25 March 2011

To whom it may concern,

Over the past year and a half, a group of private bison ranchers, industry experts, bison researchers, and conservationists concerned with bison have met to discuss several key issues related to the long term conservation of bison and their ecosystem.

The discussions focused on understanding the best available science as well as the practical application of that science to bison management in the following three general topics related to bison conservation:

1) Maintain the **wild characteristics** of bison while avoiding domestication.
2) Restore and maintain **biodiversity and ecosystem functions**;
3) Conserve the **genetic diversity and genetic integrity** of bison;

From the discussions on these three general topics, we have drafted the proposed set of guidelines that accompany this letter. These guidelines are meant to help bison herd managers achieve conservation of bison as a species and the ecosystems which they inhabit. The guidelines are the result of a collaborative effort and not the possession or product of a single person or institution.

The guidelines are intended to help bison managers manage their herds to achieve conservation outcomes for the species and the ecosystem. The guidelines are based upon elements of the Vermejo Statement as well as other scientific information, and the practical experience of herd managers and conservationists participating in the group. This is a living document. The guidelines must be periodically updated as new scientific information arises and experience in managing bison herds to help meet conservation goals is gained. Additionally, this work aims to meld science with the economic and social realities for North American bison management. Both the document and the group are meant to change to continuously include new ideas, information, and perspectives.

The central goal for the guidelines is that they lead to better management practices and conservation goals by bison managers in North America. The guidelines can also act as a stimulus and mechanism to create greater awareness of and initiate dialogue on issues concerning the need to conserve and maintain the genetic integrity and wild characteristics of bison while maintaining the economic viability of bison ranching enterprises.

Before these guidelines are final, we welcome you to please review them and comment as to how they can be improved. We greatly value your input and expertise in bison management and conservation. Comments will be accepted over the next 45 days until May 9, 2011. After which time, the Bison Conservation Working Group will organize and review all comments received. We will then, through a documented process, review the submitted comments and change the document to better recommend scientifically valid and practical issues that have not been addressed in the current draft document.

Following the comment period and review of the document based on comments received, we will finalize the guidelines. The Guidelines will then be published for use as a tool to be used by bison herd managers and others interested in the bison industry.

We thank you for your time and consideration of this important issue as well as your constructive comments.

Sincerely,

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Steve Forrest, WWF-US
Alejandro Grajal, Chicago Zoological Society
Duane Lammers, Wildlife Biologist and Bison Consultant
Chad Kremer, Bison Herd Manager Custer State Park and independent bison rancher, Kremer Buffalo Company
Thomas LeFaive, Turner Ranches
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Dan O'Brien, Wild Idea Buffalo
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Tom Olson, Conservation Committee Chair, Canadian Bison Association
Shane Sarver, PhD, Black Hills State University
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Bison Conservation Management: Proposed Guidelines for Herd Managers

Version 1.0 For Public Comment

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Bison Conservation Management: Proposed Guidelines for Herd Managers

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i. About The Bison Conservation Working Group

The Bison Conservation Working Group is comprised of private bison ranchers and industry experts, conservationists concerned about bison, and bison researchers. The Working Group was initially convened to create scientifically premised guidelines for private bison herd managers interested in supporting deeper or more thorough bison conservation. As the group's work progressed it became apparent that the guidelines should focus on outcomes and not the type of land owner. With this in mind the Working Group changed its direction, slightly, and shaped a document that could be used as a tool by managers of any type of herd – regardless of whether it was a public, private, or NGO managed herd.

The Working Group attempted to use the latest and most widely recognized scientific and management information on bison biology and conservation as a framework for designing guidelines that herd managers can adopt to conserve bison as a wild species. However, the Working Group recognizes that much research remains to be done to help answer important management questions. Thus, it is expected that these guidelines will be regularly updated as more information becomes available. These guidelines are the result of a collaborative effort and not the possession or production of a single person or institution.

The guidelines are subject to change based on public comment, and new scientific information. They can complement other initiatives and intend to learn from other bodies of work. This tool is meant to be used on a voluntary basis.

1. Introduction

Beginning with the ancestors of today's bison, various species of bison have inhabited North America for at least 300,000 years (Potter et al. 2010). The continent now harbors one species, the American bison (Bison bison), which consists of two subspecies, the wood bison and the plains bison. At their peak population, bison herds of tens of thousands of animals roamed across the North American landscape, from wood bison found as far north as northern Alaska and the Northwest Territories to plains bison whose range spanned nearly coast to coast North America (including Canada, northern Mexico, and the United States). Within the last 200 years, the continental bison population decreased from 30-50 million to roughly 1,000 in 1889 and then rebounded to around 400,000 today (Gates and Ellison 2010). During this time, bison were a source of food for multiple species (including humans), were a major grazer of grasslands, formed wallows that created mini-wetlands, and in various other ways strongly shaped many North American ecosystems (Freese et al. 2007).

Currently, the vast majority of bison are managed by private enterprises. Of the roughly 400,000 animals in North America, an estimated 93% are managed by private enterprises (nearly all plains bison); while the remaining 7% are in government and non-government organization herds (Gates and Ellison 2010). There are risks and advantages to both private and public management models. The current prominence of private ownership of bison reflects the early history of bison conservation whereby the seemingly inevitable extinction of bison in the late 19th century was averted in large part by private landowners—James McKay, Charles Goodnight, Walking Coyote, and Frederick Dupree, and others— who rounded up the few remaining plains bison to establish herds that eventually became the founding stock for nearly all public and private plains bison herds today (Potter et al. 2010).

