of short early seral-stage grasses in proximity to patches of taller late-seral stage grasses) then most wildlife species should prosper (Fuhlendorf and Engle 2004, Fuhlendorf et al. 2006). Grazing and grazers can also benefit wildlife in other ways, for example, bison wallowing creates depressions in the landscape that can provide critical habitat for some wildlife species such as anurans (Gerlanc and Kaufman 2003).

The Niobrara River flows west-east through the park. The headwaters are approximately 50 miles upstream from the park. About 11 miles of stream meander through the park. Flow is generally about 10-20 cubic feet per second with the peak flow typically in March; however, dense stands of cattails (*Typhus* sp.) and the non-native pale yellow iris greatly impede flow in some reaches (Stasiak et al. 2011). Nevertheless, the shallow stream is perennial and would provide a dependable year-round water source for bison.

Stasiak et al. (2011) reported that the native fish community is nearly absent from the Niobrara River within the park boundary. Only the white sucker (*Catostomus commersonii*) and green sunfish (*Lepomis cyanellus*) were found. The loss of native species may be due in part to the stocking of non-natives for sport-fishing (Stasiak et al. 2011). Stasiak et al. (2011) viewed the northern pike (*Esox lucius*) as a non-native to the reach of Niobrara River within the park; the authors concluded that pike had decimated the native fish populations. They felt that the system could be restored using a combination of a pisciside, water management, and control of the non-native pale yellow iris.

Aquatic invertebrate life appears healthy although there is some evidence of a decline as the number of pollution-tolerant species is increasing (Tronstad 2012). Water quality is being monitored as part of a multi-park monitoring program (Tronstad 2012). Prairie streams, and aquatic life in the region, evolved in the presence of bison (Fritz et al. 1999).

There are no known federally-listed endangered or threatened species at the park. Species that are known to occur in the region include the Preble's meadow jumping mouse (*Zapus hudsonius preblei*), American burying beetle (*Nicrophorus americanus*), and blowout penstemon (*Penstemon haydenii*). The lack of observations in the park, despite biological inventories, and the specific habitat requirements of the species, make it unlikely that they occur in the park.

High priority natural resource issues at the park include the control of non-native species, especially plant species such as the pale yellow iris. Exotic plant control is generally done using herbicide applications, but other means such as grazing are being considered. However, the park has no full-time natural resource program so many natural resource issues do not get the attention they deserve.

Overview of Relevant Bison Ecology, Management, and Comparisons to Cattle

The following discussion is not intended to be a comprehensive review of bison ecology and management. Rather, it is a brief summary of the information and issues relevant to reintroducing bison to Agate Fossil Beds National Monument. For a more comprehensive review of bison ecology and management see Reynolds et al. (2003).

Bison Ecology

The Plains bison is generally considered the largest animal in North America. Adult males are often reported as weighing 1,500-2,000 pounds while the average weight of adult females is generally reported as around 1,000 pounds. However, there is considerable variability across the specie's range (Reynolds et al. 2003). Adult (2.5 years and older) female bison at Wind Cave National Park average 899 lbs and 5.5 years and older males average 1,600 lbs, assuming a natural age distribution (Licht et al., in prep). In contrast to that, adult female bison at Badlands National Park average about 1,057 lbs (Licht et al., in prep).

Bison are generally a brown color; however, white bison are occasionally observed and these animals are held in high reverence by many Native American tribes. White bison can either be true albinos (with pink eyes) or leucistic (white fur, but with blue eyes). McHugh (1979) speculated that these genetic aberrations occur at the rate of 1 per 100,000-1 million animals. No white bison have been reported from NPS units.

Bison are primarily grazers and are often the largest consumer of forage in prairie ecosystems. Across their range bison diets generally consist of about 90 percent grass (Reynolds et al. 2003). Bull bison tend to take a higher proportion of C_4 (i.e., warm season) grasses than female bison, juveniles, or calves (Post et al. 2001). Calves tend to have the most nutritious diets, although these differences could be more the result of post-parturition herd movements than they are selective foraging by calves. The diet for all sex and age classes can change throughout the year. For example, a study in a tallgrass prairie in eastern Kansas found that bison select warm season (C_4) grasses during the summer months and cool season (C_3) grasses during other seasons (Post et al. 2001). During winter months bison often rely heavily on shortgrass species such as buffalo grass (*Bouteloua dactyloides*), blue grama (*Bouteloua gracilis*), and hairy grama (*Bouteloua hirsuta*), as these grasses cure better. Surprisingly and unfortunately, much of the research on bison diets comes from outside of the mixed-grass prairie ecosystem (Reynolds et al. 2003).

Grazing, along with other behaviors such as wallowing, nutrient cycling, and hoof impacts, have earned bison the title of a keystone species by some scholars (Knapp et al. 1999, Fuhlendorf et al. 2010). Selective grazing of grasses by bison releases forbs from competition pressure with graminoids and thereby increases plant diversity in prairie ecosystems (Coppedge et al. 1998). This release of forbs benefits other species such as pronghorn antelope, insects, and seed-eating birds. Hence, grazing is considered an ecological driver in the Great Plains.

Bison grazing strongly interacts with fire (Vinton et al. 1993, Fuhlendorf and Engle 2004), another driver of grassland ecosystems. Fire creates high quality forage by reducing the ratio of dead to live plant material and increasing the nutrient content of growing vegetation. This attracts bison and other grazers, often for considerable periods and from considerable distances

(Biondini et al. 1999). In turn, heavy grazing reduces plant biomass, dead material, and fuel loads, thereby reducing fire intensity and affecting fire patterns and behavior. The inter-relationship of fire and grazers can create a diverse landscape consisting of a mixture of early seral stages in close proximity to late seral stages.

Many scholars now feel that bison did not historically migrate long distances (Hart 2001). A common model is that bison were nomadic, moving across the landscape to meet their foraging and drinking needs. The presence of water, recent fire events, plant phenology and composition, and precipitation likely influenced movements (Vinton et al. 1993, Hart 2001, Fuhlendorf and Engle 2004). The successful restoration of bison to enclosed parks and other sites is evidence that they can exist and prosper on relatively small sites, even in northern climates.

Bison have a strong social order that has implications for management, especially for management of small populations and/or on small reserves. Mature bulls tend to spend most of the year in very small groups or travel alone, only associating with the cows for extended periods during the summer mating season (Berger and Cunningham 1994). Cows, juveniles, and calves form larger herds that generally persist in size throughout the year although individuals may move between herds. The herds are often lead by a matriarchal animal with the subordinate animals having an established pecking order. Dominance is often strongly correlated with age (Rutberg 1983). Disruption to the herd composition and social hierarchy can lead to altered behavior and movement patterns and increased tension within the herd. In one incident, calves introduced into an established herd received high levels of antagonism by resident animals (Coppedge et al. 1997).

Bison mating occurs during summer, peaking in late July to early August (Berger and Cunningham 1994, Reynolds et al. 2003). During the mating season adult males join the large cow-calf herds. Males become increasingly aggressive toward each other, with much bellowing, gesturing, and sparring. Serious fights, including those that result in serious injuries or fatalities, are less common, but do occur. Dominant males tend females in estrous and will not tolerate other males nearby. Oftentimes several males will aggressively pursue a female in estrous. A small percentage of prime-age adult males may do most of the breeding (Berger and Cunningham 1994). As a result, the genetically "effective population size" of the herd may only be about a third of the total population (Halbert 2003, Gross and Wang 2005).

Birthing takes place in early May in the Northern Plains, although a small number of calves may be born before and after that period. Prior to parturition females may wander away from the main herd to give birth; this behavior may be more common in habitats with woody vegetation (Lott 1991). Single calves are the norm. Many studies have reported that the sex-ratio of fetuses or newborns tends to lean toward males although the disparity is negligible (Reynolds et al. 2003). First year survival tends to be slightly higher for female calves. Cow-calf pairs maintain close contact at first, but the calves become more independent as time goes on. Cows may not calve every year, especially if parturition in the previous year occurred late in the season (Green and Rothstein 1991), or if nutritional needs are not met (Gogan et al. 2013). Females typically first breed at the age of two and first give birth at age of three (Berger and Cunningham 1994, Millspaugh et al. 2008, Gogan et al. 2013). Males can probably breed starting around three years of age, however, prime age males (6-9 years old) typically do most of the breeding and may be sought out by females (Berger and Cunningham 1994).

Bison survival is high, especially in sites where natural predators are no longer present. For example, Millspaugh et al. (2005) reported annual survival for bison at National Park Service units in the Northern Great Plains as about 98% until the animals reach age 12. Pyne et al. (2010) reported similar survival rates for calves and yearlings, but a lower 94% survival for adult females and 80% survival for adult males at Badlands National Park. The disparity between the studies, which relied on the same Badlands National Park roundup database, appears to be due to assumptions about recapture probabilities. The onset of senescence is generally reported as being around 13-15 years (Halbert et al. 2005, Pyne et al. 2010).

In the absence of natural predators, disease may be the most significant natural mortality factor in bison. Diseases such as pneumonia, arthritis, arteriosclerosis, brucellosis, and tuberculosis along with parasites are known in bison. Although bison and cattle are closely related and share many parasites, the presence of a disease or parasite in one species does not necessarily mean the other species will contact it or be vulnerable. For example, Van Vuren and Scott (1995) found that even when bison and cattle share a range they do not have the same levels or types of parasites. For a list of diseases relevant to bison see the notes from an NPS bison workshop conducted at the Tallgrass Prairie National Preserve in 2003 (National Park Service 2004), the bison management plan for Wind Cave National Park (National Park Service 2006a), or Reynolds et al. (2003). Disease management is a significant factor in bison management and is discussed in more detail in the following section.

Bison Management

The conservation status and history of bison is well chronicled (Reynolds et al. 2003). Bison may have once numbered in the tens of millions (Shaw 1995), but were almost extirpated in the late 1800s. At their population nadir there may have been less than a thousand bison left in the world. Through public and private restoration efforts they recovered from those perilous lows. By one estimate there were 385,000 animals as of 2001 (Bragg et al. 2002). However, Reynolds et al. (2003) stated that “there is a misconception that the North American bison as a wildlife species is secure and will survive in perpetuity.” As a result of the genetic and other concerns, the International Union for the Conservation of Nature and Natural Resources (IUCN: also known as the World Conservation Union) places the “American bison” in the “Lower Risk, Conservation Dependent” category in the Red List of Threatened Species. The organization has recently made bison conservation a high priority and has developed a Bison Specialist Group operating under the Species Survival Commission. The State of Nebraska considers wild bison as extirpated in the state: all bison in Nebraska are classified by the state as livestock.

The reason for the concerns about bison conservation is that a large percentage of bison are in private ownership and are managed primarily for profit and sometimes to the detriment of conservation goals. For example, private herds often have degraded genetics and skewed demographics (Bragg et al. 2002, Halbert 2003). Halbert (2003) found considerable evidence of cattle introgression in bison, especially in private and state herds. Yet even federal herds have genetic concerns. Halbert et al. (2007) found evidence of limited cattle introgression in the Badlands and Theodore Roosevelt National Park herds. No evidence of cattle introgression was found in the Wind Cave National Park herd. As a result, the Wind Cave herd has been highly sought by conservation groups and others looking to start new herds. However, recent and more sophisticated genetic testing has found evidence of cattle introgression in that herd as well, although the results have not been published in a peer-reviewed scientific journal. Within the next few years single-nucleotide polymorphism (SNP) test may be available that will allow for identifying genetically pure bison.

In addition to concerns about cattle introgression, genetic diversity remains a very high concern for bison conservationists (Gross and Wang 2005, Halbert et al. 2007, Dratch and Gogan 2008). Gross and Wang (2005) modeled NPS bison herds and concluded that a herd size of 400 was needed for a 90% probability of retaining 90% of heterozygosity for 200 years and 1,000 animals were needed for a 90% probability of retaining 90% of alleles. The Yellowstone National Park herd is the only federal herd that consistently reaches the latter goal. One way to reach that population target and thereby better conserve genetic diversity is to use a metapopulation approach. For example, the Wind Cave herd is currently about 450 animals. A recent park expansion may allow that herd to increase another hundred or more, but it would still be short of the 1,000 animal goal. However, if Wind Cave bison were used to start other herds, as it was with the Tallgrass Prairie National Preserve herd (National Park Service 2009), the genetic size of the Wind Cave herd increases. If Agate Fossil Beds National Monument supported about 200 animals as a satellite herd of Wind Cave, along with the animals from Tallgrass Prairie National Preserve, the 1,000 animal criteria may be reached. Dratch and Gogan (2008) recommended immediate and aggressive action to increase the size of herds such as that at Wind Cave. Licht et al. (2014) encouraged more consideration of metapopulation management in the NPS, and observed that it is often practiced in other countries in closed parks and preserves.

Bison herd sizes at Badlands, Theodore Roosevelt, and Wind Cave National Parks and Tallgrass Prairie National Preserve, are typically about 700, 650, 400, and 20 animals, respectively (Table 4: however, populations in recent years have exceeded those numbers due to new agency policies prohibiting the use of *cost recovery* to fund roundups; see the discussion below). Yellowstone National Park and Grand Teton support another 3,900 free-ranging animals between them. The U.S. Fish and Wildlife Service has five herds ranging from hundreds of animals to just a few dozen, bringing the Department of the Interior population to about 7,500 animals in 11 herds[1] . There have been several attempts to develop a coordinated Department of the Interior bison strategy, including strategies to move animals between herds using a metapopulation approach (Halbert et al. 2007), but those initiatives have not made much progress as of early 2013. A 2008 workshop recognized the genetic value of the DOI herds, cautioned against mixing herds, and recommended a population or metapopulation target of 1,000 animals to preserve genetic diversity (Dratch and Gogan 2008).

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[1] The reported number of federal herds depends on how herds are defined. For example, Theodore Roosevelt National Park has two isolated herds as does Fort Niobrara National Wildlife Refuge. Bison occasionally venture into Grand Canyon National Park from neighboring lands, but they are generally not considered a federal herd. Bison are present at Wrangell-St. Elias National Park and Preserve in Alaska, but they are predominantly wood bison and the site is outside the historic range of plains bison. Chickasaw National Recreation Area has a small number of bison, but they are not considered a conservation herd. The tally here defines herds as administrative units with the year-round presence of a conservation herd of plains bison.

Table 4. Bison management at Midwest Region Parks.

