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Natural Resource Stewardship and Science

Grand Canyon Bison Nativity, Genetics, and Ecology

Looking Forward

Natural Resource Report NPS/NRSS/BRD/NRR—2016/1226

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Bison at Grand Canyon National Park
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Abstract

In response to a request for technical assistance by Grand Canyon National Park (GRCA), the National Park Service (NPS) Biological Resources Division (BRD) assembled an inter-agency discussion on bison nativity, genetics, landscape size and bison abundance and density for consideration within GRCA planning for bison management. This report describes how a team of wildlife biologists from the NPS, U.S. Forest Service (USFS) and Arizona Game and Fish Department (AGFD) convened, deliberated, and agreed that: 1) the wild, free-ranging bison that may occupy GRCA North Rim and adjacent USFS jurisdictions are native wildlife at the west-southwest edge of their continental historic range; 2) the genetics of the current herd can be improved and are not in conflict with NPS, USFS, and AGFD missions and policies; 3) a large landscape of about 215,000 acres on GRCA and Kaibab National Forest lands is suitable for cooperative bison management and protection of sensitive resources and values; 4) a very low density of 80-200 bison (0.0004 – 0.001 bison/ac) represent a conservative approach to best addressing a suite of prevailing interagency bison management considerations; and 5) initial population reduction to reach population objectives would be best achieved in the near-term via combined approaches so that in the long-term hunting outside the park can serve as the primary population management approach. As a small population at the edge of the historic range, this herd will likely be more vulnerable to environmental stochasticity, long-term genetic loss and random effects on population ecology than larger herds. Hence, for the long-term the herd should likely be a satellite of a larger meta-population, with local management that strives to simultaneously protect sensitive resources while addressing near- and long-term small population conservation.

Acknowledgements

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Background

In Spring 2015, the Grand Canyon National Park (GRCA) superintendent requested the National Park Service (NPS) Biological Resources Division (BRD) to assemble and lead an inter-agency discussion on bison (*Bison bison bison,* Linnaeus, 1758) nativity and genetics within NPS, U.S. Forest Service (USFS), and Arizona Game and Fish Department (AGFD) missions and policies; and landscape size and bison abundance for consideration within GRCA planning for bison management. BRD invited individuals from the NPS, USFS, and AGFD to participate in these discussions (team), who are denoted as authors of this report. The team was convened via conference calls hosted by BRD and subsequent written reports and key findings were reviewed and agreed upon by full team consensus, with an emphasis to inform park planning as requested, and also with awareness of the importance of eventually communicating these topics to internal and external stakeholders. Following an initial team report (Plumb 2015a), the GRCA Superintendent requested the team to reconvene to further discuss and identify bison abundance and density that would best meet the goals of the agencies involved in bison management planning in and near GRCA. The team reconvened via conference calls as described in Plumb (2015b). During fall 2015, team members participated in discussion for a deterministic bison population model (Sturm and Holm 2015) that estimated population abundance under several population management scenarios. The team also reviewed the International Union for the Conservation of Nature's (IUCN) bison guidelines (Gates et al. 2010) for potential applicability to bison management at GRCA and adjacent USFS lands. This report is not a formal bison management plan nor does it represent any formal agency decisions. This report simply describes how a team of wildlife biologists from the NPS, USFS and AGFD collaboratively convened, deliberated, and reached consensus agreement on several key topics of bison management; that supersedes and synthesizes multiple internal agency reports, with additional discussion and references.

Nativity

In this report, nativity of bison in northern Arizona is considered at the intersection of regional archeological, historical and traditional knowledge evidence, and continental scale scientific assessments for the species. Archeological and historical records of bison in northern Arizona have been summarized by Mead (2002) and Huffer (2013). And while, synthesis of such evidence has recently increased (e.g. Huffer 2013), arguably evidence may be constrained by the overall limited effort put into investigating the issue. Most recently, bison remains were unexpectedly identified at the Cave Creek Midden in southern Arizona suggesting a 3,000 year-old hunting kill site (Wismer et al. 2016), confirming that new information can indeed be derived, even from previously examined archeological sites. Mead (2002) concluded that “Bison were in and adjacent to the Grand Canyon over the past 11,000 years and therefore can be considered ‘native’ to the park.” Huffer (2013) concluded that “If bison were present in the Southwest, as the evidence suggests, they likely entered the region only occasionally as small, dispersed herds.”