Species extinction can occur via two avenues: 1) the last individuals of a species die or 2) the genetic makeup of a species changes substantially over time, whether through natural evolutionary processes, anthropogenic selection, or hybridization resulting in the extinction of the species' distinct genetic material (Freese et al 2007). To be more specific, anthropogenic selection is like domestication, wherein, over several generations traits are purposefully selected for human needs thereby resulting in detectable changes in morphology, physiology, and behavior between the domestic and their wild origins and relatives (Boyd 2010). Bison narrowly escaped the first form of extinction in the late 1800s, but now conservationists are concerned that bison face the second form of extinction or, at the least, the loss of the bison as a "wild" species. With only about 20,000 plains bison (and just 11,000 wood bison) in public and NGO managed herds, a large majority of these and commercial herds number fewer than 400 animals, some of the ecological interactions (e.g., big predators) that shaped the evolutionary history of the bison largely disrupted. This small herd size also raises there are concerns about a loss or significant change in the genetic diversity of bison (Gates and Ellison 2010). Three genetic issues are of particular concern: 1) the small size of most bison populations exposes the species to inbreeding and loss of genetic diversity. 2) artificial selection of bison for specific traits such as rate of gain, color, or docility; 3) introgression of cattle genes in the bison genome, a legacy of early attempts, around the turn of the 20th century to cross breed bison and domestic cattle (Boyd et al. 2010).

Despite dramatic changes in land use across the former range of the plains bison over the past 200 years, with appropriate management the wild character of bison can flourish. Careful attention to maintaining the wild character of bison, the operation of natural selection in bison, and the bison's historic influence on ecosystems can lead to considerable success in both conserving the wild bison genome and the biodiversity of bison habitats. But this should happen within the confines of both a range bounded by fences and the practical social and economic realities that range managers must factor into their herd management decisions

As many conservation organizations, government agencies, and private enterprises work towards long term restoration goals, it is important to take interim steps to restore and conserve the bison's' genetic and behavioral traits that so strongly influences the ecosystems they inhabit. However, bison herd management options are limited by jurisdictional boundaries as well as conflicting land uses, such as agriculture, energy and housing developments. These factors restrict the size of large areas available for full ecosystem conservation approaches, and therefore require that a set of population and genetic tools be made available to help herd managers undertake practical steps toward bison conservation.

1.1. Goal

The main goal of these guidelines is to help herd managers to conserve the wild characteristics of bison through the conservation of the species' genetic and behavioral traits, while at the same time supporting ecosystem functioning and biodiversity conservation goals within the range which the herd inhabits.

1.2. Principles:

This document is a recommended set of guidelines intended to help bison managers manage their herds to achieve conservation outcomes for the species and the ecosystem. The guidelines are based upon elements of the "Vermejo Statement"[1] and Sanderson et al. (2008) as well as other scientific information, and the practical experience of herd managers and conservationists participating in the group. The Bison Working Group does not assume this is a definitive document. Instead, these guidelines must be periodically updated as new scientific information arises and more experience is

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[1] http://www.americanbisonsocietyonline.org/LinkClick.aspx?fileticket=lF9Z%2BqPNtm0%3D&tabid=3140

gained in managing commercial and public bison herds. Finally, these guidelines aim to meld existing science with the economic and social realities within the bison herd management in North America.

To contribute to the ecological restoration of bison in a holistic manner, these guidelines encompass three specific principles of herd management:

- Maintain the **wild characteristics** of bison while avoiding domestication.
- Conserve the **genetic diversity and genetic integrity** of bison;
- Restore and maintain **biodiversity and ecosystem functioning**;

1.3. Outcomes:

While addressing these Principles the guidelines are designed to allow for a certain degree of flexibility and adaptation based on the characteristic of each habitat, range or herd. However, it is also likely that these guidelines will impose minimum levels for herd size and range size. These limits will restrict which bison herds can qualify as conservation herds[2] by achieving the different aspects of the guidelines. For example, these guidelines propose a minimum ranges size of 5,000 acres and a minimum effective population size of 500 breeders (see definition of effective population size in the glossary). Although these guidelines offer some alternative management options for smaller herds or ranges, it is likely that management objectives for bison herds will fall into one of two categories:

- Bison conservation herds – These are herds that are managed by meeting and achieving outcomes in the guidelines proposed below for "wild characteristics" and "genetic diversity & genetic integrity" categories
- Bison conservation herds with ecological restoration – These are herds that are managed by meeting and achieving outcomes in the guidelines proposed below for three categories (i.e. "wild characteristics" , "genetic diversity and genetic integrity" and "biodiversity and ecosystem functioning")

1.4. Use of these Guidelines

The central goal for the guidelines is that they lead to the implementation of better management practices by bison managers in North America to achieve conservation goals. The guidelines can also act as a stimulus and mechanism to create greater awareness of and initiate dialogue on issues concerning the need to conserve and maintain the genetic integrity and wild characteristics of bison while maintaining the economic viability of managed bison herds.

These guidelines can be used to determine the number of bison in public and private herds that meet these outlined conservation guidelines in North America.

Each section lists the guidelines pertaining to each of the three goals followed by further description of each guideline.