Management Practice	Badlands NP	Tallgrass N. Pres.	Theodore Roosevelt NP	Wind Cave NP
Average Herd Size	700	20	650	400
Population Goal (Winter)	Less than 700	75	100-300 in NU and 200-500 in SU	400-500
Acres Available to Bison	60,000	1,074	70,500	28,132
Forage Allocated to Ungulates	33%	25%	35% (includes elk)	25% (includes elk)
Bison Intake Rate	1.2 AUE to 1,000 lb cow with 2.6% intake	26 lbs day or 3% body weight	15 lbs dry weight per day; 1.7% of body weight for yearlings and adults	1.2 AUE to 1,000 lb cow with 2.6% intake
Typical Culling Strategy	50-80% of yearlings	Proposed 45% every 3rd year across all age-sex classes	Proportional across all age classes except calves	80% of yearlings annually
Disease Testing	Test for brucellosis	Test for brucellosis, tuberculosis, Johne's on import; proposed testing for brucellosis and tuberculosis	Test for brucellosis, tuberculosis, and Johne's - all negative	History of brucellosis; eradicated via shooting. Vaccinations until 1998. Test for brucellosis.
Vaccinations	When required for transport	Proposed for brucellosis for calves; when needed	Brucellosis vaccine when requested	When needed for transport
Water Management	Permanent impoundments. Sage Creek. Some artificial water maintained for bison.	Streams present with stock ponds from prior land use	Little Missouri River. Some artificial water maintained to distribute grazing.	3 perennial streams and 12 developed sources to distribute grazing
Survey Methods	Roundups and fall and winter horseback/aerial surveys	Absolute counts from foot or vehicle	Roundups and aerial and foot survey	Roundups
Vehicle Collisions	None (gravel county road through bison pasture)	None (no public roads in pasture).	Four during the last 3 years (3 in SU and 1 in NU)	Average 8-9 accidents per year; 0-8 bison deaths annually last 30 years; but, 14 in winter of 2013-14.
Escapes	About 4 annually	None	Average 15 annually in SU and 6.5 in NU	< 4 in past 16 years
Herd Origin	50 bison from Theodore Roosevelt NP in 1963-64 and 3 from Fort Niobrara NWR	13 from Wind Cave NP in 2009	29 bison (5 bulls: 24 cows) from Fort Niobrara NWR in 1956	6 bulls:8 cows from NY in 1913 and 2 bulls:4 cows from Yellowstone in 1916
Management Plans	Bison Management Plan in prep	Bison Management Plan in 2009.	No bison-specific plan.	December 2006

National Park Service policies call for conserving the three widely recognized elements of biological conservation: i.e., the preservation of natural conditions, natural processes, and species composition (National Park Service 2006b). These policies are followed to the extent practicable when it comes to bison management. However, management must sometimes mitigate for missing natural processes. For example, natural predation (e.g., by wolves) does not occur at National Park Service units in the Northern Great Plains so managers must cull surplus animals. They try to do this in a way that results in relatively natural conditions. For example, Wind Cave National Park culls yearlings at a 1:1 sex ratio (Millspaugh et al. 2005, National Park Service 2006a): this results in a relatively natural sex structure. It also better conserves genetic diversity (Perez-Figueroa et al. 2012).

Figure 10. Aerial view of roundup facility at Wind Cave National Park.

Badlands, Theodore Roosevelt, and Wind Cave National Parks all have permanent corrals and processing facilities to remove surplus bison. (Small bison operations sometimes use portable corrals, some of which can be purchased from commercial manufacturers.) Grandin (1999) provides guidance on handling bison and the construction of handling facilities. NPS bison roundups generally take place over a couple days in October and involve dozens of people to process the animals (including veterinarians on site). Animals are typically pushed into the corrals via helicopter at Theodore Roosevelt and Wind Cave National Parks: Badlands uses riders on horse to move the bison. In all cases animals are marked with microchips implanted in the ear. Various morphological, health, and genetic measurements and samples are taken. The animals may be tested for brucellosis and tuberculosis depending on state requirements (both the state in which the park is located and the state where surplus bison may be transferred to). Historically, the costs for the roundups and associated expenses were paid by the entities receiving the bison on a reimbursable basis known as *cost recovery*. The prorated costs usually came to about $250-$450 per bison. However, around 2010 this model of funding the roundups was prohibited by changes in agency policy. The reasons for the change are ambiguous and remain a source of frustration to the parks. As a result of the change the parks are currently exploring other options to fund roundups including acquiring a permanent funding increase. The recipients of surplus bison from the parks are typically Native American Tribes as directed by Department of the Interior policies and solicitor guidance, although conservation organizations, state parks, and other non-profits have received a few animals. If other National Park Service units need bison they are typically given preference.

Brucellosis is a noteworthy disease of bison because of its potential and perceived impacts on cattle and effects on bison management. The disease has been the source of much controversy, management, and research at Yellowstone National Park (National Park Service 2000).

Brucellosis appears to be an exotic disease brought over by domestic cattle (Meagher and Meyer 1994). It is a contagious bacterial disease that in one form (*Brucella abortus*) can infect both bison and cattle. In bison it can cause a cow to abort a fetus; however, the animals soon develop immunity and successfully reproduce in later years. However, no such resistance or immunity develops in cattle. The disease is transmitted through ingested organic materials including placentas and uterine discharges. In the 1960s to 1980s Wind Cave National Park shot several hundred bison in a successful effort to eradicate brucellosis from their bison herd (National Park Service 2006a). Yellowstone National Park and partner agencies have recently made a commitment to eliminate the disease from the Greater Yellowstone Region (National Park Service 2000); however, elimination is confounded by the presence of the disease in elk (Schumaker 2013, Treanor 2013, White et al. 2013). Nebraska and South Dakota are currently declared brucellosis-free states. The Nebraska Department of Agriculture issued an order on April 1, 2011, requiring bison and elk from the Greater Yellowstone area to be individually marked and to have a Certificate of Veterinary Inspection prior to entering the state (www.nda.nebraska.gov/animal/cattle_bison_gya.pdf).

Bovine tuberculosis is another noteworthy disease in part because of states concerns and requirements regarding the disease. Bison appear to have first contacted the disease from domestic cattle (Tessaro et al. 1990). The bacterium *Mycobacterium bovis* can be transmitted through the air or by ingested milk, urine, feces, and other bodily fluids, although inhalation appears to be the primary transmission in bison (Tessaro et al. 1990).

Nebraska state law generally treats bison the same as cattle in regards to disease management and importation (Nebraska Administrative Code 2012). Specifically, the law requires that all bison greater than 2 months of age be tested for tuberculosis prior to entering the state. A permit is needed prior to bringing animals into the state, the animals must be individually identifiable, and they must either: 1) originate from an accredited herd, or 2) originate from a herd that has a negative whole herd test within 1 year prior to entry, or, 3) be individually tested and found negative within 60 days prior to entry. The explicit requirements for bison regarding brucellosis are ambiguous in the code; however, the requirement for cattle is that animals of “test-eligible age” originate from a “certified brucellosis-free herd, a Class Free state, or a country recognized by APHIS as free of brucellosis.” Animals from a Class A state require testing within 30 days of entry into Nebraska. Such requirements probably also apply to bison, with the exception of special conditions for bison from the Greater Yellowstone Area (special order dated April 1, 2011).

Bison are a feature tourist attraction in parks in which they occur. Bison are generally docile animals that are indifferent or slightly intolerant of people. All parks with bison allow people to travel on foot in areas where bison occur and have established hiking trails in such areas. At some parks, such as Yellowstone National Park, bison wander through administrative areas, park housing, visitor centers, and other places where people congregate. Badlands and Theodore Roosevelt National Parks have unfenced campgrounds within areas where bison roam and both parks, along with Wind Cave National Park, allow backcountry camping in areas with bison.

However, bison can be aggressive to people under some circumstances and have caused human fatalities at national and state parks. Bulls during the breeding season and cows with young calves are especially dangerous. Bison managers often advise visitors to stay at least 25 yards away from bison. At some parks, such as Yellowstone National Park, park-promulgated regulations require visitors to stay at least 25 yards from bison and violators can be ticketed. At some sites with bison and large numbers of tourists, such as Custer State Park, managers take extra precautions during the breeding season including regular oversight of visitors near bison. Agitated or aggressive bison may display warning signs including prolonged direct eye contact with the intruder, head waving, snorting and grunting, pawing of the ground, a bucking action, and a raised tail.

Figure 11. Woven-wire bison fence at Wind Cave National Park.

All bison herds in the Great Plains are fenced to varying degrees. Page (i.e., woven) wire fencing is often used, especially in public herds. Badlands, Wind Cave, and Theodore Roosevelt National Parks all use woven-wire fencing, typically 7-8 feet high (Figure 11). Many private herds rely simply on 5-strand barbed-wire fencing and/or electric high-tensile fences. Tallgrass Prairie National Preserve uses a 5-strand barbed-wire fence that has an electric strand offset between the second and third wire (Figure 12); however, park staff question whether the electric strand is necessary (Kristen Hase, Tallgrass National Preserve, pers. comm.). Bison-proof fences typically cost a few thousand dollars per mile to erect. Some parks also place fences around administrative areas to keep bison out, e.g., Wind Cave National Park. Cattle guards are generally effective in blocking bison movements where fences meet roads.

Badlands, Theodore Roosevelt, and Wind Cave National Parks all have roads going through bison-occupied lands. The road through Wind Cave National Park is a major highway and gets significant traffic including semi-truck and other commercial traffic. Speed limits are generally reduced within park boundaries. For example, the speed limit on Highway 385 through Wind Cave National Park is reduced to 45 mph. Signs warn drivers of the potential for bison and large wildlife on the road. Collisions with bison do occasionally occur, but number just a few each year, if any. However, the number of bison deaths due to vehicle collisions increased

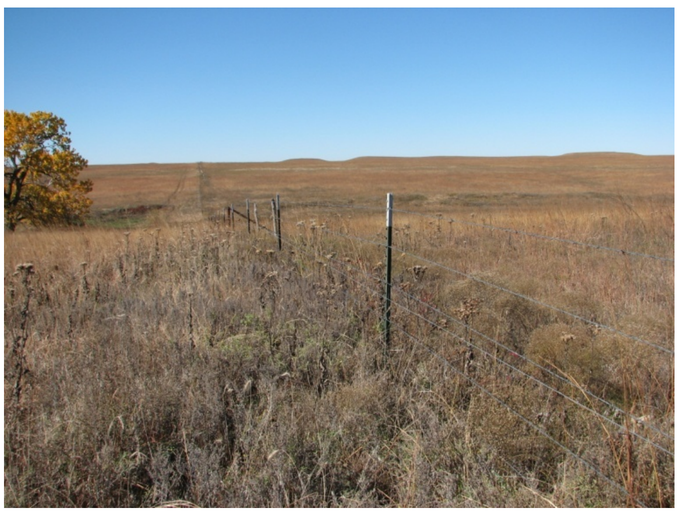

Figure 12. Five-strand bison fence at Tallgrass National Preserve.

to 14 at Wind Cave NP in the winter of 2013-14; it is suspected that trucks with road salt that turned around within the park attracted bison to the roads and contributed to the increased deaths. No significant injuries or legal cases have occurred as a result of collisions with bison.

Differences Between Bison and Cattle

This feasibility study evaluates only the feasibility of reintroducing bison to Agate Fossil Beds National Monument. However, cattle are sometimes perceived as being ecologically synonymous with bison, and hence, there have been several studies comparing the two (Towne et al. 2005, Fuhlendorf et al. 2010, Kohl et al. 2013). Plumb and Dodd (1994) suggested that cattle may be more appropriate grazers on small natural areas under some conditions; however, their evaluation focused primarily on foraging behavior, and did not consider the other ecological differences between bison and cattle (see this discussion) nor did they address the policy, visitor experience, genetic conservation, Native American, and other benefits of bison restoration to natural areas. The following discussion is a brief overview of the ecological similarities and differences between bison and cattle. Whether cattle could and should be introduced to the park in lieu of bison is better addressed as part of the NEPA process.

The primary and most obvious similarity between bison and cattle is that both species remove primary productivity (i.e., plants) and convert it to energy, tissue, and waste products. As part of that process they affect vegetation condition, composition, and function which in turns affects grassland wildlife, hydrology, soils, and other resources. With active management the similarities can become greater (Towne et al. 2005, Fuhlendorf et al. 2010, Kohl et al. 2013). For example, managers can move cattle across the landscape in a way that mimics the more nomadic natural tendencies of bison. Managers can also use a patch-burn approach that both cattle and bison respond to similarly (Fuhlendorf et al. 2006). With good management both species can benefit rangeland resources whereas with poor management (e.g., long-term extreme under or overstocking) both species can cause adverse impacts on rangeland resources.

However, even under similar management practices bison and cattle do have differences, some of which are subtle and some of which are more profound. Even the subtle differences can affect the biological diversity of a site. This is not surprising as bison evolved in the relatively arid Great Plains and other Great Plains species evolved in concert with them whereas domestic cattle generally derived from wetland-associated species in Europe and Asia.

There are a number of notable differences between bison and cattle (Table 5). Generally speaking, in terms of grazing behavior bison move across the landscape more, they select areas with intermediate biomass, they spend less time actually grazing, their diet consists of a higher portion of grasses versus forbs and woody material, and they are better able to digest low-quality, high-fiber, low-protein graminoids. These differences can result in differences to a site's biodiversity. For example, in a controlled study Towne et al. (2005) found a 15% difference in plant community composition after 10 years of grazing by bison versus sites grazed by cattle. In another study, deer mice (*Peromyscus maniculatus*) abundance was higher in areas grazed by bison than those grazed by cattle, perhaps due to bison creating larger grazed patches or perhaps due to the increase in seed-producing forbs on the bison sites (Matlack et al. 2001). Sometimes the biodiversity benefits of bison are more subtle and indirect. For example, when snow is on the ground bison may disproportionately graze hilltops where the wind-blown snow cover is less.

This pattern may enhance habitat for the early spring courtship and dancing rituals of sharp-tailed grouse and prairie chickens.

Other bison behaviors, such as wallowing, males disturbing the ground during the breeding season, and horning trees also differ from cattle behavior and can alter species richness and grassland biodiversity (Coppedge et al. 1998). Collins and Barber (1986) found that disturbance via wallowing and other means increased diversity in a mixed-grass prairie.

Table 5. Ecological differences between bison and cattle.

Issue	Bison	Cattle
Grazing Time	Spend about a quarter of their time grazing.[1]	Spend about half their time grazing.[1]
Forage Digestibility	Bison are better able to digest low-quality, high-fiber, low-protein forage.	Do not digest low-quality, high-fiber, low-protein forage as well as bison, although they do digest high-quality forage at a comparable rate.
Plant Selectivity	Bison diets consist of about 90% grass.[2,3]	Cattle diets are only about 70% grass with the remainder forbs and woody material.[2,3]
Micro-habitat Selectivity	Areas with intermediate plant biomass.[1]	Areas with high plant biomass.[1]
Movement	Bison move farther distances while grazing and are more likely to graze steep slopes and hilltops.	Cover less ground while grazing and less likely to reach hard to access areas.
Behavior	Bison wallow, thereby creating micro-habitats in grassland landscapes. Rutting bison roll and paw at the ground disturbing the soil and altering vegetation. Rutting bison may horn trees, while all ages and sexes may rub them, injuring and sometimes killing them.	Domestic cattle do not display the localized soil-disturbing behaviors that bison do, thereby not creating the same type and frequency of micro-habitats on the landscape.
Water and Riparian Areas	Spend less time near water.[1,4]	Spend more time near and in streams and ponds.[1,4]
Woody Areas	Infrequent in woody areas.[4]	Spend more time near woody vegetation, perhaps in part for foraging reasons and in part for shelter.[4]
Metabolism	Slows down during the winter to conserve energy.	Does not noticeably slow in the winter.
Climate	Much better to withstand extreme temperatures, including extreme cold periods. Better able to forage in deep snow	Can succumb to extreme cold conditions, especially when experienced in combination with food deprivation.

[1] Kohl et al. (2013).