Tribal Stories

Some tribal stories mention bison in southern Utah and northern Arizona. The stories below are not presented as the definitive extent of such, but only as those stories that have been shared for the team’s consideration. A Hopi oral history story relates how members of the Ute Tribe once travelled to visit their Hopi relatives the Greasewood Clan, and brought a herd of bison as a gift. After several years, the Utes went back home, and the bison continued to roam west to the Little Colorado River and beyond. Today, the Hopi perform buffalo dances to honor the Utes and the gifted bison; the Greasewood Clan occasionally performs the Ute Katsina and Ute social dances to remember this history (personal communication, 2016, email to GRCA from Leigh J. Kuwanwisiwma, Tepwungwa - Greasewood Clan). A story of the Kaibab Paiutes, who name bison as maohoy’ kootch (lit. blanket cow) (Martineau 1992, pp. 124) says “At one time there used to be buffalo around the ledges on the north side of the Colorado River near the Kaibab Mountains. Overanxious Hopi or Hualapai ate them before they could increase and they became extinct. Soonungwuv *(otherwise Sun’avai, depicting Coyote, per personal communication, 2016, Benn Pikyavit, Southern Paiute, Kaibab*) placed them there. Old timers say you could dig down a little ways and still find their manure” (Martineau 1992, pp. 124). A Southern Paiute story recorded by John Wesley Powell in the 1870s describes an encounter between Yam-puts (porcupine) and Kuts (buffalo) and says that “Yam-puts was down by the brink of the river calling to Kuts to take him across, for he did not know how to swim himself. On the other side of the river there was a great herd of buffalo, and after much entreaty, one of them swam across to Yam-put’s side and told the latter to get on his back. ….When they got to land….then all the herd who were watching them ran away” (Fowler and Fowler 1971, pp. 86). Thus, some regional traditional Tribal stories and knowledge suggests occasional bison presence with some use and exchange of bison or bison goods.

Historic Range

Some authors beginning in the late 19th century did not always include northern Arizona within estimates of the American bison historic range (Hornaday 1889, Hall and Kelson 1959). We now know that the American bison had the largest historic range and broadest array of ecological settings of all North American native ungulates; across boreal, coniferous and deciduous forests, Holarctic settings, local riparian to major river deltas, desert and montane grasslands, great and high plains, inter-mountain basins, and from coastal plains upwards towards 10,000 feet elevation. Recent publications on continental scale bison conservation have recommended including New Mexico, northern Mexico and much of Arizona including the Grand Canyon and Kaibab Plateau area as within the southern and west-southwestern extent of the species continental historic range (Patterson et al. 2003, List et al. 2007, Sanderson et al. 2008, Gates et al. 2010, COSEWIC. 2013, DOI 2014, Plumb et al. 2014) (Figure 1).