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[2] The IUCN's American Bison Specialist defines a conservation herds as "wood and plains bison populations managed by national or state/provincial public governments and non-governmental organizations whose primary mission is nature conservation" (Gates and Ellison 2010). These guidelines broaden the scope to focus on results of herds managed for conservation outcomes, regardless of ownership classification.

The following sections are the proposed guidelines for herd managers:

2. Wild Bison Character

Central to bison conservation, as with other species, is the maintenance of its wild character. It is believed by some that present herd management can remove a number of essential social and behavioral traits that can lead to erosion of the wild nature of bison. To maintain wild character of bison, bison managers should follow these five guidelines:

- Allow bison to interact with other bison
- Have a mixed age class and sexes for behavioral outcomes
- Allow bison to interact with their habitat
- Allow natural foraging throughout the year
- Minimize human handling

2.1. Allow bison to interact with other bison. Larger and more diverse herds will allow richer interactions. Managers should allow these interactions with as few restrictions as possible. Special attention should be paid to maintain a family group structure that resembles that of natural populations wherein matrilineal groups are the norm (Gross et al. 2010).

2.2 Mixed age class and sexes. Herd management should encourage wild behavioral outcomes in a mixed age class. Such interactions will allow for a variety of behaviors within the herd and allow younger animals to potentially learn certain behaviors from older animals. Critical to the maintenance of a healthy herd of diverse age class and sexes is to avoid systematic removal (harvest or culling) of animals. Harvesting animals above a certain age, (for example, all animals over 10 years old), could lead to elimination of some behavioral traits. It is known that older animals, including some that are post-breeding age, help ensure a diverse age structure and their social and ecological memory may influence herd social behavior and foraging patterns. Older animals may have behaviors, such as wallowing and horn rubbing, not always demonstrated by younger animals that may influence ecosystem structure and processes. Furthermore, a natural diversity of age classes may create various forms of competition (e.g., for food resources, breeding, social hierarchy) and social interactions that favor natural selection instead of human-driven selection. Furthermore, the herd's genetic health is significantly affected by the sex ratio of breeding males to breeding females; different age classes' interactions and herd size (see section 3.3.). The ultimate goal is to emulate the age structure of the largest existing mixed age class herds. Assessing "natural" social structures is difficult because existing herds have all had different management techniques (Brodie 2008). The proportion of calves, yearlings, and cows will vary between populations and across time (Brodie 2008).In spite of the difficult nature of such an assessment, several studied populations demonstrate a range of 10 to 42 yearlings per 100 cows. The number of calves per 100 cows has been shown to range between 31 and 35 calves in protected area populations (Brodie 2008). These variations provide some guidance to aim for, and more data should be sought to better understand the demographic structure that herd managers should aim for.

2.3. Allow bison to interact with their habitat- Just like bison should be left to interact with other bison, wild herds should be allowed to interact with their habitat. This implies that bison would be allowed to conduct natural foraging throughout the year. Continuously reduce supplemental feeding, and implement it only when absolutely necessary. Grasses, forbes and sedges are the recommended supplemental feed. If possible, bison should also have the full complement of species that correspond to natural northern plains ecosystem (or wherever the herd in question exists), including predators, parasites and competitors.

2.4. Minimum general size of a range - The minimum general size of a ranch to make a modest contribution to the bison's role in ecosystem functioning is currently 5,000 acres of rangeland (Sanderson et al 2008). This minimum range size is an attempt to replicate the natural roaming patterns of a bison herd and their effect on the rangeland. It is likely that the area required by a herd will depend on the ecoregion (See map in Appendix 1) and its forage productivity, as well as seasonal and longer term variations in rainfall, and other factors affecting productivity. So more productive ecoregions with higher carrying capacity may have similar herd sizes in a smaller ranch than less productive ecoregions. In a short grass prairie, however, this size should support an effective herd size of 500. The minimum size should be 5,000 acres with adjustments made for carrying capacity. Given that a large portion of the bison are managed in the short grass prairies of the Northern Great Plains, there will need to be a considerably larger amount of land mass to carry an effective herd of 500 animals. Therefore a herd manager should ensure that the stocking rate does not exceed the range's carrying capacity.

Bison ranges smaller than 5,000 acres may contribute to conservation efforts, but this will require deeper engagement in maintaining genetic and behavioral traits in smaller herds. For example, herd managers may engage in collaborative management among two or more bison ranges located near each other, so they can effectively assemble 5,000 or more acres of total land. Similarly, exchanges of animals among cooperating managers may increase the effective population size of the herd (see below section 3.4)

In order to more fully contribute to large scale ecosystem restoration, the Vermejo Statement estimates that 50,000 acres or more will be required as a range to have a "large" contribution to ecosystem restoration through bison management (Redford and Fern 2007).

2.5. Minimize human handling - Animals should be worked (through the corrals) at most only once a year or less. This will allow reduced stress for the bison, and minimize negative behavioral impacts, injuries and mortality that may result from round-up and confinement. Exceptions to this guideline may result from the need to manage parasite, disease outbreaks and other unexpected, urgent management needs.