[2] Plumb and Dodd (1993)

[3] Van Dyne et al. (1980)

[4] Fuhlendorf et al. (2010)

Methods

Determining Carrying Capacity

Perhaps the most important piece of information needed to evaluate a bison restoration at Agate Fossil Beds National Monument is a determination of how many bison the site should or could support. There are several ways to establish a desired population level or carrying capacity. A population level could be established based on visitor expectations, tolerance of neighbors, genetic conservation, or assumed natural or pre-Columbian bison densities. One could even let range conditions, weather, and other natural processes dictate bison abundance; however, in small parks without predators such an approach is no longer acceptable for ecological, political, logistical, aesthetic, and ethical reasons.

The typical way to establish a desired population level for large ungulates—and especially for grazers such as bison—is to determine a stocking density based on annual forage productivity at the site. Based on that productivity, and assumptions about herbivore consumption rates and other variables, the number of animals a site could support can be determined. All NPS units in the Northern Great Plains use some form of a plant productivity model as the primary factor in establishing bison population goals. This method is the same as what some cattle ranchers use and is the method strongly promoted by the U.S.D.A. Natural Resources Conservation Service (Natural Resources Conservation Service 2003).

The ideal way to determine plant productivity at a site is to conduct field studies; however, such studies have not been done for Agate Fossil Beds National Monument (although vegetation monitoring does occur at the park, it does not adequately capture plant productivity). So I used U.S.D.A. Natural Resources Conservations Service data, specifically, values from the agency's Web Soil Survey website (Natural Resources Conservation Service 2014b). The website uses the same values in the agency's long-established Field Office Technical Guides, but in a digital format with geographic information system (GIS) capabilities. I used the website to delineate a reasonable bison pasture of 2,676 acres (see the Study Area section). The GIS calculated the area of each soil type within my *Area of Interest* (AOI). For each soil type values were provided for annual productivity, expressed as annual dry weight production per acre in dry, normal, and favorable (wet) years. Calculating annual forage productivity for the park was a matter of summing the per-acre productivity values by the number of acres in the AOI.

The next step was to determine how much forage the grazer of interest consumes. To expedite that step ranchers often use the concept of an *Animal Unit* (AU) with an AU defined as a 1,000 lb beef cow nursing a young calf. Such a cow-calf pair is generally assumed to need approximately 26 pounds of oven-dry matter forage daily, or 30 pounds of air-dry forage. The amount of forage required by one AU for one month is called an *Animal Unit Month* (AUM). Hence, for a cow-calf pair the AUM would require 912 pounds of air-dried forage (1 AU x 26 lbs forage daily x 30.4 days in an average month). The AUM approach is especially useful for managing sites where the available vegetation changes dramatically between seasons and/or where only short-term grazing is desired (e.g., for livestock grazing in alpine areas). I did not use the AUM approach under the assumption that bison would be year-round residents at Agate Fossil Beds National Monument.

To develop carrying capacities for bison, deer, pronghorn antelope, and other ungulates, animals that differ from cattle in size and have differing forage intake rates, range managers often use *Animal Unit Equivalents* (AUE). Table 6 comes from Bragg et al. (2002) and provides a list of AUE relevant to Agate Fossil Beds National Monument.

Table 6. Animal use equivalents (Bragg et al. 2002).

Species and Age Class	Animal Unit Equivalent (AUE)
Bison	
Bull – mature	1.5
Cow – with calf	1.25
Cow – dry	1.0
Bull – 2-year old	1.0
Heifer – bred	1.0
Bull/Cow – 13-24 month	0.8
Calf – weaned to 12 months	0.5
Cattle	
Bull – mature	1.35
Cow – with calf	1.0
Cow – dry	0.92
Bull/Cow – 2 years old	0.8
Bull/Cow – 1 year old	0.6
Mule Deer – mature	0.2
White-tailed Deer – mature	0.15
Pronghorn Antelope – mature	0.2

However, there are problems with the AUE approach. Specifically, the literature varies greatly in terms of AUE values. For example, Bragg et al. (2002) use 1.25 for a bison cow-calf pair whereas Miller (2002) used 0.9 and Holechek (1988) used 1.8. Furthermore, some researchers have questioned whether the standard assumptions for a cattle cow-calf pair are still appropriate due to increases in cattle weights over the past several decades (Uresk 2010). Due to these considerations I did not use the AUE approach as my primary means to establish a carrying capacity, but did use it as a quick corroboration of my primary method.

A somewhat similar approach, but one that directly and precisely accounts for varying body mass, is to multiply animal weight(s) by a constant forage intake to estimate the amount of forage consumed daily by the animal(s). Miller (2002) presented forage intakes of 2.1 to 2.8% of a bison's body mass in summer and 1.4 to 1.8% in winter. Feist (2000) reported bison dry matter intake rates of 2.2 to 3.0% in summer and 1.4 to 1.8% in winter. Westfall et al. (1993) used 1.7% of body weight for yearlings and adults, and 3.1% for calves, for a forage allocation model at Theodore Roosevelt National Park. A widely used constant for cattle dry matter intake is 2.667% (Pratt and Rasmussen 2001, Meyer 2010). This constant is often applied across ungulate species, sexes, ages, reproductive status, season, forage quality, and other variables. I used the intake rate of 2.667%, but frame the results with lower (2.0%) and higher (3.0%) intake rates as well. Once a herbivore intake rate is established, the next step is to determine the weight of an animal or average weight within a herd.

Bison weights can vary greatly between sites and between years and are dependent on a variety of factors such as range condition. Wind Cave National Park routinely rounds up its bison herd and weighs animals during the process. The average weight of cows 2.5 years old and older is 899 lbs while the average weight of males 2.5 and older is 1,358 lbs, assuming a natural age distribution (Licht et al., in prep). Assuming a normal sex and age structure (Millspaugh et al. 2005) the average fall weight of all Wind Cave National Park bison (including calves) is 899 lbs. In contrast, the average fall weight of Badlands National Park bison is 1,057 lbs (Licht et al., in prep). In both cases the recorded weights are from October when the adult animals are likely at their heaviest; late winter/early spring bison weights can be 10% less (Miller 2002). I used 1,000 lbs for the primary analysis. Should the source bison come from a site with a dramatically different weight, such as Wind Cave National Park, the estimates presented here can be easily revised (i.e., changed proportionally) to account for the differing weights.

Once the land area of interest is delineated, annual plant productivity is calculated, a forage intake constant is established, and an average animal weight determined, the next step is to identify how much of the available forage should be allocated for consumption by herbivores. It is widely accepted that plants need to retain 40-60 percent of their leaf material to conduct photosynthesis and to produce carbohydrates and other products. In other words, plants need about 50% of their annual productivity to sustain themselves. As a result, many land managers follow the "*take half, leave half*" rule (Pratt and Rasmussen 2001). However, some range managers assume that a portion of the unused productivity will be trampled, soiled by animal waste, consumed by insects and smaller wildlife, and lost to other natural processes, so they allocate less than 50% for ungulate consumption. In some cases land managers may opt to take a relatively lower or higher percentage of the annual productivity to meet other range management goals (e.g., for a particular bird species that has certain habitat requirements). Generally speaking there is no right value as anywhere within the 15-50% range is sustainable and probably within natural variation. With this in mind, I used a 33% forage allocation to bison for my primary analysis, but framed the results using a lower (15%) and higher (50%) allocation.

Table 7. Summary of assumptions and values to determine stocking rate.

Variable	Lower Limit	Preferred Value	Upper Limit	Rationale
Pasture Size	2,325	2,676 acres	na	Generally follows property boundary but excludes small area to east of Highway 26. Lower limit also excludes administrative area in NE corner.
Productivity	Dry Year	Normal Year	Wet Year	Values come from U.S.D.A. Natural Resources Conservation Service and use their definitions.
Bison Weight	900 lbs	1,000 lbs	1,050 lbs	Preferred value derived from known October weights of bison, including the calf cohort, at Badlands National Park assuming a normal herd sex and age structure.
Forage Intake Per Body Weight	0.0200	0.02667	0.0300	The literature varies regarding a forage intake and intakes can vary between sites, seasons, animal status, and other variables. The preferred value is widely used.
Forage Allocation	15%	33%	50%	The lower limit is very light grazing whereas the upper value is used by some commercial operations.

Ideally, once an ungulate stocking density is established, and animals are introduced to the pasture, future population targets would be refined based on vegetation monitoring and adaptive management principles (Natural Resources Conservation Service 2003). For example, if plant structure is found to be changing to unacceptable levels, or floral composition is changing in undesired ways, then the targeted herd size should be adjusted. There are several easy and quick methods that can be used to monitor plant productivity and structure (Natural Resources Conservation Service 2003) and they should be considered as part of a bison restoration program at the park as the current Inventory and Monitoring Program protocol (Symstad et al. 2012) was not designed for that purpose.

Modeling Herd Demographics and Culling Strategies

In the absence of predators, bison herds can grow about 16% annually (Millspaugh et al. 2008). Agate Fossil Beds NM does not support wolves or bears (*Ursus* sp.), natural predators of bison, so the herd would quickly exceed the site's carrying capacity. While there are several ways to control population growth (e.g., shooting, reproductive control), most are unfeasible and would likely be dismissed in a full environmental assessment so they will not be evaluated here. In Northern Great Plains parks the accepted and widely-used method of keeping a herd within the site's carrying capacity is to periodically round up the bison and remove surplus animals via live transfer out of the park. That scenario is the only one evaluated here.

Within the framework of a bison roundup and removal strategy there are a myriad of variations that could be used. For example, bison could be rounded up every year or every fifth year. The removal (cull) could target only yearling animals or be proportional across all age classes. Ultimately, the selection of a culling strategy is dependent on herd objectives (e.g., desired growth rate, sex and age composition, genetic diversity), logistical considerations (e.g., available personnel and infrastructure), preferences of the recipients of bison (e.g., what sex and age classes they want), and other factors. Weather, fire, and other stochastic variables also come into play as they affect range conditions. All these considerations make it unrealistic to expect rigorous adherence to a fixed long-term strategy. Nonetheless, modeling various plausible culling scenarios helps decision-makers evaluate the feasibility of bison restoration and to plan for long-term management. For this study two models were used to evaluate bison growth rates, culling strategies, and the consequences of the strategies on herd demographics and genetics.

A bison demographic and culling model was developed by Millspaugh et al. (2005) for Badlands, Wind Cave, and Theodore Roosevelt National Parks under a National Park Service funded agreement. As part of the project park-specific bison demographic parameters (e.g., survival rates, fecundity) were calculated and used to populate the model. The model allows the user to input various starting populations, culling strategies, and other criteria such as stochasticity and density-dependent impacts, if desired. The model projects changes in herd demographics to year 25. (Copies of the Excel-based model can be obtained by contacting the National Park Service - Midwest Region Wildlife Biologist.)

For purposes of analyzing potential growth rates, herd demographics, and culling strategies for Agate Fossil Beds National Monument I generally relied on the model and demographic rates developed by Millspaugh et al. (2005) for Wind Cave National Park. However, as pointed out by Pyne et al. (2010), survival estimates that assume recapture may overestimate actual survival rates. Pyne et al. (2010) used a different approach that accounted for incomplete recapture in bison roundups. Their study resulted in slightly lower survival rates, more so for bulls; however, their study was conducted at Badlands National Park whereas the Millspaugh et al. (2005) values derived from the Wind Cave herd, which is the most likely source of animals for Agate Fossil Beds National Monument. Being that there were pros and cons to both datasets I opted to use the mid-point between the estimates from the two studies (Table 8). The values generally differed only by a few percentage points, with the greatest disparities being in the mature male class and the extremely old classes.

For fecundity rates I used the values from the Millspaugh et al. (2005) model. Although Pyne et al. (2010) reported 67% fecundity for the Badlands herd they expressed concern about the accuracy of the results and did not provide age-specific rates, a requirement for input in the Millspaugh et al. (2005) model. Hence, for 2-year olds I used the fecundity rate of 0.05, for 3-year olds 0.54, for 4-year olds 0.71, and for 5 to 10-year olds I used a rate that averaged 0.80. For older animals the rate declined steadily from 0.65 for 11-year olds to 0.01 for 17-year olds.

Table 8. Reported bison survival rates and values used in the models.

Parameter	Pyne et al. (2010)[1]	Millspaugh et al. (2005)	Value Used in Models
Survival			
Female			
Calf	0.96	0.98	0.97
Yearling	0.94	0.98	0.96
3 to 9	0.94	0.99	0.97
10	0.94	0.99	0.96
11	0.94	0.98	0.96
12	0.94	0.95	0.95
13	0.94	0.94	0.94
14	0.94	0.92	0.93
15	0.89	0.86	0.87
16	0.89	0.74	0.74
17	0.89	0.56	0.56
18	0.89	0.33	0.33
19	0.89	0.12	0.12
20	0.89	0.07	0.07
21	0.89	0.00	0.00
Male			
Calf	0.94	0.98	0.96
Yearling	0.93	0.99	0.96
3 to 9	0.80	0.99	0.90
10	0.80	0.98	0.89
11	0.80	0.98	0.89
12	0.80	0.97	0.88
13	0.80	0.90	0.85
14	0.80	0.79	0.80
15	0.80	0.63	0.63
16	0.80	0.35	0.35
17	0.80	0.14	0.14
18	0.80	0.08	0.08
19	0.80	0.00	0.00

[1] Pyne et al. (2010) reported results in age classes of 0.5, 1.5, 2.5-14.5, and ≥ 15.5 for females and 0.5, 1.5, 2.5-9.5, and ≥ 10.5 for males.

Each modeling scenario started with 40 yearling bison at a 50:50 sex ratio. I assumed this as the starting population in part because yearlings are the age class generally made available as surplus by Wind Cave National Park and in part because they are the most easily handled. I also ran simulations assuming a starting population of 20 yearling bison (50:50 sex ratio) under the assumption that the park may want to start with a smaller initial herd.

I considered running simulations that included older females in the reintroduced herd as such animals may provide social structure and behavioral benefits to the newly established herd. However, including older females in lieu of some yearlings could reduce the number of founder animals by some unknown amount as the cows may be dams of some of the yearlings. I assumed that genetic concerns were a higher priority than behavioral considerations and therefore I did not run such simulations, but I suggest the scenario be re-evaluated in the future and be strongly considered if advances in technology allow for the rapid and reliable identification of parents and offspring as part of the translocation process. Should that happen a reintroduction could consist of a few older females and yearlings that are not their offspring.

Culling strategies modeled were designed assuming a long-term average of about 166 animals (see the sections for Carrying Capacity). If the long-term herd size differs from that the culling results would generally have a proportional change. I did not use model modules for stochasticity, weather, and density-dependence as they did not seem necessary for bison modeling and any inputs would have been speculative (in other words, a deterministic model was run). The model results represent the herd in early fall, i.e., after calving, but prior to fall culling.

The Millspaugh et al. (2005) model was the primary model used for assessing herd growth, composition, and culling strategies; however, there were limitations with the model in regards to a proposed reintroduction of bison to Agate Fossil Beds National Monument. For example, yearlings will likely be the only age class reintroduced to the park yet the Millspaugh model does not easily allow one to turn off reproduction in years when there may be insufficient breeding-age males (as would be the case in the first few years if only yearlings were introduced). And the Millspaugh et al. (2005) model only projects changes to year 25, a duration that may be adequate when starting from a stable age distribution, but one that has limitations when starting from a herd with only yearlings. Furthermore, the Millspaugh et al. (2005) model does not analyze the potential genetic impacts of inbreeding.