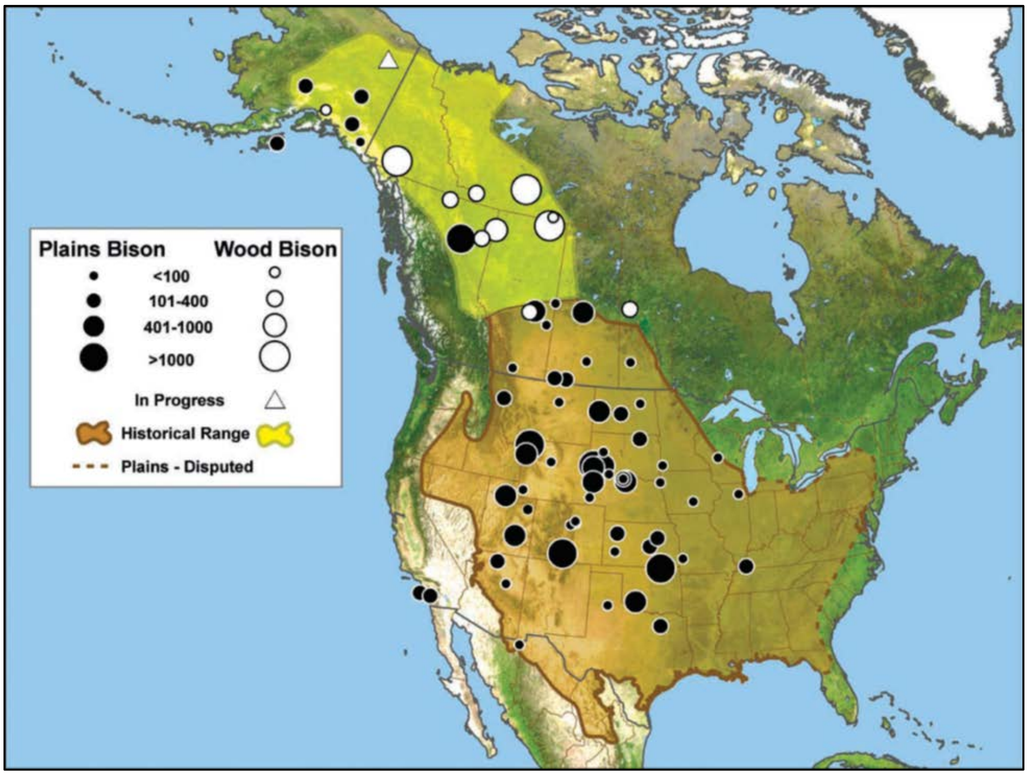

Figure 1. Locations and size classes of bison conservation herds in North America. Historic ranges of wood and plains bison were based on Stephenson et al. (2001) and Sanderson et al. (2008), as reported in Gates et al. (2010), and adopted in DOI (2014). Used by permission.

List et al. (2007) reported that archeological and historical accounts from Mexican archives from AD 700 to the 19th century document that the historic range of the bison includes northern Mexico and adjacent areas in the United States, and further makes a strong argument that bison originally occupied southwestern grasslands, and also that those grasslands co-evolved with large herbivores. While limited discovery of historic bison artifacts and artwork, and general lack of widespread cultural emphasis on bison within currently associated tribes to the greater Grand Canyon region suggests that wild bison in northern Arizona may have only occurred at very low density or limited abundances; the comprehensive review of the status of the American bison by IUCN considers the Kaibab/GRCA area as be within the west-southwestern edge of the species historic range (Gates et al. 2010). Steen and Barrett (2015) recently illustrated that even populations at the edges of a species' range have value to the overall conservation of that species and can be integral parts of ecological communities wherever they occur; they urged decision makers and biologists to consider such arguments and not reflexively deprioritize the conservation of species at the edges of their geographic ranges.

Presence and Absence

There will always remain uncertainty about historic temporal and spatial variability of bison occupancy and movement patterns across the full extent of the species historic range, yet it is known that there were regional areas within the historic range where bison were continually present over long periods and other regional areas across the historic range where bison likely occurred at low densities, as well as regional areas where bison were known to have been present followed by prolonged absences before reoccurring or remaining absent (Gates et al. 2010, Stephenson et al. 2001, Plumb et al. 2014). Examples of naturally occurring local and regional bison extirpation are evident in the historical and archeological literature. For example, Flores (1991) argues that ecological and archeological evidence suggests that periodic extensive drought resulted in multiple intervals spanning decades and centuries, when bison were almost totally absent regionally from the southern plains, with two major periods of absence between BC 5000-2500 and between AD 500-1300. There is compelling evidence that aboriginal peoples also interacted with environmental drivers and stressors to have a strong role in local and regional spatio-temporal distribution and abundance of bison across the historic range (Isenberg 2000, Stephenson et al. 2001, List et al. 2007, and Potter et al. 2010).