3. Bison Genetic Diversity and Genetic Integrity

Building the genetic integrity and maintaining genetic diversity within a bison herd is important for resistance to disease, maintenance of reproductive health, long-term adaptability, and a host of other biological traits. Managing a single bison herd's genetic health as well as the genetic health of all North American bison has been complicated by the introgression of cattle genetic material. The effects of cattle DNA introgression in bison are not well understood and considerable research is being conducted on this issue. Nevertheless, there is general agreement that introgression should be assiduously avoided in bison herds that show no sign of introgression, and introgression should be minimized or maintained at low levels where it exists. However, an aggressive strategy to "weed out" cattle genes from a herd should also consider the possibility that some unique bison alleles could be lost in the process. Thus from a species perspective, it is important to work towards reducing cattle introgression without reducing the bison genetic diversity

A specific challenge to managing a bison herd is the need to balance the financial viability of an operation with the need to avoid unduly influencing the natural selection processes that have shaped the wild bison genome. The objective here is to maximize the influence of natural selection while minimizing the effects of human selection based on selective harvesting or culling methods. For example, the long-term effects of domestication are apparent in domestic cattle where intentional has resulted in an animal that is dependent on human management, and has produced anatomical abnormalities such as a smaller pelvic girdle which cause calving difficulties, and, in general, is no longer wild and is maladapted to the natural environment (Boyd et al. 2010, Gross et al. 2010).

The following five recommendations are intended to maintain herd genetic diversity and natural selection processes, as well as to manage cattle introgression:

- Random (harvesting or culling) selection model
- Breeding competition and Effective population size
- Managing cattle genetic introgression (genetic testing)
- Alternative genetic management for small herds.

3.1. Random (harvesting or culling) selection model – As mentioned above (section 2.2) human selection can lead to rapid erosion of genetic diversity in a herd. Therefore, bison should not be selected for harvest based on specific traits. For example, the scientific literature has that trophy hunting for big game animals can have surprisingly fast and undesirable genetic consequences. For example, trophy hunting of bulls based on big bodies, wide heads, or big horns may result in a population with these traits diminished.

Similarly, breeding for a single-trait (e.g., color, carcass type, specific body conformation) should be assiduously avoided. In general, whether the harvest is by round up, hunting, or other means, care should be taken to avoid systematically removing animals with specific traits that would not, under natural conditions, be subject to mortality through disease, predation, and other natural causes.

Some exceptions to consider include the removal of particular animals with behavioral traits that affect handling, such as animals that leave the herd to charge handlers. Artificial genetic selection will most likely not occur if the herd is relatively large (several hundred animals) and an animal is occasionally removed for behavioral reasons. However, a repeated pattern of selective removal of aggressive animals may lead to docility traits in a herd that run counter to the wild nature of bison. Another potential removal from the herd may include animals that are not participating in breeding. If present, predators would likely take severely weak or ill animals, particularly if they leave protection of the herd.. They should also avoid the systematic removal of females that have missed one year of reproduction. It is believed a random selection model, while not meant to replace natural selection processes, can allow enough variation in harvest methods from year to year to mimic natural processes. However, herd managers should investigate potential causes of failed breeding that might be corrected. Using tools such as blood tests to check for mineral deficiencies and diseases can lead to answers to these questions.

Example 1. One possible example of random selection consists of an annual 20% replacement for females, in which the first year, every 5th animal through the chute would be held for replacement. Then the second year might be the first 20% of females through the chute, and then the third year might be the middle 20% through the chute. At the fourth year, the whole procedure can be repeated. Herd managers are encouraged to vary their random selection models, as well.

3.2. Breeding Competition and Effective population size –

A conservation herd should include multiple bulls that are allowed to breed with multiple females at a time. This allows for competition among males, an important feature of natural selection under natural conditions. Studies have shown that a sex ratio of 33-36% males to 67-34% females (adults and young combined) is generally found under natural conditions (Brodie 2008). Gross (2010) places the sex ratio at 40 males to 60 femails. It is also possible that the proportion of breeding males may be smaller than breeding females because males mature later and have a higher mortality rate. The ideal adult sex ratio is slightly skewed to females (such as 55 cows per 100 animals). Intermediate sized herds, which range between 250-750 animals will need more active management to ensure long-term genetic health, while larger herds of over 750 and into the 2,000-3,000 range will require less active management (Gross et al. 2010). These larger herds will likely need 20 or more mature bulls per 100 cows. The breeding competition will help reduce chances of genetic drift and inbreeding, in combination of the monitoring and maintenance of an effective population size.

Effective population size is a technical term that specifically refers to the total number of breeding individuals under theoretically ideal conditions that contribute to the genetic diversity in an isolated population. These ideal conditions are seldom if ever attained in real populations. But because not all breeding animals are capable of breeding, the effective population size is generally smaller than the actual number of mature animals in the population (called the "census population size"). In species populations with a highly skewed sex ratio (polygamous) species the effective population size is much smaller than the overall number of mature animals with other producers' herds. General recommendations , assume that the "effective population size" of a conservation herd should be a minimum of approximately 500 breeding animals (this is based on scientific recommendations based on extinction probabilities for isolated populations). Thus, for example, if a bison herd has an adult sex ratio of 1 male: 10 females, a population of about 1,500 adult animals is needed to achieve an effective population size of 540 (see example in Appendix 2, Table 1: a more skewed sex ratio requires a larger herd to achieve a desired effective population size). (Note that our use of the term "herd" should not be confused with groups of animals that often form within herds and do not consistently associate, but among which breeding generally occurs.). For a herd with a ratio of 40:60 male to female, the effective population size would be 100. For a herd with a 1

A herd with 1,500 animals and a male to female ratio of 1:5, the effective population size is 1,000 animals. For a herd with a total size of 2,000 animals and a male to female ratio of 1:15, the effective population size is 500 animals.