Therefore, I also used the model VORTEX (Lacy and Pollak 2014) to assess herd growth, composition, and culling strategies. Regarding these analyses and parameters, VORTEX was primarily used to corroborate or better interpret the results from the Millspaugh et al. (2005) model. The reason that I did not use VORTEX as my primary model for assessing herd growth, composition, and culling strategies is that it did not always allow for the precise age and sex-specific inputs (e.g., culling rates) that the Millspaugh et al. (2005) model did nor did it give age and sex-specific outputs. In this feasibility study the primary use of the VORTEX model was to better understand changes to bison genetic diversity under varying herd sizes and culling strategies and under the assumption of inbreeding. The input values (e.g., survival rates, fecundity) used in VORTEX were the same as those listed earlier in this section (Table 8). A full discussion of the use of VORTEX and the assumptions and model parameters used is in the following section.

Genetics Analysis

I used VORTEX (Lacy and Pollak 2014) to model changes to bison genetic diversity under a variety of herd sizes, culling strategies, and source herds. VORTEX assigns founders unique alleles (i.e., an infinite allele model) and then tracks individuals over time to calculate expected and observed heterozygosity, allele retention, and number of lethal alleles. When inbreeding depression is enabled the model simulates assumed impacts of inbreeding on herd demographics. VORTEX has been used by others to model genetic changes and theoretical impacts to small bison herds (Halbert et al. 2004).

I used age-specific functions (Lacy et al. 2014, Lacy and Pollak 2014) to input the same survival and fecundity values used in the Millspaugh model (see the previous section). For example, for the mortality rate for females I used the function:

LOOKUP(A:3;4;3;3;3;3;3;3;3;4;4;5;6;7;13;26;44;67;88;93;100)

where *A* is the descriptor for age and the sequential numbers are the mortality rates for ages 1-21. VORTEX does not allow for age-specific harvests nor does it accept functions for that module, rather, harvests can only come from classes using the function variables of *J* (juvenile), *U* (sub-adult), *F* (adult female) and *M* (adult male). So for harvests I multiplied the function variable by the culling rate for the scenario (e.g., "*F* * 0.40" for harvesting 40% of adult females). Other VORTEX input parameters are listed below.

Reproduction

Reproductive System: Polygynous
Age of first offspring for females: 3
Maximum age female reproduction: 17
Age of first offspring for males: 3
Maximum age male reproduction: 17
Maximum lifespan: 21
Maximum number of broods per year: 1
Maximum number of young per litter: 1
Sex ratio of young: 50:50
Density Dependent Reproduction: off
Percent Adult Females Breeding: see previous section for age-specific fecundity
Environmental Variation (EV) in % Breeding: 0
% Males in Breeding Pool: 15

Mortality

Age 0 to 1: 3% for females and 4% for males
Age 1 to 2: 4% for females and 4% for males
Age 2 to 3: 3% for females and 10% for males
Age >3: see previous section for age and sex-specific mortality

Other Variables

Iterations: 1,000
Years: 100
Inbreeding depression: on
Lethal equivalents:6.29
Percent due to recessive lethals: 50

Environmental Concordance of Reproduction and Survival: on
Catastrophes: 0
Carrying Capacity: variable
Starting Population: unless otherwise noted simulations started with 20 female and 20 male yearlings
Harvest: variable, see culling strategies

Bison are polygynous breeders with prime age animals breeding more than other age groups. Berger and Cunningham (1994) reported that males in the age range of 7-12 do relatively more breeding based on field observations whereas Derr et al. (2011) found that males 6-9 years old breed relatively more based on genetic analyses. Derr et al. (2011) also found that 1-year old males successfully breed; however, this result has not been reported elsewhere in the literature. For males I established age of first offspring as three years of age, i.e., first breeding is at two years of age. To model disproportionate breeding by dominant individuals in the age class 7-12 I used a sinusoidal function that increased their probability of being in the reproductive pool for the year. This also increased their likelihood of multiple breeding in a year, a pattern confirmed by Berger and Cunningham (1994) and Derr et al. (2011).

Within an age cohort certain individuals may be dominant breeders (Berger and Cunningham 1994, Derr et al. 2011). To model this I created an individual state variable that randomly assigned half of the initial males, and all new males, as dominant and the other half as sub-dominant.

To best compare and contrast genetic changes due to varying herd sizes (e.g., 100, 166, 300 animals) I had to ensure that the mean population size over the 100-year runs were comparable to the starting size of the herd, thereby removing the potential bias of incremental herd growth or decrease. For the same reason, I had to make sure that each culling strategy (e.g., removal of 70% of yearlings) resulted in a long-term mean of 166 animals. To accomplish this and remove potential biases due to long-term herd growth or decline I made slight adjustments to the harvests, specifically, for comparing genetic changes due to varying herd sizes the cull actually took 70.12% of yearlings. For comparing the impacts of culling strategies I slightly adjusted the sub-adult culling rate for each scenario so that the long-term average population size for all four culling strategies was approximately 166 animals.

VORTEX includes a module for analyzing the theoretical impacts of inbreeding on population demographics (Lacy 2000, Lacy et al. 2014). After calibrating the harvest rates so the long-term average population size was similar to the initial herd size (for comparing the impact that herd size has on genetics) or the long-term mean population size was approximately 166 animals (for analyzing culling strategies) I then activated the inbreeding depression module in VORTEX to analyze how inbreeding theoretically affected herd demographics over 100 years as a result of herd size or culling strategy.

In addition to modeling genetic changes within varying herd sizes and culling strategies at Agate Fossil Beds National Monument, I also modeled the herd as if it was a metapopulation with free interchange between the Agate Fossil Beds National Monument, Tallgrass Prairie National Preserve, and Wind Cave National Park herds. While this assumption of free genetic interchange is implausible due to logistical and other reasons the analysis is informative from a theoretical perspective. Furthermore, a metapopulation approach toward bison management has been recommended.

Real world genetic values (e.g., heterozygosity, allele retention) and changes over time will likely differ from those modeled here. The VORTEX model I used assumed that animals in the starting population were unrelated whereas in reality the founder animals will likely be closely related as they will probably originate from the same source herd. Ideally, once a source herd is identified simulations would be run using the known allele frequencies of that herd, such as was done for modeling the transfer of Badlands National Park North Unit bison to the South Unit (Licht 2014). In addition, VORTEX conducts culling by randomly removing individuals from the population (within the juvenile, sub-adult, and adult age classes). If the actual culls vary from this assumption of randomness then the results here may not represent reality. For example, if entire family units of cow, yearling, and calf are removed in a cull it could result in a quicker loss of genetic diversity than a random cull.

Other Analyses

There are a variety of other issues and considerations that warrant evaluation in a bison reintroduction feasibility study; however, they do not easily lend themselves to quantitative or modeled analyses. For these I used a more qualitative analysis based on the scientific literature, experiences at parks with bison, and best professional judgment. For example, defensible predictions can be made about bison movement and foraging patterns, the composition of sub-herds, impacts to other wildlife species, the frequency of bison escapes, conflicts with visitors, and other issues. These are qualitatively discussed in the results section.

Result and Discussion

Carrying Capacity

Annual normal-year plant productivity for the recommended 2,676-acre bison pasture is 4.9 million lbs. (see the Study Area section). Productivity drops to 3.8 million lbs in a dry year and increases to 6.4 million pounds in a wet year (Table 3). Based on a pasture size of 2,676 acres, forage productivity for a normal-precipitation year, a mean bison weight of 1,000 lbs, a daily forage intake rate of 2.667% of body mass, and 33% forage allocation to bison, Agate Fossil Beds National Monument could support 166 bison, including calves, or about 136 yearlings and adults. In a dry year the park could support 129 bison and in a wet year 219 (including calves). Different objectives (e.g., the amount of forage allocated to bison) and different assumptions (e.g., intake rates) result in different carrying capacities (Table 9). The most conservative carrying capacity is 52 animals while the most liberal is 443. If the administrative, housing, and other areas in the northeast corner of the park are not available to bison (an area of about 300 acres), then the normal precipitation-year capacity is about 147 bison. The results can generally be adjusted proportionally for other assumptions. For example, if one assumes an average bison weighs 1,050 lbs (approximately the average Badlands National Park bison) then the results would all be reduced .86 (900/1,050). So the mid-point modeled herd size would be 159 instead of 185.

Table 9. Modeled bison carrying capacity (includes calves) assuming 2,676 acres.

Forage Production Allocated to Bison	Forage Intake as Percent of Body Mass	Range Condition		
		Dry Year Carrying Capacity	Normal Year Carrying Capacity	Wet Year Carrying Capacity
15%	0.02000	78	101	133
	0.02667	59	76	99
	0.03000	52	67	89
33%	0.02000	173	222	292
	0.02667	129	166	219
	0.03000	115	148	195
50%	0.02000	261	336	443
	0.02667	196	252	332
	0.03000	174	224	295

Using an AUE approach comes up with similar results. For example, using a 1,000 cattle cow-calf pair and a daily consumption rate of 26 lbs as the standard, a forage allocation of 33%, and assuming an AUE of 1.2 for bison (a midpoint between yearling and adult male bison AUEs), the 2,676 acres in the park could support 142 yearling and adult bison in a normal year. If the year's calf crop is added to that it would be similar to the 166 bison estimated using the body mass method. Assuming a pasture size of 2,676 acres, and a yearling/adult herd size of 142 bison, the stocking density is approximately 1 adult/yearling bison to 19 acres. This is comparable to the stocking rates for cattle in the region.

Culling strategies could change these results. For example, a disproportionate removal of bulls would result in a higher percentage of lighter-weight cows and hence, more animals could be supported. However, it is assumed that a normal age and sex structure is desired.

Herd Demographics and Culling Strategies

The most likely approach for keeping the bison population within the carrying capacity of the site is to periodically round up and remove surplus animals by live-transporting them out of the park. Management has numerous options regarding how to implement the culls with there being tradeoffs between the alternatives. Based on the assumed stocking rate of 166 bison (including calves), four plausible culling strategies were evaluated. The strategies were modeled using both the Millspaugh et al. (2005) and VORTEX (Lacy and Pollak 2014) models (the latter for genetic analysis: see the next section). Figures 13-16 are from the Millspaugh et al. (2005) model.

Strategy #1. Cull 70% of Yearlings Annually. This strategy removes 70% of male and female yearlings every year. Such a strategy is typical of many private and some public herds (e.g., Wind Cave National Park). The strength of the strategy is that it removes the easily-handled yearlings. The downside is that it requires frequent culls, results in an un-natural age distribution, and results in little annual variability in grazing pressure. Assuming an initial herd of 40 yearlings at a 50:50 ratio, there are no culls until year 9 to allow the herd to reach the desired population size. If the initial herd is comprised of only 20 yearlings the first cull is not needed until year 12.

Strategy #2. Cull 40% of Each Age/Sex Class Every 3 Years. This strategy removes 40% of each age/sex class, including calves, every third year. Such a strategy has been used in some public herds (e.g., Theodore Roosevelt NP, excepting calves) and is proposed for others (i.e., Tallgrass Prairie National Preserve). The strength of the strategy is that it requires less work than an annual cull, maintains a relatively natural age distribution, and shows inter-year variability in herd size which may better mimic natural processes. The downside is that it requires removal of older animals including the difficult to handle mature bulls. Assuming an initial herd of 40 yearlings at a 50:50 ratio, there is no need for culls until year 11. If the initial composition is 20 yearlings then the first cull is not needed until about year 14.

Strategy #3. Cull 60% of Each Age/Sex Class Every 5 Years. This strategy removes 60% of each age/sex class, including calves, every fifth year from a bison population. The strength of such a strategy is that it requires less work than an annual cull, maintains a natural age distribution, and shows inter-year variability that may better mimic natural processes. The downside is that it requires removal of older animals including the difficult to handle mature bulls. This strategy is poorer at conserving genetic diversity than the preceding two strategies (see the next section). Assuming an initial herd size of 40 yearlings at a 50:50 ratio, there is no need for culls until year 11. If the initial composition is 20 yearlings the first cull is not needed until about year 14.

Strategy #4. Cull 80% of Each Age/Sex Class Every 9 Years. This strategy removes 80% of each age/sex class, including calves, every ninth year. The strength of such a strategy is that it requires infrequent handling, maintains a relatively natural age distribution, and shows inter-year variability; however, the variability may be excessive and could be harmful in drought years. Other downsides are that the strategy requires removal of older animals including the difficult to handle mature bulls, the cull is a large operation involving many animals, and the strategy is the poorest at conserving genetic diversity. There is no need for culls until year 12. If the initial composition is 20 yearlings the first cull is not needed until about year 15.

Strategy #1. Cull 70% of Yearlings Annually.

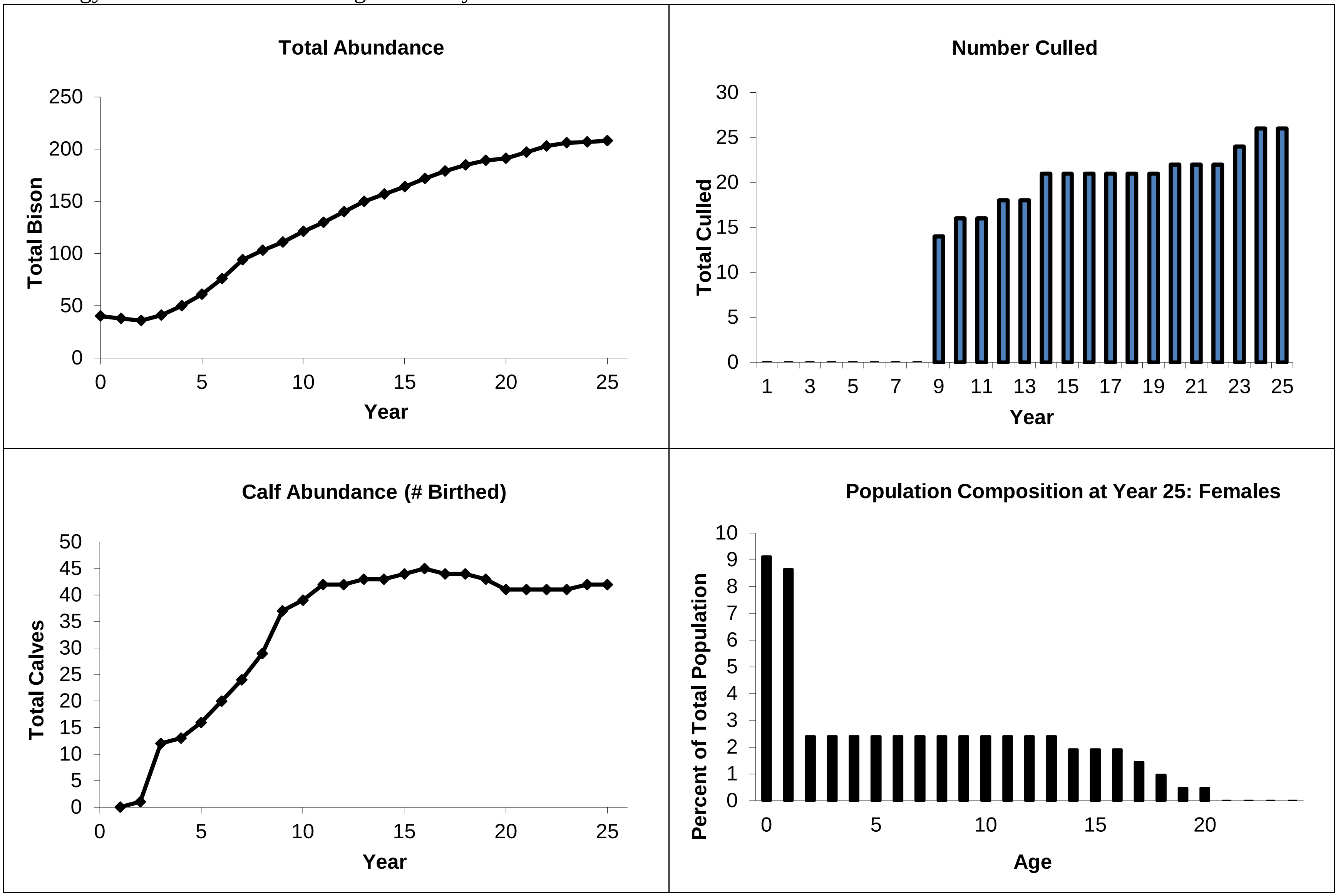

Figure 13. Bison demographics resulting from 70% annual cull of yearlings only.