A more contemporary example of regional extirpation is when in July of 1842, Charles Fremont's exploration encountered bison along the shortgrass plains of the Rocky Mountain front. He then continued north along the Cache LaPoudre River (in what is now northern Colorado) into the Laramie high plains nestled between the Medicine Bow Mountains and the Laramie Range (in what is now southeast Wyoming) and encountered a very large regional landscape void of bison and other wildlife like pronghorn antelope. Bison were known to have previously occupied the Laramie high plains, and their bones can still be occasionally found in the surrounding high country. Fremont (1872) reported that "Everywhere the soil looked parched and burnt; the scanty yellow grass crisped under the foot, and even the hardiest plants were destroyed by want of moisture" and his contact with disparate small bands of Crow Indians who were hunting indicated "that bison were very scarce, and little to no grass to be found." The relatively rapid disappearance of bison from the several thousands of square miles of the Laramie high plains is suggested in response to severe drought combined with swarming grasshoppers, so that by the time Fremont arrived, there was "No grass, no buffalo – food for neither horse nor man." Thus, in response to natural environmental forces in conjunction with environmentally stressed people, by the early 1840s the bison of the Laramie high plains had dispersed or died, ultimately never to return. A localized example was described by Charles Goodnight (Haley 1936, in Hart and Hart 1997) how during a drought in 1867, bison gathered on the Colorado River (that drains southeast from out of the Llano Estacado in northwest Texas) and died of starvation by the thousands. He described that while there was good grass on the Rio Concho 30 miles away, the bison had stayed in the Colorado drainage and died en masse.

Such variability in temporal and spatial occupancy patterns are thought to have occurred throughout the bison's historic range, and should be considered anywhere where long term bison conservation is contemplated (Gates et al. 2010). While these examples above are not specific to northern Arizona, they do speak to dynamic ecological forces including the role of humans that shaped landscapes across the bison historic range, where local bison abundance and density were responsive to local and regional conditions across years, decades, centuries and millennia– even within what is now considered to be portions of the core historic range and most certainly at the edges of that historic range.

NPS Policy

All parks in the NPS system share in the common mission of stewardship of America's national heritage. The NPS has authority to manage wildlife populations and habitats under the NPS Organic Act (16 USC 1, 2-4), the General Authorities Act, as amended (16 USC 1a-1 et seq.), and other authorities. NPS policies for wildlife management are set out in section 4.4 and other provisions of NPS Management Policies 2006 (NPS 2006). NPS policy defines native species as those that "have occurred, currently occur or may occur as a result of natural processes on lands designated as units of the national park system" (NPS 2006). Upon extensive review by the NPS, U.S. Fish and Wildlife Service (FWS), Bureau of Land Management (BLM), Bureau of Indian Affairs, and with concurrence from the department's science bureau the U.S. Geological Survey; the Department of the Interior (DOI) Bison Conservation Initiative (see DOI 2014) adopted Sanderson et al. (2008) and Gates et al. (2010) as the best available sound science describing the bison continental historic range for purposes of ongoing DOI-wide and bureau-specific bison conservation planning and stewardship activities, that includes areas at the edge of the species' historic range such as the Grand Canyon region (see Figure 1).

It is well known that the wild, free-ranging bison that now occupy the House Rock Valley and Kaibab Plateau of the Kaibab National Forest and GRCA North Rim are descendants of 86 privately owned bison brought to northern Arizona in 1906 by Charles Jones, a notable rancher and bison conservationist (Easton and Brown 1961, Meade 2002). Records also indicate that the herd consisted of animals caught from the wild in Texas and New Mexico, along with other animals procured from Kansas, Nebraska, Montana and Manitoba (Easton and Brown 1961). As noted below in the genetics section of this report, it is also well known there was limited success between 1906-1909 in forced cross-breeding of those bison with cattle (Mead 2002 and Wakeling 2006). By 1909, in large part due to the failed forced cross-breeding effort, the bison herd was reduced to 15-20 animals. Despite this near total failure, this small group of bison survived under little to no management, in an essentially free-ranging condition, and subsequently increased until 1927, when 98 free-ranging descendants were conveyed to Arizona for management (Brown 2012).

Some have suggested that as the current wild free-ranging bison at GRCA and adjacent USFS lands are known descendants of bison once privately owned for a relatively brief time over a century ago, they must necessarily fall under NPS policy for non-native animals. Indeed, the facts - wherein wild bison were brought into private ownership, restored to a part of their historic range, forcibly cross-bred with cattle for a brief time, then largely abandoned for twenty years, until brought under state authority for most of the past century - do not demand application of NPS non-native animal policy. Rather, the wild bison that today occupy areas on the Kaibab Plateau within the greater Grand Canyon region, including NPS jurisdiction on the GRCA North Rim, came to do so by migrating and dispersing on their own out of the House Rock Wildlife Area, where they had been managed by AGFD as wildlife for decades. Since arriving, and largely remaining, on the Kaibab Plateau, their exhibited ecology as free-ranging wildlife (e.g. habitat selection, movement, and population ecology) at the authoritatively recognized west-southwestern edge of their historic range is consistent with NPS policy as native wildlife.