The goal of managers, given all of the above information, should be emulate natural bison populations as much as possible. There are two extremes that are feasible for these guidelines. On the lower end of the spectrum a sex ratio of 1 male: 10 females will require a larger total population to have an effective population with little risk of genetic drift. A sex ratio of between 33 and 40 males to 67 to 60 females is a preferable option that managers can strive for. It is believed that a sex ratio outside of these bounds will lead to some negative impacts on the conservation of the herd's genetic resources, especially with a herd that has a sex ratio below 1 male to 10 females.

3.3 Alternative management for small herds

The working Group acknowledges that some ranches may not be able to achieve the proposed minimum standards here of a minimum range of 5,000 acres and a minimum effective population size of 500. Those managers still interested in participating in the bison restoration initiative can implement an animal exchange cooperative program that mimics these conditions. For example, owners of small bison herds can create the equivalent of a large herd and reach the effective population size goal of 500 by periodically exchanging breeding animals with the other producers' herds. This will require careful planning of the appropriate combinations of sex, number of animals, and frequency of exchanges. In one example, if three managers who each have 300 animals regularly exchange animals they have, de facto, created a total population size of 900. Careful attention to breeding effectiveness, such as increasing male to female ratios as close to 1:1 as possible, may even increase the effective population size to close to 500, and thus these three managers will be able to maintain the genetic diversity of the cooperative herd (i.e. a 'metapopulation'). A potential scenario for such exchanges is that new individual breeders should be introduced to the herd every two to six years to maintain diversity if the herd size is below the effective population size of 500. Bringing bulls into the herd is generally a faster and more effective way to introduce genetic diversity than bringing in females. The bulls should come at a young enough age to integrate them into the social cohort of the herd while not impacting herd health. Managers should be attentive to avoid introducing diseases with exchanged animals.

3.4. Managing cattle genetic introgression (genetic testing)

Because of attempts to hybridize bison and cattle around the end of the 19th century and beginning of the 20th century, cattle gene introgression remains a threat to the genetic integrity of wild bison and requires close attention by herd managers. This genetic introgression has occurred both in the mitochondrial DNA and nuclear DNA. However, the effects of cattle gene introgression on bison biology are poorly understood and no upper limit has been established for the percent of cattle DNA in bison. More research on this issue is required before more detailed recommendations can be made.

Managers should attempt to reduce the degree of cattle gene introgression where feasible and where such efforts to do not jeopardize bison genetic diversity. Managers should be cautious in their attempts to reduce levels of cattle nuclear DNA because animals that are removed from the herd because of cattle nuclear introgression may also possess rare bison alleles that may be lost from the herd. However, removal of animals with cattle mitochondrial DNA haplotypes does not generally pose this risk.

Whenever possible, herd managers should conduct genetic testing to understand the genetic make-up of their herd. Testing 20% of the animals will generally provide the necessary information for the herd (N. Halbert and J. Derr, personal communications). If cattle genetic introgression is found before reaching the threshold of 20% it may be possible to stop testing, as a herd manager will therefore know that cattle genes are present in the herd. There are currently three laboratories that undertake DNA testing for bison. These labs are listed in Appendix 5.

If the manager determines that there is no cattle introgression in the herd, then animals with cattle DNA should not be introduced. If managers determine the presence of cattle mitochondrial DNA or nuclear DNA in a herd, then they should devise a plan to reduce cattle genetic introgression. More on this topic will be elucidated in an upcoming conference on bison herd genetic management.

4. Restoration and Management of Biodiversity and Ecosystem Functioning
Bison are considered a keystone species within several North American ecosystems. As such, they contribute to the maintenance of biodiversity and ecosystem functioning. Given that bison are now confined to often relatively small ranges with fenced boundaries rather than roaming across North American landscapes in their historic manner, the following guidelines are meant to help herd managers manage the ecosystem which their bison inhabit. This section is particularly applicable at those ranches with large areas for habitat restoration and biodiversity conservation objectives. Bison conservation will be based on healthy populations and healthy ecosystems. In order to meet the biodiversity criteria and qualify for ecosystem restoration, the following seven items should be met by herd management in order to enhance ecosystem functions and biodiversity conservation.

- Maintain proven habitat structural diversity
- Utilize natural patterns and processes in bison range
- Conserve Species of interest based on state and national fish and wildlife agencies
- Create and implement on-range biodiversity conservation plan
- Interact with biodiversity within the range
- Herbicide and pesticide use should be minimized.
- Minimize surface water developments that impact hydrologic and riparian function

4.1. Maintain proven habitat structural diversity – Throughout a bison range, there are a variety of habitat types. It is important to maintain as many of these as possible. To achieve ecological restoration of the landscape the following should occur:

- Maintain healthy riparian areas.
- Allow for and maintain healthy plant and species diversity.
- Allow for and do not intervene in wallows.

Heterogeneity both within and between habitats is important for representation of the suite of grassland birds, some of which require specific types of grasslands that result from intense grazing to those which require structurally complex grasslands that develop from an absence of or light grazing. Other habitats -wetlands, riparian areas, and differences from site to site of plant species composition- may provide habitats for different life stages of species of interest, and should be maintained.