Strategy #2. Cull 40% of Each Age/Sex Class Every 3 Years.

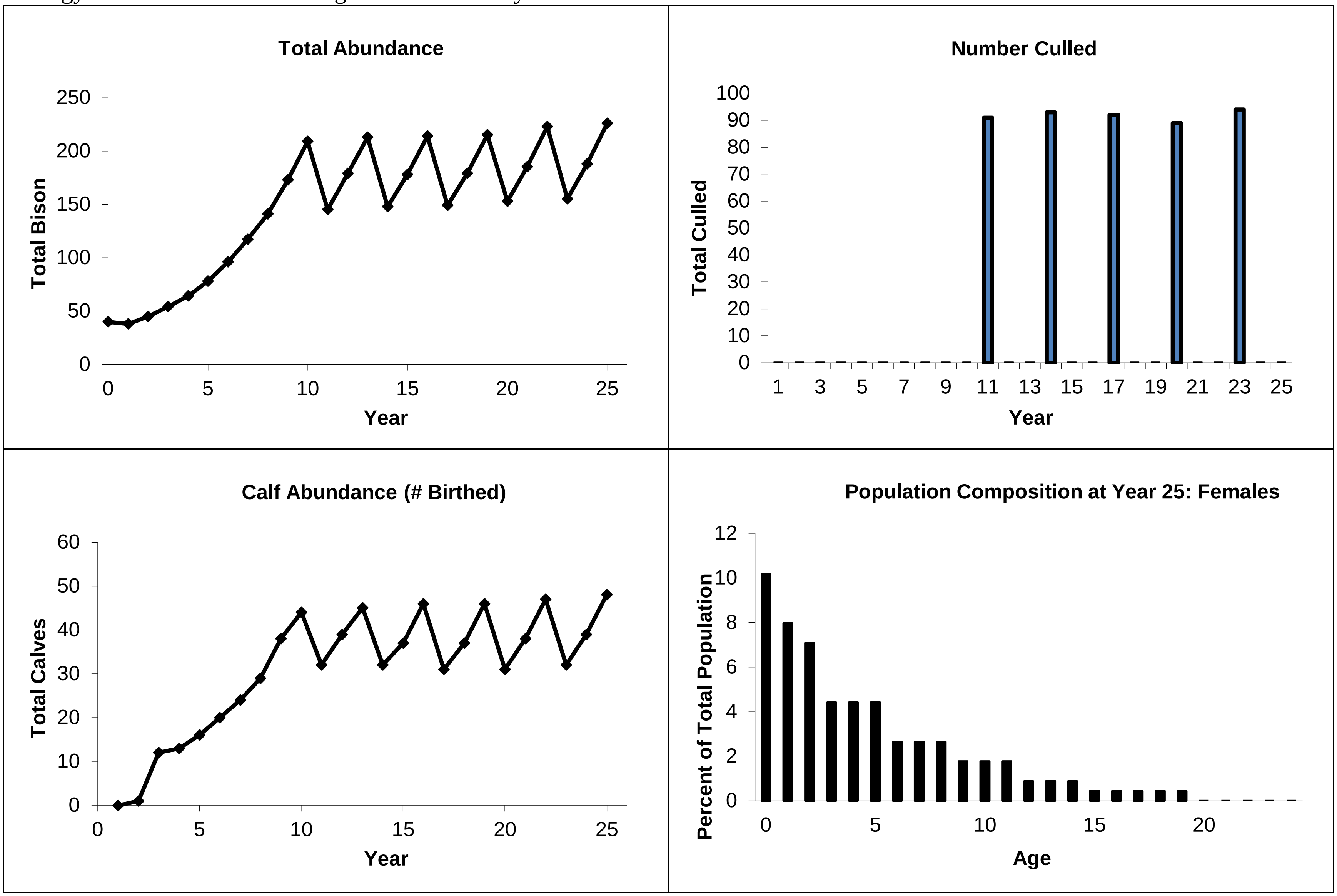

Figure 14. Bison demographics resulting from 40% cull every 3 years.

Strategy #3. Cull 60% of Each Age/Sex Class Every 5 Years.

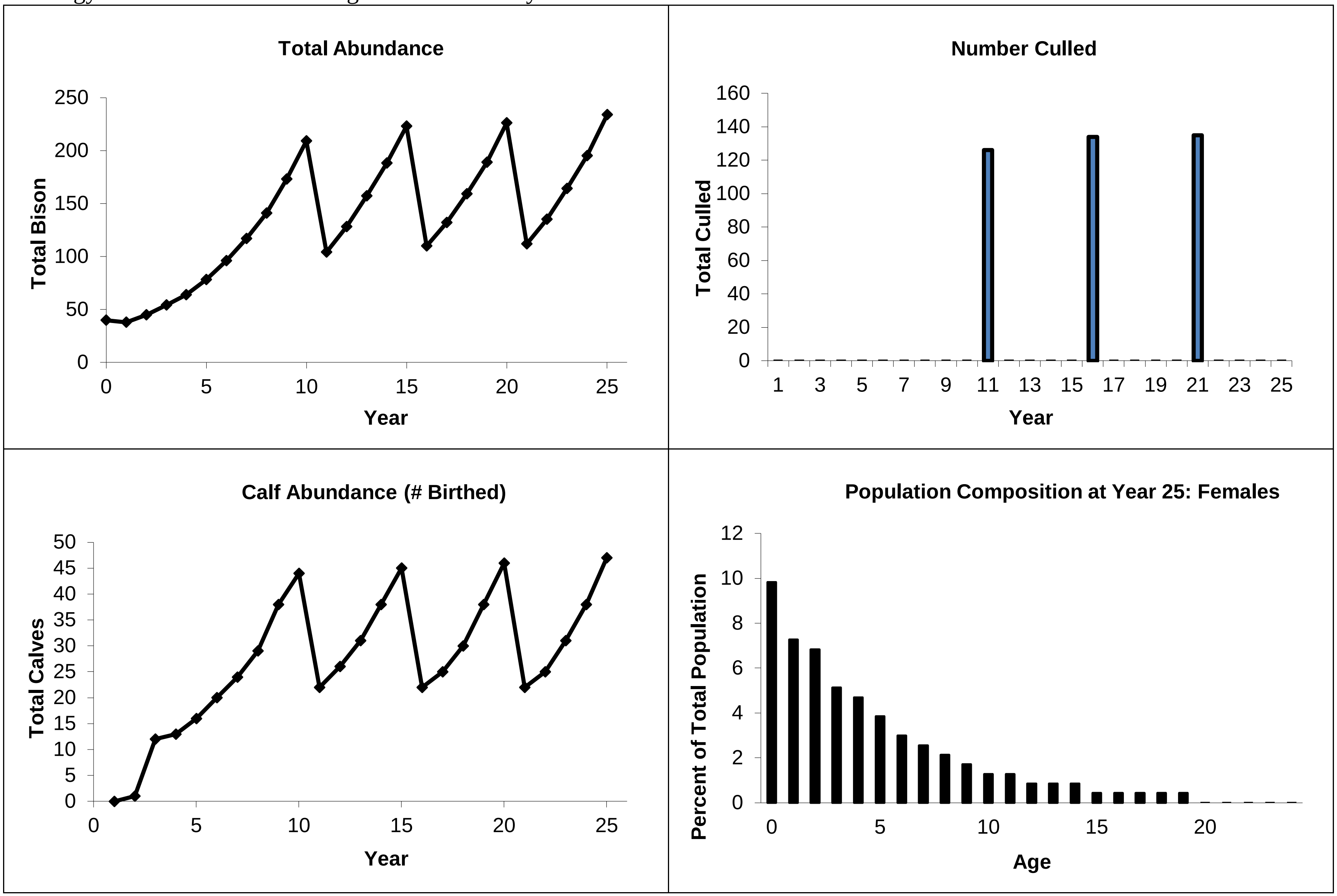

Figure 15. Bison demographics resulting from 60% cull every 5 years.

Strategy #4. Cull 80% of Each Age/Sex Class Every 9 Years.

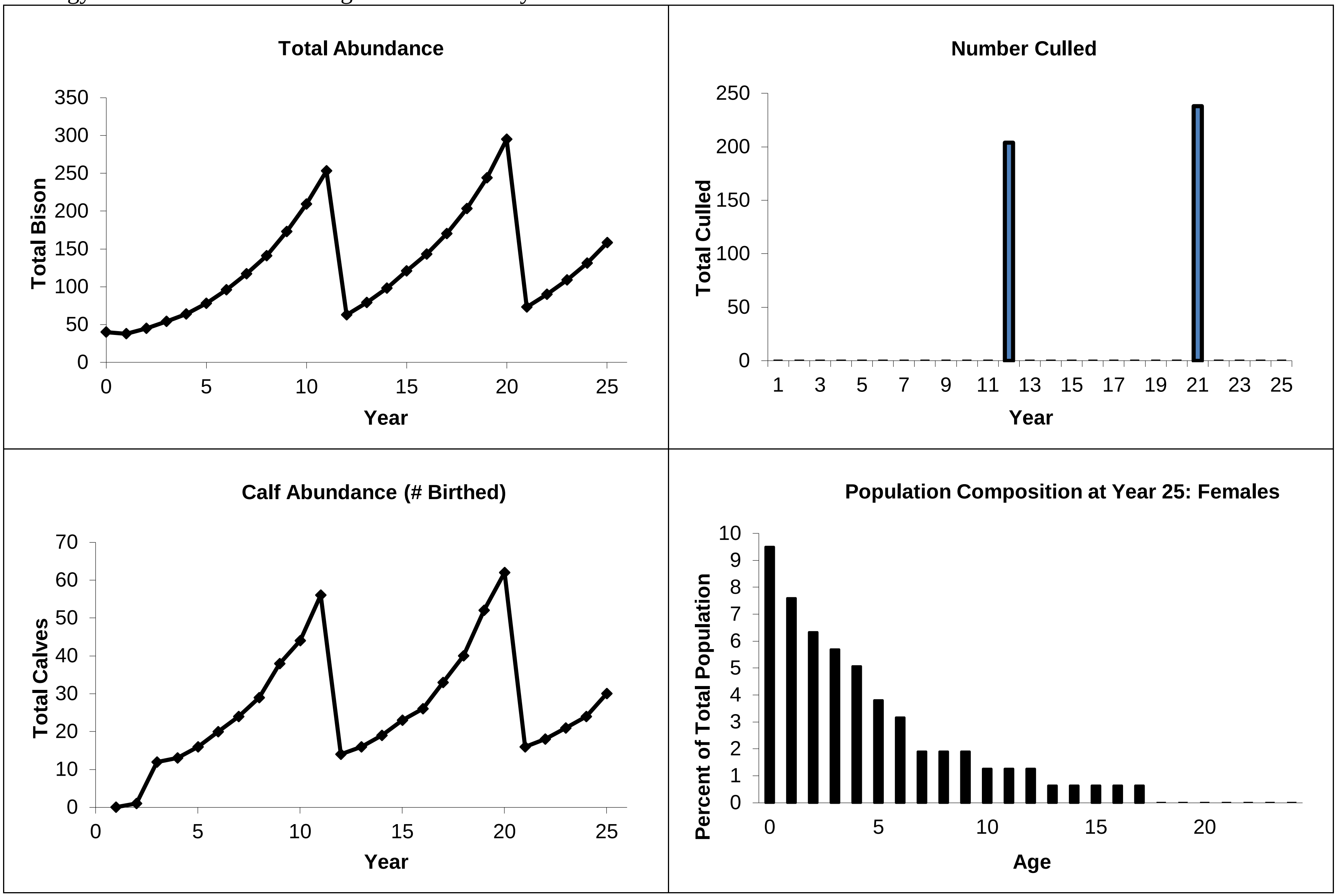

Figure 16. Bison demographics resulting from 80% cull every 9 years.

Genetics

I used VORTEX (Lacy and Pollak 2014) to model theoretical genetic changes over time under the varying herd sizes and culling strategies developed and analyzed elsewhere in this report. Under the assumption that the herd could be managed as part of a metapopulation with herds from Wind Cave National Park and Tallgrass Prairie National Preserve I modeled larger herd sizes. Last, for the various herd sizes I modeled theoretical demographic changes due to inbreeding.

The larger the bison herd the better genetic diversity is conserved, all else being equal (Table 10). For example, a herd that averages 300 animals conserves 0.9366 of its heterozygosity and 32.80 alleles per locus compared to a herd of 100 animals that conserves only 0.8195 of its expected heterozygosity and 11.43 alleles (assuming an annual cull of 70% of yearlings). Assuming the Agate Fossil Beds and Wind Cave herds were managed as a metapopulation, i.e., with movement of animals between the herds, the combined herd of 616 bison would conserve 0.9724 of its expected heterozygosity and 71.93 alleles after 100 years. The greatest benefits are realized when the existing Wind Cave herd, along with potential growth of the herd due to a recent expansion, is managed as a metapopulation with herds from Tallgrass Prairie National Preserve and Agate Fossil Beds National Monument. However, this modeled output has numerous assumptions one of which is free genetic exchange between the herds. In reality, exchange of animals and genetic material would be periodic, limited to a small number of animals, and perhaps targeted based on genetic analyses of individual bison. Modeling such scenarios is beyond the scope of this study, but could be done by better data and more sophisticated models.

Table 10. Modeled 100-year genetic changes under varying herd sizes with 70% yearling cull.

		No Inbreeding Depression				With Inbreeding Depression	
Starting Herd Size	Scenario	Mean Herd Size	Final Expected Hetero-zygosity	Final Observed Hetero-zygosity	Final Number Alleles	Mean Inbred Population Size	Percent Decline Due to Inbreeding
100	Agate Lower Limit	120	0.8184	0.8394	11.3	49[1]	59%
166	Agate Recommended Size	175	0.8843	0.8986	18.0	90[2]	49%
300	Agate Upper Limit	300	0.9355	0.9430	32.5	195	35%
450	Wind Cave	443	0.9586	0.9636	49.0	329	28%
616	Agate and Wind Cave	615	0.9706	0.9741	68.2	492	20%
716	Agate, Tallgrass, and Wind Cave	751	0.9755	0.9784	82.1	607	19%
966	Agate, Tallgrass, Wind Cave, and Wind Cave Addition	973	0.9819	0.9843	109.4	832	14%

[1] 2.4% of simulations went extinct; they are included in mean population size

[2] 0.1% of simulations went extinct; they are included in mean population size

Across culling strategies, removing 70% of the yearlings annually best conserved genetic diversity compared to less frequent culls that took a proportion of all age classes (Table 11). This is not surprising as a yearling-only cull would not take entire family groups whereas the multi-age class cull could take closely related social units including perhaps, some founder animals. Furthermore, less frequent culls mean that a larger proportion of the herd is taken, producing a short-term bottleneck for the population.