AGFD Policy

Arizona statute guides bison management as native wildlife on USFS lands adjacent to GRCA. In Arizona Revised Statutes (A.R.S.) Title 17, Article 1. Definitions and Authority of the State: Sec. 101A23 ‘‘Wild’’ means, in reference to mammals and birds, those species that are normally found in a state of nature. In Sec. 101A24, ‘‘Wildlife’’ includes all wild mammals. Specifically, A.R.S. 17-101B2 lists bison (buffalo) as a game mammal and A.R.S. 17-101B3 lists bison as a big game animal in Arizona.

USFS Policy

A recent Memorandum of Understanding between the USFS and AGFD, states that the USFS agrees “To recognize the Commission’s and the Department’s responsibility to make determinations as to which fish and wildlife species are native or naturalized to the state of Arizona, and in which areas of the state those species should be established or maintained.” Per statute and agreements, the AGFD considers the wild, free-ranging bison at the North Kaibab National Forest, including the House Rock Wildlife Area, to be native wildlife. In 2014, the USFS issued the Final Environmental Impact Statement for the Kaibab National Forest Land and Resource Management Plan and stated that as the IUCN North American Bison Specialist Group has documented that the Kaibab National Forest is within the historic range of bison (Potter et al. 2010), and as AGFD has determined that this is a native wildlife herd, the USFS considers wild free-ranging bison on the Kaibab National Forest as native wildlife (USDA 2014).

Summary

After careful consideration of the above information, the team agreed by consensus that wild, free-ranging bison that may occupy GRCA North Rim lands and adjacent jurisdiction are native wildlife at the west-southwest edge of their continental historic range. It is important to highlight that bison as native wildlife under NPS, AGFD and USFS law, policy and management goals does not preclude them from being managed at appropriate abundance and density for conservation purposes, to support wildlife related recreation, or to protect other natural and cultural resources and values.

Abundance and Density

The team discussed and agreed to several key elements regarding bison population abundance and density, including that:

1) a bison population at GRCA and adjacent lands should reflect low to very low density (e.g. bison abundance ÷ landscape size) at the west-southwestern edge of the historic range, which should be substantially less than NPS bison conservation herds located elsewhere in more central historic range (see DOI 2014);
2) population abundance should be considered as a single population across a large landscape and not be piecemeal pro-rated to respective jurisdictions;
3) population abundance should be well below where forage abundance across a larger landscape would be a limiting constraint, and thereby seek to mitigate most habitat impacts at the larger landscape level, though some site-specific impacts to locally sensitive resources may still need to be addressed by a suite of management actions;
4) under low to very low density conditions, the annual population growth rate should be expected to approach the upper limit for the species (e.g. ~15-20%, λ=1.15-1.2);
5) total population size and resultant annual population growth should not exceed potential for hunting on lands adjacent to the park to effectively and consistently serve as the primary population growth rate control mechanism in the long-term; and
6) that population abundance objectives should recognize relevant concerns for a small population.

There is considerable variation in bison population abundance, landscape size, and density across the 17 DOI bison herds that are distributed across NPS, FWS, and BLM lands (DOI 2014). The most comparable DOI bison herds to the GRCA/Kaibab National Forest situation are the low density wild, free-ranging bison populations that occur on BLM lands in Utah, amongst arid mixed grass/shrub/forest habitats. The Utah Henry Mountains population density is approximately 0.001 bison/acre (e.g. 325 bison/ 300,000 acres) and the Utah Book Cliffs population density is 0.0003 bison/acre (e.g. 450 bison/1,400,000 acres) (DOI 2014). In contrast, NPS bison herds amongst the northern Great Plains occur at density 1-2 orders of magnitude above these Utah populations. The Badlands National Park population density is approximately 0.01 bison/acre (e.g. 650 bison/64,000 acres) and the Wind Cave National Park population density is approximately 0.016 bison/acre (e.g. 450 bison/28,000 acres) (DOI 2014). We propose an upper limit bison density for the GRCA/Kaibab National Forest at 0.001 bison/acre. For the landscape described below (Figure 3), this would be a density comparable to the Henry Mountains bison population; thus yielding approximately 200 bison (e.g. 0.001 bison/acre x 215,000 acres).