4.2. Maintain natural patterns and processes in bison range- Herd managers should encourage natural patterns and processes in the bison range. Natural patterns and processes could include such activities as natural seed dispersal, fire, flooding, and other naturally occurring phenomena. This would allow for as much unmanaged grazing as possible for the bison. It also includes the use and balance of such natural environmental forces such as fire, native seed dispersal, creation of wallows, natural wetlands, predators, parasites and ecological succession.

4.3. Create and implement on-range biodiversity conservation plan with special focus to conserve species of interest based on state and national fish and wildlife agencies. - Once the manager creates and enacts a management plan that includes due diligence to identify key species of interest that occur in their area, they are encouraged to work with a government agency, accredited/reputable private enterprise, conservation group, or academic institution to develop a management plan for each species of interest and articulate measurable goals for each species. Such plans should include conservation and management regimes for grassland species, such as grassland birds, endangered plants and other keystone species, such as prairie dogs. Examples of such plans could include grazing management plans that adjust stocking rates (e.g., NRCS sage grouse initiative), grazing management plans that adjust timing of grazing (e.g., Colorado mountain plover plan), reintroduction/restoration projects, habitat enhancement for native species (wetland mitigation banking), exclosures for sensitive species (e.g. endangered plants), and hunting/harvest management plans.

4.4. Interact with biodiversity within the range. - Allow for other, non-bison species, predators or competitors for grass to inhabit the range if they are present. Predator control is not acceptable unless there is a basis, such a as a manmade structure, like a fence, wall, or road, that the predator(s) use as hunting aids to take a disproportionate number of bison. If cross fences are used as a management tool, the impacts of fencing on other wildlife should be considered in their design and their effectiveness monitored. Wildlife-friendly fencing is recommended (see appendix 3). Fences should not impede or harm wildlife migrations or species.

4.5. Herbicide and pesticide use should be minimized. - Use of agrochemicals such as herbicides and pesticides should be minimized and highly targeted. While their use can be justified to control invasive species or disease/parasite outbreaks, their used should be in accordance with the instructions from the manufacturer and appropriate safety and storage protocols should be followed. Managers should be particularly careful to avoid or minimize wide-ranging ecosystem effects of agrochemical application, such as endocrine- disruptive herbicides on amphibians.

4.6. Minimize surface water developments that impact natural and healthy hydrologic and riparian function. Water can come from a diversity of sources, both artificial and natural. Natural hydrology is encouraged, which can be facilitated by off-stream groundwater development. Restoring and maintaining natural stream flows, wetlands, and associated riparian areas is encouraged.

Appendix 1. Glossary

- Agrochemicals – fertilizers or pesticides (fungicides, herbicides, insecticides, etc…)
- Allele - An alternative form of a gene. One of the different forms of a gene that can exist at a single locus (spot on a chromosome). Also one of the different forms of any segment of a chromosome. (from medterms.com)
- Biodiversity – The genetic, taxonomic, and ecosystem variety in living organisms of a given area, environment, ecosystem, or the whole planet (McAllister 1991).
- Carrying Capacity – the maximum population of an organism a given habitat can support indefinitely (Rees and Wackernagel 2005).
- DNA introgression – The transplantation of genese between species resulting from fertile hybrids mating successfully with one of the parent species (http://en.mimi.hu/biology/introgression.html)
- Ecosystem – an area that contains organisms (e.g. plants, animals, bacteria) interacting with one another and their non-living environment. Ecosystems can be of any size (e.g. forest, meadow, and log). https://www.uwsp.edu/natres/nres743/Definitions/Ecosystem.htm
- Ecosystem functioning – The collective intraspecific and interspecific interactions of the biota, such as primary andsecondary production and mutualistic relationships. The interactions between organisms and the physical environment, such as nutrient cycling,soil development, water budgeting, and flammability.
- Endangered species - The classification provided to an animal or plant in danger of extinction within the foreseeable future throughout all or a significant portion of its range. (fws.gov)
- Genetic diversity - 1) Genetic variation between and within species, which is measured by determining the proportion of polymorphic loci across the genome, or by the number of heterozygousindividuals in a population.
  (2) The different genetic combinations in a gene pool.
  (3) The existing genetic variation within a population. (http://www.biology-online.org/dictionary/Genetic_Diversity)
- Genetic drift - The process of change in the genetic composition of a population due to chance or random events rather than by natural selection, resulting in changes in allele frequencies over time. http://www.biology-online.org/dictionary/Genetic_drift
- Genetic heterozygosity - (Science: genetics) The presence of different alleles at one or more loci on homologous chromosomes. (http://www.biology-online.org/dictionary/Heterozygosity)
- Heterogeneity - The quality of being made of many different elements, forms, kinds, or individuals
- Hydrological functioning – The manner in which water effects and interacts with the earth's soil, rocks, and other features. In this case, it is important that the manner in which water interacts with these factors is not significantly altered by human structures or manipulation.
- Inbreeding - The mating of two closely related persons. Also called consanguinity. The act of matingclosely related individuals.The mating of organisms between relatives, which usuallydecreases heterozygosity in the gene pool and done by selective breeders to produce hybrids (http://www.biology-online.org/dictionary/Inbreeding)
- Invasive species - 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health. (**Executive Order 13112**). (USDA)