Table 11. Modeled 100-year genetic changes under various culling strategies.

	No Inbreeding Depression				With Inbreeding Depression	
Culling Strategy[1]	**Mean Population Without Inbreeding**	**Final Expected Heterozygosity**	**Final Observed Heterozygosity**	**Final Number Alleles**	**Mean Inbred Population Size[2]**	**Percent Decline Due to Inbreeding**
70% Cull	168	0.8466	0.8888	16.18	76	55%
40% Every 3 Years	166	0.8513	0.8654	13.07	40	75%
60% Every 5 Years	171	0.8258	0.8394	11.32	33	81%
80% Every 9 Years	170	0.7515	0.7703	7.90	22	87%

[1] For purposes of standardizing the long-term mean population sizes the calf cull was adjusted; the 3-year cull was 39%, the 5-year cull was 41%, and the 9-year cull was 70%.

[2] Includes all runs, both extant and extinct.

Under most scenarios a self-sustaining and genetically healthy bison herd is possible at Agate Fossil Beds National Monument for the foreseeable future. It's worth remembering that the modern Yellowstone herd started with just 30-50 animals and the Wind Cave herd with just 20 animals; the key for genetic conservation is to allow quick growth and to maintain a large population for a long time. Most scenarios evaluated here result in a genetically effective herd size of at least 50 individuals, a long-used rule-of-thumb for genetic conservation (Soule 1980). Genetic modeling also suggests that high levels of genetic diversity can be conserved under all the population levels and culling strategies evaluated here, although the actual values will be strongly influenced by the relatedness, size, and composition of the initial population. When starting with only 20 yearlings (at a 50:50 sex ratio) the 100-year final observed heterozygosity was 0.8406 and the final number of alleles was 11.21, both less than a herd that starts with 40 individuals. The observed heterozygosity levels in all the scenarios is well above the levels (0.38) reported for the genetically-impaired Texas State Bison herd (Halbert et al. 2004).

Other Considerations

Movement Patterns

Bison are social animals with relatively predictable herd structures. Cows, yearlings, and calves typically travel in large herds that may number in the hundreds whereas adult males typically travel in small bachelor herds consisting of just a few animals. However, during the summer breeding season the adult males join the cow/sub-adult herds. During that time of year most bison will be part of a large herd, with the exception of non-breeding bulls or bulls traveling between herds. Some predictions can also be made about foraging patterns within the park. Bison typically forage in places where there is new or green growth. The topography of the park and the varying soil and moisture types results in a patchwork of vegetation communities dominated by either warm-season or cool-season grasses. In spring the animals may be travelling in distinct cow-calf herds and bachelor herds on the south facing slopes, foraging on the new growth (Figure 17). In summer most of the animals will come together during the breeding season. They may spend much of their time in the moist-soil areas; however, they will likely also forage in upland areas where warm-season grasses predominate. In fall the animals will separate back into distinct cow/sub-adult herds and adult bull bachelor groups. This pattern will likely continue into winter, although bison may make more use of the hilltops dominated by warm-season grasses (which cure better and make better winter forage).

However, disturbance such as burn patterns may over-ride these generalities as bison will likely focus on such areas regardless of topography, soil type, plant composition, and social behaviors. Dodd and Smith (1994) reported that the fire-return interval at the park was five years or less. Burn patterns will greatly influence bison behavior and movements, and in return, bison movements will greatly influence burn patterns and fire plans and objectives.

Water

Bison make regular visits to surface water to drink, if not daily, then every few days. In larger landscapes they may concentrate their spatial use near surface water during drought periods (Kohl et al. 2013). Badlands National Park has used this characteristic to facilitate their late summer-early fall bison roundups as the permanent water sources in the park are near the bison corrals. However, the central location of the Niobrara River within Agate Fossil Beds National Monument and the small size of the park suggests that drinking water should have relatively little bearing on seasonal bison movement and foraging patterns.

Adult bison can consume about 12 gallons of water daily. Assuming a herd of about 150 adults, that comes to 1,800 gallons a day. The Niobrara River has a flow rate of about 10-20 cubic feet per second, or 75-150 gallons per second. Under these conditions the bison needs could be met with less than a half a minute of flow. Even with bison abundance at peak levels and during low flow periods there should be no concern about water availability for bison, bison impacts on flow, or impacts to downstream users. One unknown is whether hard freezes in the winter could prevent bison access to the water. The park should monitor this situation closely.

Exotic Plants

Agate Fossil Beds National Monument staff have observed that the noxious plant pale yellow iris is uncommon on sites outside of the park that have cattle grazing, but is common within the park where there is no grazing and hence, they have speculated that the reintroduction of a grazer to the park may help control the non-native plant. This dissimilarity has been observed within the park boundaries as well as a small leased in-holding with periodic cattle grazing appears to have less prevalence of the iris than do the park fee lands without grazing (J. Spaak, pers. comm.). The pale yellow iris can form extensive monocultures that preclude other plants. It may do this by forming a “hard-pan” effect on the soil that precludes the establishment of other species. Its speculated that the mechanical action of cattle hooves breaks up the pan thereby allowing other plant species to become established (J. Spaak, pers. comm.). Consumption appears to play less of a role in control of the plant; in fact, cattle that have digested the plant display signs of gasteroenteritis and chronic diarrhea and subsequently avoid the plant. Whether bison would impact or control to the same extent as cattle is uncertain. Although bison will visit the Niobrara River for water, they will probably spend less time at the site than cattle (Fuhlendorf et al. 2010, Kohl et al. 2013). They too will likely avoid consuming the plant, but the mechanical action of their hooves could break up the hard soil pan the same way that cattle hooves do (J. Spaak, pers. comm.).

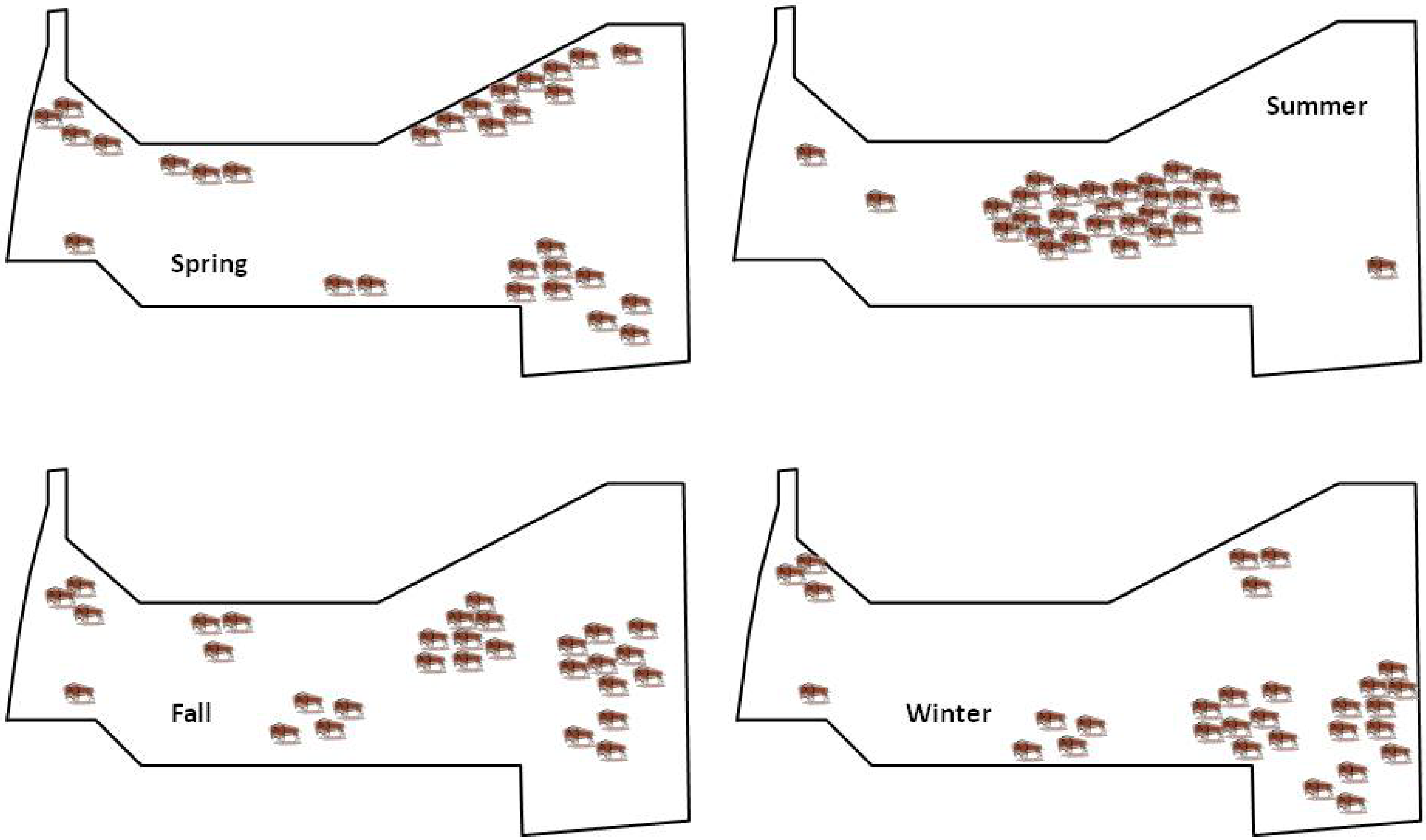

Figure 17. Graphic representation of bison herd structure by season.

Biodiversity

The reintroduction of bison to the site, at densities that remove 15-50% of the annual plant productivity, will likely lead to an increase in plant and animal biodiversity at the site. The degree of these changes is dependent on stocking densities and other factors and therefore, only generalizations can be made here. Studies have found that bison create heterogeneity on the landscape, both via their grazing and other behaviors such as wallowing (Collins and Barber 1986). In some cases bison may revisit grazed patches repeatedly as their grazing stimulates new plant growth (Knapp et al. 1999). Bison selection for grasses tends to open up thick stands of grass allowing for an increase in forbs (Coppedge et al. 1998). At Agate Fossil Beds National Monument this trait may be most noticeable in the moist soil areas along the Niobrara River where dense stands of grass grow, including Kentucky bluegrass, a non-native species. Bison grazing may lead to an increase in the composition, form, and function of plant diversity that can lead to an increase faunal diversity.

The presence of bison should improve habitat for pronghorn antelope within the park as bison select for grasses which releases forbs; pronghorn prefer the latter. However, the presence of pronghorn will depend on what type of fencing is used as a woven-wire fence could effectively fence pronghorn out of the park. Swift fox could also benefit; however, the grazing level would have to be high to create the short vertical structure preferred by the small canine. Depending on the grazing intensity there could be slight shifts in the grassland bird community. For example, heavy grazing may tend to increase the presence of horned larks (*Eremophila alpestris*) at the site and decrease the number of meadowlarks, although the latter will likely remain very abundant.

The diversity and heterogeneity created by bison will be most substantial if bison are reintroduced and an active burn program is conducted. The combination of the two would create a rich, diverse, and healthy park ecosystem. Burning should be done in patches (e.g., 100 acre burns), thereby creating the landscape diversity that bison prefer as well as many other species.

Although roundups will remove most bison, some animals will die of old age and other natural causes. Dead bison should be allowed to decompose in situ. In the short-term the carrion is an important and substantial food for many scavengers; in the long run bison decomposition sites are rich in minerals and nutrients which will lead to more plant diversity. Skulls, especially bull skulls, may need to be removed from the field as they are prone to theft. Wind Cave National Park smashes skulls or removes the horns to make them less susceptible to theft.

Figure 18. Vertical structures would need to be protected from bison rubbing.

Infrastructure

The presence of bison could cause conflicts with other resources, infrastructure, neighbors, and the visiting public. Some of these impacts, such as potential impacts to cultural or paleontological resources, are better addressed in an environmental assessment with input by experts on those resources. The degree of impacts that bison have on park infrastructure will depend in large part on the delineation of the bison pasture. A boundary that encompasses the administrative area will likely have more impacts and conflicts. The most common impact will likely be bison rubbing on vertical structures. Bison regularly rub against hard objects, probably to remove winter hair, but perhaps also simply to relieve itching caused by ecto-parasites. Vulnerable structures, such as weather stations, will have to be protected with a fence or other barrier. Yet these impacts may be deemed tolerable and manageable. For instance, Yellowstone National Park has bison wandering through administrative and visitor areas with lots of infrastructure with few significant impacts. Conversely, Wind Cave has established a fence exclosure around its administrative area (the Badlands and Theodore Roosevelt administrative areas are away from the bison pastures).

As of the writing of this report neighboring lands were used primarily for cattle grazing. With a well-built fence there should be few if any bison escapes from the park, based on the experience at other Northern Great Plains parks with bison. The relatively small size of the park and modest topography will make fence inspection and maintenance easier than at other parks.

A black-top county road traverses east-west through Agate Fossil Beds National Monument. The potential for vehicle-bison collisions is a concern, especially at night when the brown animals are difficult to see. However, in other parks with county or secondary roads the number of vehicle-bison collisions is negligible. Badlands has about 10 miles of gravel county road and reports no accidents. In contrast, Wind Cave National Park has a highway going through the park, although speed limits are restricted to 45 mph within the park. They report about 8 bison-vehicle accidents annually. Signing and speed restrictions can help reduce the likelihood of wildlife-vehicle accidents.

Visitors
Agate Fossil Beds National Monument gets only a modest number of visitors, mostly during the summer months. Hiking is mostly done on the established walking trails leading to fossil sites. The presence of bison will have some impact on visitations to the park and on visitor experience. In terms of visitation the presence of bison should increase visitation rates, although how much is difficult to say. It will depend in part on how much the bison are promoted. Most visitors will likely view the presence of bison as a positive experience, enhancing their time and experience at the park. A small number of visitors may have some hesitation about hiking trails when bison are in proximity. In some cases visitors may get too close to bison, requiring intervention by park staff. Bison are most likely to be aggressive when defending young calves or during the late summer breeding season; both periods occur during the peak summer visitation period. Outreach and monitoring of visitor behavior can help reduce potential conflicts.

Handling
Bison will need to be periodically rounded up and surplus animals removed. The park should practice the handling and data-collection methods currently used by other Northern Great Plains parks with bison, such as Wind Cave National Park (National Park Service 2006a). For example, all animals processed in roundups should be marked with passive subcutaneous tags which allow for life-long identification of the animal as well as external metal tags as subcutaneous tags do get lost. Tissue and/or blood samples should be collected. Tail-hair follicles should be collected as they are currently the preferred sample for genetics work. Animals should be weighed, shoulder height measured, and reproductive status ascertained. The park should coordinate with the state veterinarian regarding current disease testing requirements and protocols as they change frequently.