As part of thinking about key issues involved with small population management, the team discussed NPS prior experience in determining a minimum population threshold for a wild, free-ranging horse population at Assateague Island National Seashore (ASIS) (Zimmerman et al. 2006). The team agreed that some of the ASIS concerns had conceptual relevance for bison at GRCA, including consideration of 1) a closed (isolated) large ungulate population, 2) potential for periodic controlled abundance and distribution, 3) population genetics, 4) population ecology (e.g. demography, survival and mortality), and 5) probability of local population extinction from a mass mortality event, predation, and disease. Taking these issues into account, expert informed opinion at ASIS identified a lower limit threshold of 80 individuals over the long term (Zimmerman et al. 2006).

Wild bison at GRCA and the Kaibab National Forest are minimally vulnerable to natural predation; are subject to hunting on USFS lands, may not be at high risk for catastrophic mass mortality – though this risk is not totally absent, currently constitute a closed (isolated) population of a species known to have been forced through a continental genetic bottleneck and then forced into another localized genetic bottleneck while undergoing forced cattle introgression upon foundation, whose population growth is expected to be able to be managed (e.g. potential for initial population reduction and then long-term hunting on lands outside GRCA); and with potential for periodic new genetics introduced into the population. Taking these issues into account, the team proposed a lower limit bison population threshold of not less than 80 individuals (e.g. density of 0.0004 bison/acre – as comparable to the Utah Bookcliffs population). This lower limit population threshold aligns with the lower end of the population abundance identified by AGFD for maintaining a wild, free-ranging bison population than can be hunted long-term on lands adjacent to the park. While these densities (0.001-0.0004 bison/acre) are comparable to the Utah wild bison populations described above, the total numerical abundance is substantially lower than IUCN guidance that calls for greater than 400 bison for long-term conservation objectives (Gates et al. 2010, COSEWIC 2014, Gates 2014). Small population issues are further discussed below, including that the Kaibab/GRCA bison could be potentially be maintained at low density across a larger landscape (e.g. higher abundance) or be managed as a small satellite herd to an overall larger meta-population.

Summary

After extensive discussion, the team agreed by consensus that a population objective of 80-200 bison (0.0004 bison/ac to 0.001 bison/ac) conservatively satisfies prevailing bison management considerations for GRCA, USFS and AGFD (Table 1), and that serving as a satellite herd to a meta-population could potentially address some small population and genetics conservation concerns.

Table 1. Qualitative bison management considerations and bison density and abundance across a proposed ~215,000 acre multi-jurisdiction bison landscape.

Consideration	Density < 0.0004 bison/ac Population <80	Density 0.0004 bison/ac to 0.001 bison/ac Population 80-200	Density 0.001 bison/ac to 0.002 bison/ac Population 200-400	Density > 0.002 bison/acre Population >400
Very low density at southwestern edge of the historic range	Yes	Yes	Maybe	No
single population at large landscape	No	Yes	Yes	Yes
well below where forage abundance across the larger landscape could be a governing constraint	Yes	Yes	Maybe	No
annual population growth rate at upper limit for the species (e.g. ~15-20%)	Maybe	Yes	Yes	Yes
will not exceed potential for hunting on USFS lands adjacent to the park to effectively and consistently serve as the primary population growth rate control mechanism in the long-term	Yes	Yes	Maybe	No
will not go below a lower population threshold	No	Yes	Yes	Yes

Genetics

Introgression

Dratch and Gogan (2010) documented how private ranchers who established the five plains bison foundation herds in the late 1800s either experimented with domestic cattle-bison crosses or purchased bison from others who were involved in such experiments (Garretson 1938, Coder 1975, Brower 2008). Consequently, both mitochondrial (Polziehn et al. 1995, Ward et al. 1999) and nuclear (Halbert et al. 2005) evidence of domestic cattle ancestry has been identified widespread in both public and private plains bison herds (Halbert and Derr 2007). Some evidence of mitochondrial or nuclear domestic cattle gene introgression has been identified in over half of all U.S. and Canadian public bison populations sampled (Ward et al. 1999, Halbert et al. 2005, Halbert and Derr 2007). Only one of >50 private bison herds examined show no evidence of cattle gene introgression (J. N. Derr, pers. comm. as reported in Dratch and Gogan, 2010).