- Keystone species – A species whose presence is crucial in maintaining the organization and diversity of their ecological communities and these species are exceptional relative to the rest of the community, in their importance. (Mills et al 1993).
- Life cycle - The whole life history of an organism, usually depicted through a series of developmentalstages (e.g. from zygote into a mature form where another zygote can be produced) in which an organism goes through.
- MtDNA (mitochondrial DNA) - Mitochondria are structures within cells that convert the energy from food into a form that cells can use. Although most DNA is packaged in chromosomes within the nucleus, mitochondria also have a small amount of their own DNA. This genetic material is known as mitochondrial DNA or mtDNA (http://ghr.nlm.nih.gov/chromosome=MT).
- Riparian area - An area of land directly influenced by water. An ecosystem that is transitional between land and water ecosystems. Riparian areas usually have visible vegetative or physical characteristics reflecting theinfluence of water. River sides, lake borders, and marshes are typical riparian areas.
- Genetic locus - The location of a gene (or of a significant sequence) on a chromosome or on a linkage map (http://www.biology-online.org/dictionary/Genetic_locus)

Appendix 2. Effective Population Size as described by Natalie Halpert, Ph.D.

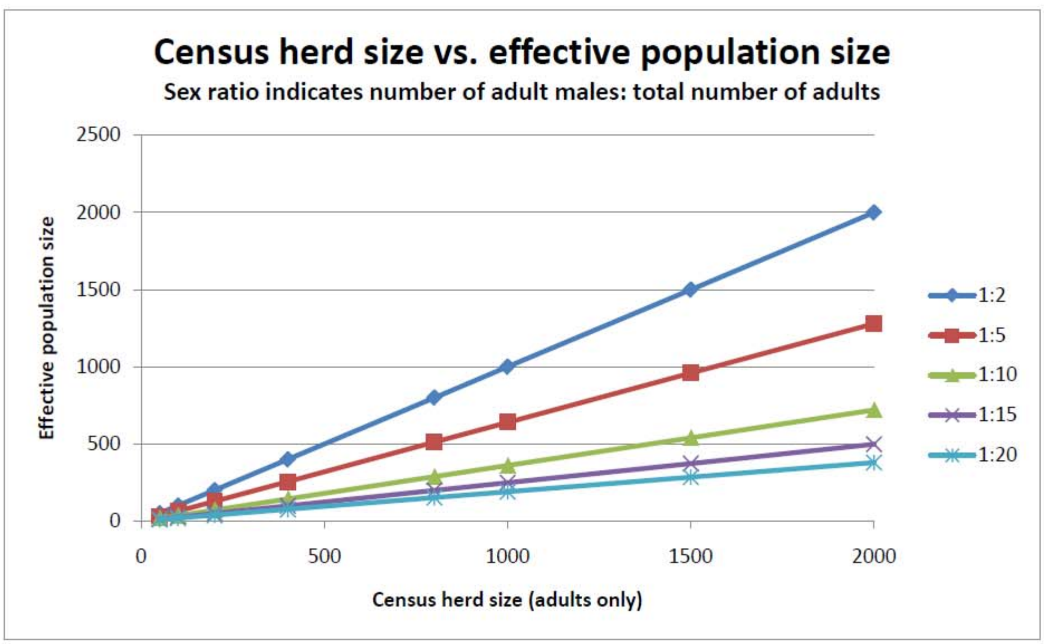
Census herd size vs. effective population size: the effect of sex ratio in bison

By Natalie Halbert, PhD
Department of Veterinary Pathobiology
Texas A&M University
January 26, 2010

Table 1: Effective population size calculated for a range of census herd sizes and sex ratios.

	Sex ratio (number of adult males: total adults)				
Census herd size (adults only)	**1:2**	**1:5**	**1:10**	**1:15**	**1:20**
50	50	32	18	12	10
100	100	64	36	25	19
200	200	128	72	50	38
400	400	256	144	100	76
800	800	512	288	199	152
1000	1000	640	360	249	190
1500	1500	960	540	373	285
2000	2000	1280	720	498	380

Figure 1: Graphical representation of effective population size, using data from Table 1.



Definitions and background information

Sex ratio refers to the number of adult males vs. the total number of adults in the herd. For example, a herd with 100 bison and a 1:2 sex ratio would have 50 adult males and 50 adult females. A herd with 800 bison and a 1:10 sex ratio would have 80 adult males and 720 adult females.

Census herd size is based on the breeding/adult individuals in the herd. Calves and juveniles are excluded from this number.

Effective population size is calculated based on both the census herd size and the given sex ratio. Effective population size is the effective number of individuals breeding, and decreases with increasing skewness in the sex ratio. For example, a herd with 1000 bison and a 1:10 sex ratio has an effective population size of 360 bison; we expect this herd to maintain genetic diversity at approximately the same rate as a herd of 360 bison with an equal sex ratio. A generally accepted cutoff of 500 is used to estimate whether artificial introduction of animals into a closed populations is needed: if the effective population size is less than 500, at least one "migrant" per generation is recommended to ensure the long-term maintenance of genetic diversity. With effective population sizes of greater than 500, the loss of genetic diversity is expected to be negligible over long periods of time. It is important to note that these calculations assume that all adults have an equal contribution to breeding. Since we know this is not the case in bison, a "target" population size of 1000 with an equal sex ratio (i.e., effective population size of 1000) has been suggested as a minimum.

Summary

It is clear from Table 1 (also shown graphically in Figure 1) that increasing skewness in sex ratio dramatically decreases the effective population size of a herd. Large numbers of bison are needed to maintain long-term genetic diversity without the introduction of additional bison when the sex ratio is skewed. For example, 1500 bison are needed if a 1:10 sex ratio is maintained (assuming an effective population size target of 500).