Source Herds
The best source of bison for Agate Fossil Beds National Monument is perhaps the Wind Cave herd. The herd has high genetic diversity and is free of brucellosis. Within a few years SNPs technology may be available that will allow for testing for genetically pure bison (i.e., to ensure there are no cattle genes in individual bison). If so, the goal should be to stock Agate Fossil Beds National Monument with genetically pure bison. This is a relatively easier way to create a genetically pure bison herd on NPS lands versus trying to purge cattle genes from existing herds.

Conclusion and Recommendations

Bison conservation is a high concern within the scientific and conservation communities in part because of the imperiled status of brucellosis free, genetically healthy, naturally behaving, and ecologically significant bison populations (Redford and Fearn 2007, Sanderson et al. 2008, Gates et al. 2010). New initiatives and goals within the U. S. Department of the Interior and the National Park Service have elevated bison conservation within the federal government (U. S. Department of the Interior 2008, National Park Service 2011). These initiatives, along with scientific studies and recommendations (Dratch and Gogan 2008), recognize that even smaller sites can contribute to bison conservation. Furthermore, agency policies call for the restoration of native species (National Park Service 2006b). A Department of the Interior (2014) report explicitly mentioned Agate Fossil Beds NM as one of the best sites to receive Yellowstone NP bison. As a result, a serious, comprehensive, and scientific evaluation of the feasibility of restoring and conserving bison at Agate Fossil Beds National Monument is warranted. This report provides such an analysis.

Ecologic Feasibility

Reintroducing and conserving bison to Agate Fossil Beds National Monument is ecologically feasible with very little risk of failure. Bison reintroductions and conservation are now routine in much of the Great Plains, on public, private, and tribal lands. Many sites are substantially smaller than Agate Fossil Beds National Monument, yet they successfully conserve bison.

The analysis conducted here indicates that a fall population of 166 bison could be conserved on a 2,676-acre site within the park. In dry years the carrying capacity would be 129 animals and in wet years 219. Different assumptions, such as the percent of plant productivity allocated to bison, result in different stocking densities, but the modeled densities generally are in the 100-300 animal range in a normal precipitation year. Larger herd sizes better conserve genetic diversity.

Assuming an initial reintroduction of 40 yearlings, the herd would reach carrying capacity in about year 9, at which time a removal of surplus animals would be required. Periodic roundups and culling of surplus animals would be the most feasible way of maintaining the herd within the park's carrying capacity. A culling scenario that balances the logistical challenges of roundups while preserving genetic diversity and keeping the herd at an acceptable carrying capacity would be to cull 40% of the herd every third year, or about 81 animals each roundup. Other culling schedules are reasonable, but all have tradeoffs.

Benefits

There would be numerous benefits to restoring bison to Agate Fossil Beds National Monument. The benefits include:

1. <u>Restoring a native species to the park.</u> National Park Service policies call for the restoration of native species when certain conditions are met (National Park Service 2006b). A bison restoration at Agate Fossil Beds National Monument clearly meets the conditions.

2. Restoring an ecological process to the park that enhances the conservation of biodiversity. Bison are considered a keystone species (Knapp et al. 1999). Restoring bison would restore grazing, one of the three drivers of prairie ecosystems and prairie health (Knapp et al. 1998). Bison grazing, along with other bison behaviors (e.g., urination, wallowing), should result in more diverse plant and animal communities at the park (Reynolds et al. 2003). The restoration of a large grazer such as bison may also reduce the prevalence of exotic plants such as the pale yellow iris. Restoring grazing is also consistent with National Park Service policies which call for the restoration of natural processes (National Park Service 2006b).

3. Improving visitation rates, stay lengths, and visitor experience and understanding. Agate Fossil Beds National Monument gets relatively little visitation, and much of it is for just a few hours, probably due in part to its relative lack of charismatic wildlife species such as bison. The presence of bison would likely increase visitation and improve the visitor experience. The relatively small size of the park, the east-west county road, and the wide open vistas mean that bison would be readily viewable.

4. Benefitting local communities via increased ecotourism. National parks with high visitation rates contribute greatly to local communities and economies. Communities such as Chadron, Mitchell, and Scottsbluff could all benefit from bison restoration at the park.

5. Restoring a Native American ethnographic, cultural, and material resource. Agate Fossil Beds National Monument has a strong connection with Native American tribes (National Park Service 2012). Bison were a critical and central element of all tribes in the Great Plains region. Restoring bison to the park would strengthen the connection between the parks and tribes, and surplus animals could provide tangible benefits to tribes.

6. Contributing to meeting U. S. Department of the Interior and National Park Service bison goals. The Department of the Interior *Bison Initiative* establishes several priorities and goals for bison conservation including increasing "existing DOI herds to 1,000 or more bison, or establish new herds or metapopulations that can reach that size" (U. S. Department of the Interior 2008). Similarly (albeit more vaguely), the National Park Service *Call to Action* calls for the restoration of bison (National Park Service 2011). Restoring bison to Agate Fossil Beds National Monument could aid in meeting federal goals. For example, the herd could be managed as part of a metapopulation that includes the Wind Cave and Tallgrass Prairie herds, effectively approaching the 1,000 animal criteria (Figure 17).

7. Establishing a metapopulation that contributes to the genetic conservation of bison. Bison are a species of conservation concern in part because of concerns about declining genetic diversity (Redford and Fearn 2007, U. S. Department of the Interior 2008, Gates et al. 2010). Dratch and Gogan (2008) recommended a metapopulation approach be used to effectively increase the size of existing NPS bison herds and thereby aid in the conservation of genetic diversity. The rudimentary analyses presented here shows that a bison herd at Agate Fossil Beds National Monument can contribute to the conservation of bison genetic diversity.

8. Establishing a genetically pure bison herd. Bison are a species of conservation concern in part because of concerns about cattle introgression (Dratch and Gogan 2008). All NPS herds in the Northern Great Plains appear to have some level of cattle introgression. With advances in SNPs technology it may be possible to stock a pure bison herd at the park, i.e., one that is free of cattle introgression. Starting a pure bison herd would be substantially easier than cleansing existing herds.

9. Establishing a satellite herd that provides redundancy in case of a catastrophe to other National Park Service herd(s). In the 1964 and again in 1979 Wind Cave National Park slaughtered a large portion of its bison herd due to the prevalence of brucellosis (National Park Service 2006a). It's conceivable that such a depopulation could happen again, greatly compromising the viability and integrity of the herd. If animals of Wind Cave National Park origin were conserved at another site the off-site herd could be used to replenish the Wind Cave herd in case of catastrophe.

10. Be a repository for Yellowstone bison. A driving impetus for this study were discussions within the Department of the Interior about where to transfer quarantined brucellosis-free bison originating from Yellowstone National Park (U. S. Department of the Interior in prep). Although that need has apparently subsided, it could resurface in the future.

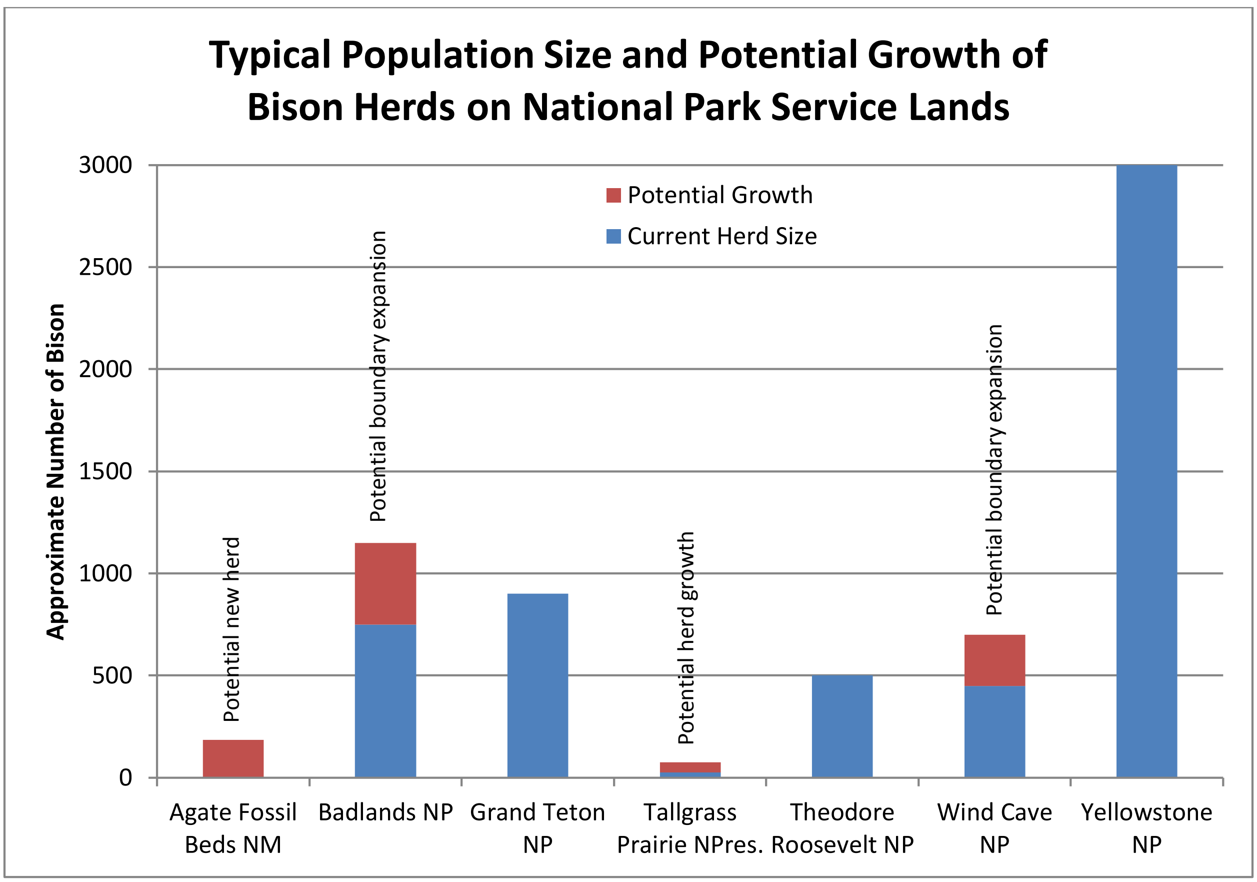

Figure 19. Bison herd size in NPS units and projected growth.

Challenges

There are several challenges to bison reintroduction at the park. They are primarily non-ecological. The challenges include:

1. Persuading others within and outside the NPS of the benefits of bison restoration. Until recently, bison restoration within the NPS was thought only appropriate for sites that consisted of tens of thousands of acres. The recent reintroduction of bison to Tallgrass Prairie National Preserve has set a precedent for smaller sites and demonstrated that they can contribute to bison conservation and the benefits outweigh the costs. The Department of the Interior (2014) report affirms that small sites have a role to play in bison conservation.

2. Developing infrastructure for bison management. Startup infrastructure primarily consists of building adequate fencing. Long-term infrastructure includes establishing either a permanent or temporary corral system. The park would need additional funding to acquire and construct the items. Furthermore, the structures could impact other resources including the cultural landscape and viewshed. These impacts would need to be evaluated in an environmental assessment.

3. Adding staff with natural resource expertise. Even in the absence of bison the park needs staff dedicated to natural resource issues and with the skills and knowledge to conduct a natural resource program. The additional of bison would make that need even more critical and should be a prerequisite for restoring bison.

4. Having a funding mechanism for bison management and culling operations. The termination of cost recovery in 2010 has seriously compromised bison management in North Great Plains parks. Until a reliable funding source is mechanism is identified it may not be prudent for Agate Fossil Beds NM to pursue a bison restoration.

5. Potential for homogenous grazing. The small size of the park may prevent bison from grazing in a heterogeneous manner, as is observed in larger systems. However, management practices such as the judicious use of prescribed fire could mitigate this concern. Fortunately, the NPS has an active vegetation monitoring program that should detect substantial changes in vegetation, both spatially and temporally.

6. Protecting paleontological resources. Agate Fossil Beds National Monument was established in large part to protect paleontological resources, many of which as in situ. Consultation with paleontologists and if necessary, mitigating measures, should be considered. Staff at Badlands National Park should be consulted as that park has both bison and extensive paleontological resources.

Recommendations and Next Steps

This report is a feasibility study of reintroducing bison to Agate Fossil Beds National Monument. The purpose of this document is to provide scientifically-developed information that management can use to make better-informed decisions regarding bison restoration at the park. Having fully evaluated the science of restoring bison to the park, within the context of bison management in the National Park Service, the author makes the following recommendations:

1. The park should discuss bison partnership and management opportunities with neighbors. The park has a neighbor that owns approximately 5,000 acres along the Niobrara River. They should be contacted regarding partnership opportunities. Private-public partnerships for wildlife conservation are commonplace and effective in other countries (Licht et al. 2014), but rarely used in the National Park Service.

2. The park should conduct a full environmental assessment to better understand all of the ramifications of such an action, many of which are outside the scope of this scientific ecological evaluation. Such a process would also bring in upper-level management, other subject-matter experts, and the public.

3. The park needs a full time natural resource specialist or biologist. Should the park pursue reintroducing and conserving bison it is critical that they have the expertise and resources necessary for such a program. Even in the absence of bison the park still, arguably, has such a need. Adding natural resource expertise should be a high priority for the park.

4. The NPS should reinstitute *cost recovery* or identified a substitute funding mechanism or source as a way to fund and conduct bison roundups and management. Cost recovery could conceivably pay the full cost of bison management at the park, once the herd reaches carrying capacity. In the absence of cost recovery, or a dedicated funding source for bison management, bison restoration at the park is fraught with uncertainty and risks and is not recommended.

Figure 20. Typical habitat at Agate Fossil Beds National Monument.

Acknowledgements

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Literature Cited

Ashton, I., S. K. Wilson, D. Swanson, M. Prowatzke, and P. Graeve. 2013. Plant community composition and structure monitoring for Agate Fossil Beds National Monument: 2012 annual report. National Park Service, Fort Collins, CO.

Berger, J. and C. Cunningham. 1994. Bison: mating and conservation in small populations. Columbia University Press.

Biondini, M. E., A. A. Steuter, and R. G. Hamilton. 1999. Bison use of fire-managed remnant prairies. Journal of Range Management 52:454-461.

Bragg, T. K., B. Hamilton, and A. Steuter. 2002. Guidelines for bison management: The Nature Conservancy. The Nature Conservancy, Arlington, Virginia.

Collins, S. L. and S. C. Barber. 1986. Effects of disturbance on diversity in mixed-grass prairie. Vegetation 64:87-94.

Coppedge, B. R., T. S. Carter, J. H. Shaw, and R. G. Hamilton. 1997. Agnostic behavior associated with orphan bison (Bison bison L.) calves released into a mixed resident population. Applied Animal Behaviour Science:1-10.

Coppedge, B. R., D. M. Leslie, and J. H. Shaw. 1998. Botanical composition of bison diets on tallgrass prairie in Oklahoma. Journal of Range Management 51:379-382.

Department of the Interior. 2014. Report by the Department of the Interior Bison Working Group to the May 2012 Secretary's directive on the placement of Yellowstone-origin bison., Department of the Interior,.

Derr, J., N. Halbert, and T. Swannack. 2011. Development of a genetic based conservation management program for the Wind Cave National Park bison herd. PMIS 121193, Texas A&M University, Texas A&M University.

Dodd, J. L. and M. A. Smith. 1994. Fire ecology and management of Scotts Bluff and Agate Fossil Beds National Monument: final report., National Park Service, Harrison, NE.

Dratch, P. and P. Gogan. 2008. Bison conservation initiative: bison conservation genetics workshop: report and recommendations. Fort Collins, CO.

Feist, M. 2000. Basic nutrition of bison. Saskatchewan Agriculture. 20pp.

Fritz, K. M., W. K. Dodds, and J. Pontius. 1999. The effects of bison crossings on the macroinvertebrate community in a tallgrass prairie stream. American Midland Naturalist 141:253-265.

Fuhlendorf, S. D., B. W. Allred, and R. G. Hamilton. 2010. Bison as keystone herbivores on the Great Plains: can cattle serve as proxy for evolutionary grazing patterns? Wildlife Conservation Society and American Bison Society.

Fuhlendorf, S. D. and D. M. Engle. 2004. Application of the fire—grazing interactions to restore a shifting mosaic on tallgrass prairie. Journal of Applied Ecology 16:1706-1716.

Fuhlendorf, S. D., W. C. Harrel, D. M. Engle, R. G. Hamilton, C. A. Davis, and D. M. L. Jr. 2006. Should heterogeneity be the basis for conservation? Grassland bird response to fire and grazing. Ecological Applications 16:1707-1716.

Gates, C. C., C. H. Freese, P. J. P. Gogal, and M. Kotzman. 2010. American bison: status survey and conservation guidelines 2010. International Union for the Conservation of Nature, Gland, Switzerland.

Gerlanc, N. M. and G. A. Kaufman. 2003. Use of bison wallows by anurans on Konza Prairie. American Midland Naturalist 150:158-168.

Gogan, P. J. P., R. E. Russell, E. M. Olexa, and K. M. Podruzny. 2013. Pregnancy rates in central Yellowstone bison. The Journal of Wildlife Management 77:1271-1279.

Grandin, T. 1999. Safe handling of large animals (cattle and horses). Colorado State University, Fort Collins, Colorado.

Green, W. C. H. and A. Rothstein. 1991. Trade-offs between growth and reproduction in female bison. Oecologia 86:521-527.

Gross, J. E. and G. Wang. 2005. Effects of population control strategies on retention of genetic diversity in National Park Service bison (*Bison bison*) herds. Report submitted to Yellowstone Research Group USGS-BRD, Bozeman MT.

Halbert, N. D. 2003. The utilization of genetic markers to resolve modern management issues in historic bison populations: Implications for species conservation. PhD dissertation. Texas A&M University, College Station, Texas.

Halbert, N. D., P. J. P. Gogan, R. Hiebert, and J. N. Derr. 2007. The role of history and genetics in the conservation of bison on U.S. federal lands. Park Science 24:22-29.

Halbert, N. D., W. E. Grant, and J. N. Derr. 2005. Genetic and demographic consequences of importing animals into a small population: a simulation model of the Texas State Bison Herd (USA). Ecological Modelling 181:263-276.

Halbert, N. D., T. Raudsepp, B. P. Chowdhary, and J. N. Derr. 2004. Conservation genetic analysis of the Texas State Bison Herd. Journal of Mammalogy 85:924-931.

Hart, R. H. 2001. Where the buffalo roamed - or did they? Pages 83-102 Great Plains Research. Center for Great Plains Studies.

Holechek, J. L. 1988. An approach for setting the stocking rate. Rangelands 10:10-14.

Knapp, A. K., J. M. Blair, J. M. Briggs, S. L. Collins, D. C. Hartnett, L. C. Johnson, and E. G. Towne. 1999. The keystone role of bison in the North American tallgrass prairie. BioScience 49:39-50.

Knapp, A. K., J. M. Briggs, D. C. Hartnett, and S. L. Collins, editors. 1998. Grassland dynamics: long-term ecological research in tallgrass prairie. Oxford University Press, New York.

Kohl, M., P. Krausman, K. Kunkel, and D. Williams. 2013. Bison vs cattle: are they ecologically synonymous? Rangeland Ecology in press.

Lacy, R. C. 2000. Structure of the VORTEX simulation model for population viability analysis. Ecological Bulletins 48:191-203.

Lacy, R. C., P. S. Miller, and K. Traylor-Holzer. 2014. Vortex 10 user's manual., IUCN SSC Conservation Breeding Specialist Group and Chicago Zoological Society, Apple Valley, MN.

Lacy, R. C. and J. P. Pollak. 2014. Vortex: a stochastic stimulation of the ecological process (Version 10.0). Brookfield, IL: Chicago Zoological Society. Retrieved from http://www.vortex10.org/vortex.html

Lawson, R. 2004. Final report of the butterfly field inventories for Agate Fossil Beds National Monument and Scottsbluff National Monument. Submitted to the Northern Great Plains I&M Program., National Park Service, Keystone SD.

Licht, D. S. 2014. Bison (*Bison bison*) Restoration and Management Options on the South Unit and Adjacent Range Units of Badlands National Park in South Dakota: a technical evaluation. Department of the Interior. National Park Service, Fort Collins, CO.

Licht, D. S., B. C. Kenner, and D. E. Roddy. 2014. A comparison of the South African and United States models of natural areas management. ISRN Biodiversity 2014.

Lott, D. F. 1991. American bison socioecology. Applied Animal Behaviour Science 29:135-145.

Matlack, R. S., D. W. Kaufman, and G. A. Kaufman. 2001. Influence of grazing by bison and cattle on deer mice in burned tallgrass prairie. American Midland Naturalist 146:361-368.

McCracken, J. D. 2005. Where the bobolinks roam: the plight of North America's grassland birds. Biodiversity 6:20-29.

McHugh, T. 1979. The time of the buffalo. University of Nebraska Press, Lincoln, Nebraska.

McKercher, L. and D. R. Gregoire. 2013. Lithobates catesbeianus. Page Nonindigenous Aquatic Species Database. USGS, Gainesville, FL.

Meagher, M. and M. Meyer. 1994. On the origin of brucellosis in bison of Yellowstone National Park: a review. Conservation Biology 8:645-653.

Meyer, T. L. 2010. Estimating livestock forage demand: defining the animal unit. University of Nebraska - Lincoln, Lincoln, Nebraska.

Miller, K. L. 2002. Planning for bison grazing on native rangeland.

Millspaugh, J., S. Amelon, T. Bonnot, D. T. Farrand, R. Gitzen, D. Jachowski, B. Keller, C. McGowan, S. Pruett, C. Rittenhouse, and K. S. Wells. 2005. Natural herd demographics and effects of population control strategies in National Park Service bison (*Bison bison*) and elk (*Cervus elaphus nelsoni*) herds. Final Report submitted to the National Park Service, Rapid City, South Dakota.

Millspaugh, J. J., R. A. Gitzen, D. S. Licht, S. Amelon, T. W. Bonnot, D. T. Farrand-Jones, D. S. Jachowski, B. J. Keller, C. P. McGowan, M. S. Pruett, C. D. Rittenhouse, and K. M. S. Wells.

2008. Effects of culling on bison demographics in Midwestern National Parks. Natural Areas Journal 28:240-251.

National Park Service. 2000. Final Environmental Impact Statement for the Interagency Bison Management Plan for the State of Montana and Yellowstone National Park. Gardiner, Montana.

National Park Service. 2004. Bison reintroduction and management plan recommendations: Tallgrass Prairie National Preserve. National Park Service, Cottonwood Falls, Kansas.

National Park Service. 2006a. Bison management plan: Wind Cave National Park. Hot Springs, South Dakota.

National Park Service. 2006b. Management policies: the guide to managing the National Park System. National Park Service, Washington D.C.

National Park Service. 2009. Tallgrass Prairie National Preserve, Kansas: Bison management plan; environmental assessment. National Park Service, Cottonwood Falls, Kansas.

National Park Service. 2011. A Call to Action: Preparing for a Second Century of Stewardship and Engagement. National Park Service, Washington D.C.

National Park Service. 2012. Foundation document: Agate Fossil Beds National Monument, Nebraska., National Park Service.

Natural Resources Conservation Service. 2003. National Range and Pasture Handbook. U.S. Department of Agriculture.

Natural Resources Conservation Service. 2014a. Fact sheets & plant guides.

Natural Resources Conservation Service. 2014b. Web Soil Survey. U. S. Department of Agriculture.

Perez-Figueroa, A., R. L. Wallen, T. Antao, J. A. Coombs, M. K. Schwartz, P. J. White, and G. Luikart. 2012. Conserving genomic variability in large mammals: effect of population fluctuations and variance in male reproductive success on variability in Yellowstone bison. Biological Conservation 150:159-166.

Plumb, G. E. and J. L. Dodd. 1993. Foraging ecology of bison and cattle on a mixed prairie: implications for natural area management. Ecological Applications 3:631-643.

Plumb, G. E. and J. L. Dodd. 1994. Foraging ecology of bison and cattle. Rangelands 16:107-109.

Post, D. M., T. S. Armbrust, E. A. Horne, and J. R. Goheen. 2001. Sexual segregation results in differences in content and quality of bison (*Bos bison*) diets. Journal of Mammalogy 82:407-413.

Powell, A. N. 2000. Grassland bird inventory of seven prairie parks. Final report to the Great Plains Prairie Cluster Long-term Ecological Monitoring Program, National Park Service., National Park Service, Wilson's Creek National Battlefield, Republic, MO.

Pratt, M. and G. A. Rasmussen. 2001. Determining your stocking rate.*in* U. S. U. C. Extension, editor.

Pyne, M. I., K. M. Byrne, K. A. Holfelder, L. McManus, M. Buhnerkempe, N. Burch, E. Childers, S. Hamilton, G. Schroeder, and P. F. J. Doherty. 2010. Survival and Breeding Transitions for a

Reintroduced Bison Population: a Multistate Approach. The Journal of Wildlife Management 74:1463-1471.

Redford, K. H. and E. Fearn. 2007. Ecological future of bison in North America: A report from a multi-stakeholder transboundary meeting., Wildlife Conservation Society.

Reynolds, H. W., C. C. Gates, and R. D. Glaholt. 2003. Bison. Pages 1009-1060 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild Mammals of North America: Biology, Management, and Conservation. The John Hopkins Press, Baltimore, Maryland.

Rutberg, A. T. 1983. Factors influencing dominance status in American bison (*Bison bison*). Zeitschrift fur Tierpsychologie 63:206-212.

Sanderson, E. W., K. H. Redford, B. Weber, K. Aune, D. Baldes, J. Berger, D. Carter, C. Curtin, J. Derr, S. Dobrott, E. Fearn, C. Fleener, S. Forrest, C. Gerlach, C. C. Gates, J. E. Gross, P. Gogan, S. Grassel, J. A. Hilty, M. Jensen, K. Kunkel, D. Lammers, R. List, K. Minkowski, T. Olson, C. Pague, P. B. Robertson, and B. Stephenson. 2008. The ecological future of the North American bison: conceiving long-term, large-scale conservation of wildlife. Conservation Biology 22:252-266.

Schmidt, C. A., P. D. Sudman, S. R. Marquardt, and D. S. Licht. 2004. Inventory of mammals at ten National Park Service units in the Northern Great Plains from 2002-2004: Final report. Submitted to the Northern Great Plains I&M Program. National Park Service, Keystone SD.

Schumaker, B. 2013. Risks of Brucella abortus spillover in the Greater Yellowstone area. Revue scientifique et technique (International Office of Epizootics) 32:71-77.

Shaw, J. H. 1995. How many bison originally populated western rangelands? Rangelands 17:148-150.

Soule, M. E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-169 *in* M. E. Soule and B. A. Wilcox, editors. Conservation Biology. Sinauer Associates, Inc., Sunderland, Massachusetts.

Stasiak, R. H., G. R. Cunningham, S. Flash, A. Wagner, and A. Barela. 2011. Draft Report: Fishes of the Niobrara River at Agate Fossil Beds National Monument: 2011 Survey. Submitted to the U.S. National Park Service, Midwest Region.

Stenger, J. M., J. A. Rehm-Lorber, C. M. White, and J. D. C. Pavlacky. 2011. Monitoring the birds of Agate Fossil Beds National Monument: 2010 annual report. Rocky Mountain Bird Observatory, Brighton, CO.

Symstad, A. J., R. A. Gitzen, C. L. Wienk, M. R. Bynum, D. J. Swanson, A. D. Thorstenson, and K. J. Paintner. 2012. Plant community composition and structure monitoring protocol for the Northern Great Plains I&M Network: version 1.01. National Park Service, Fort Collins, CO.

Tessaro, S. V., C. C. Gates, and L. B. Forbes. 1990. The brucellosis and tuberculosis status of wood bison in the Mackenzie Bison Sanctuary, Northwest Territories, Canada. Canadian Journal of Veterinary Research 57:231-235.

Towne, E. G., D. C. Hartnett, and R. C. Cochran. 2005. Vegetation trends in tallgrass prairie from bison and cattle grazing. Ecological Applications 15:1550-1559.

Treanor, J. J. 2013. Integrating ecology with management to control wildlife brucellosis. Revue scientifique et technique (International Office of Epizootics) 32:239-247.

Tronstad, L. 2012. Aquatic invertebrate monitoring at Agate Fossil Beds National Monument: 2011 Annual Report. National Park Service, Fort Collins CO.

U. S. Department of the Interior. 2008. Department of the Interior: Bison conservation initiative. Washington D.C.

U. S. Department of the Interior. in prep. Report by the Department of the Interior Bison Working Group to the May 2012 Secretary's Directive on the placement of Yellowstone-origin bison.

Uresk, D. W. 2010. Cattle weights on USDA Forest Service lands by state with cow and calf forage consumption. Rangelands:26-29.

Van Dyne, G. M., N. R. Brockington, Z. Szocs, J. Duek, and C. A. Ribic. 1980. Large herbivore sysystem. Pages 269-537 *in* D. J. Bryemeyers and G. M. V. Dyne, editors. Grasslands, systems analysis and man. Cambridge University Press, Cambridge, U.K.

Van Vuren, D. and C. A. Scott. 1995. Internal parasites of sympatric bison, *Bison bison*, and cattle, *Bos taurus*. Canadian-Field Naturalist 109:467-469.

Vequist, G. W. and D. S. Licht. 2013. Wildlife Watching in America’s National Parks: A Seasonal Guide. Texas A&M University Press, College Station, Texas.

Vinton, M. A., D. C. Hartnett, E. J. Finck, and J. M. Briggs. 1993. Interactive effects of fire, bison (Bison bison) grazing and plant community composition in tallgrass prairie. American Midland Naturalist 129:10-18.

Westfall, J. A., Jr., L. R. Irby, and J. E. Norland. 1993. A forage allocation model for four ungulate species in Theodore Roosevelt National Park. Montana State University, Bozeman, MT.

White, P. J., J. J. Treanor, C. Geremia, R. L. Wallen, D. W. Blanton, and D. E. Hallac. 2013. Bovine brucellosis in wildlife: using adaptive management to improve understanding, technology and suppression. Revue scientifique et technique (International Office of Epizootics) 32:263-270.

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