Appendix 3. Wildlife Friendly Fencing

Information on wildlife friendly bison fencing can be found in this document :

http://www.canadianbison.ca/producer/Resources/documents/BisonGuidelinesJune30_2006_Web.pdf

Appendix 4. Ecoregions and Current Bison Distribution
Maps of historic distribution and of current herds could be inserted from Gates and Ellison (2010), Figure 7.4.

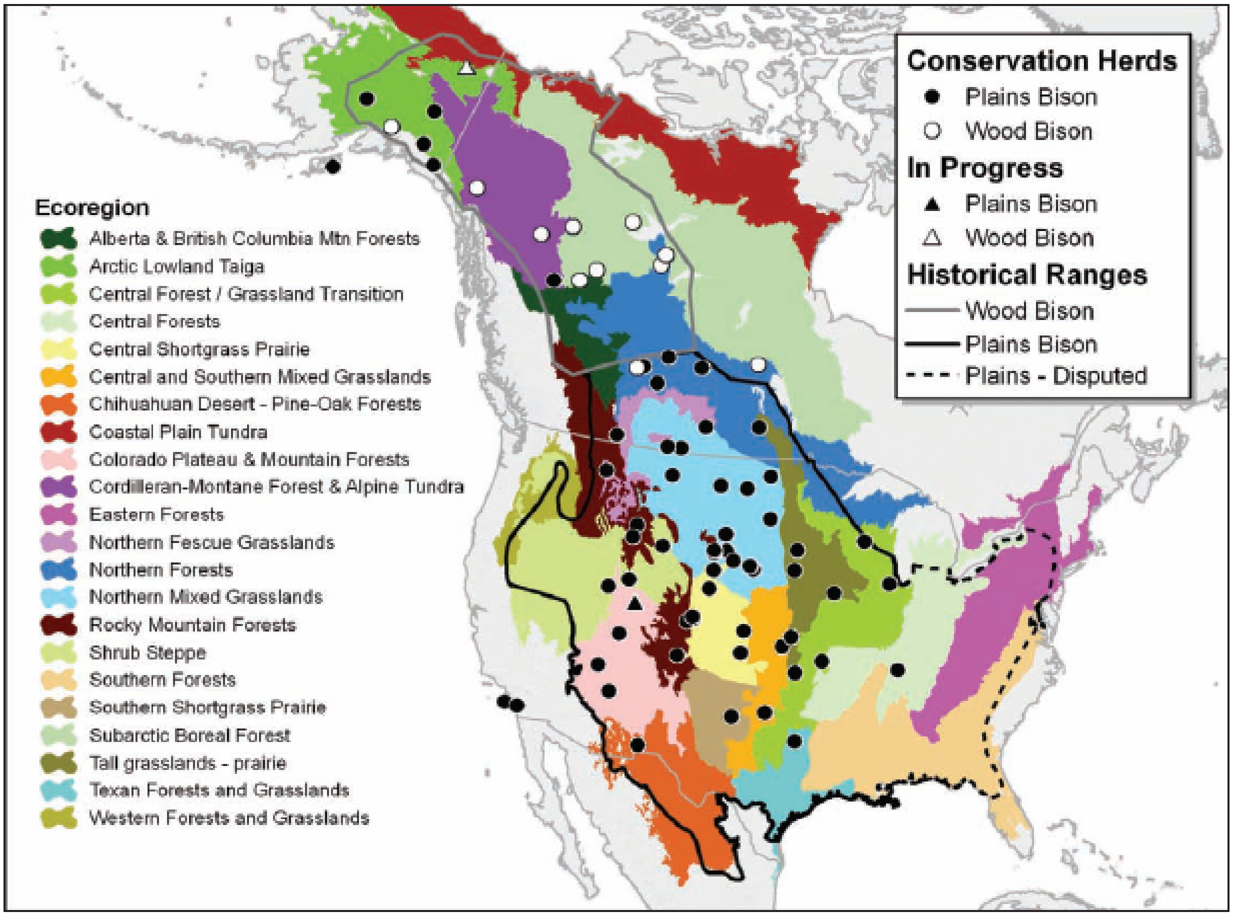


Figure 7.4 *Representation of plains and wood bison conservation herds in original ranges and major habitat types in North America. Habitat types were based on Sanderson et al. (2008).*

Appendix 5. Recommended DNA testing methods
There are ever developing methods to test bison DNA. The following three labs can best provide the service:

1) CCBR/WestCore
Black Hills State University
1200 University Avenue
Spearfish, SD 57799
605-643-6854
westcore@bhsu.edu

2) http://www.cvm.tamu.edu/dnacore/bovid.shtml

3) Veterinary Genetics Laboratory
University of California, Davis
One Shields Avenue
Davis, CA 95616-8744
http://www.vgl.ucdavis.edu/services/bison.php
Tel (530) 752-2211

Appendix 6. Recommended biodiversity and ecosystem assessment methods.
In the United States, state offices of the USDA's Natural Resources Conservation Service (NRCS; http://www.nrcs.usda.gov/technical/) is one of the best places for obtaining technical assistance and guidelines for assessing the ecological conditions of private lands. In both the United States and Canada, state/federal fish and game agencies and university extension programs can often provide technical assistance or educational program for landowners interested. Federal and state agencies can often provide the names of qualified private contractors who can conduct habitat assessments.

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