Genetic information from the wild, free-ranging bison that currently occur in and around GRCA, Kaibab National Forest, and House Rock Wildlife Area confirms historic records (Mead 2002) about attempts between 1906-1909 to forcibly cross-breed the Jones bison with cattle (Wakeling 2006, Hedrick 2010). Derr (2003), Wakeling (2006) and Hedrick (2010) reported that the very large majority of the House Rock Valley/Kaibab/GRCA bison that have been sampled to date possess cattle mitochondrial DNA, while Hedrick (2010) found that cattle chromosomal DNA was estimated at <2%.

Introgressed cattle mitochondrial DNA is passed intact across generations for females, but not subsequently for males; and introgressed cattle chromosomal DNA can be subject to decline due to inter-generational selection - in that not all males and females contribute equally to each successive generation. This herd has some of the relatively highest introgression levels amongst bison managed as wildlife by State or Federal agencies (Hedrick 2010, Dratch and Gogan 2010), and the pervasiveness of cattle genes in this herd may be the result of the very small population size after introgression (e.g. 15-20 animals by 1909). Elsewhere, when cross-breeding was attempted amongst larger herds (e.g. relatively fewer introgressed animals), subsequent selective factors amongst the larger herds may have winnowed residual cattle genes from a larger founding herd over time and many bison generations (per Hedrick 2010). In a very small founding herd, the forced cattle genetic introgression would have served to imprint a relatively larger portion of the total subsequent survivors. Thus, it is not surprising that after generations of natural selection across nearly 80 years, the current Kaibab/GRCA bison population continues to show considerable continuing evidence of cattle mitochondrial DNA and much lower levels of cattle chromosomal DNA.

New research techniques, including single nucleotide polymorphism analysis, indicate that generally less than 1% of the overall conservation bison genome is composed of introgressed genetic material from domestic cattle (ABS 2011). Most geneticists see this as a low level of introgression, and there is no evidence that this level poses a threat to conservation of the bison species; and that some cattle-gene introgression in most bison herds, including conservation herds is acceptable for the conservation of the species as free ranging wildlife (ABS 2011). Thus, if managed through natural selection as wildlife, bison herds with cattle-gene introgression can still be of high conservation value. Indices such as genetic purity should be less of a concern than more forward-looking indicators of success in bison conservation such as restoring ecological function, adaptability, and natural selection; and attempts to excise cattle nuclear DNA from bison pose risks to conserving overall genetic variation (ABS 2011). Dratch and Gogan (2010 recommend that when cattle mitochondrial introgression is higher, supplemental genetics augmentation of bison females with strong conservation genetics can be considered to improve population genetics, and that long-term genetic monitoring should be conducted to determine the effectiveness of such efforts.

Heritable Traits

While Hedrick (2010) and Dratch and Gogan (2010) found that only a few bison conservation populations today do not possess some lingering mitochondrial or chromosomal DNA legacy of early 20th century cattle-bison cross-breeding efforts, Hedrick (2010) goes on to explain how incipient reproductive isolation between the bison and cattle species differentially influenced the ancestry for these two types of genes. Hedrick (2010) observes that an initial interspecific cross between bison and cattle rarely produced viable male offspring (see also discussion in Hedrick 2009), which in turn supports "Haldane's Rule" that, if upon species cross-breeding, one sex is absent, rare or sterile, there is evolutionary incompatibility of the two species' DNA. Further supporting this hypothesis, results from recent molecular genetic studies of whole mitochondrial DNA sequence (Achilli et al. 2008) estimate that bison and the ancestor of domestic cattle diverged in the early Pleistocene approximately two million years ago suggesting that there should be significant reproductive isolation between cattle and bison.

What does cattle DNA introgression mean for the wild, free-ranging bison population that currently lives on GRCA and USFS lands in northern Arizona? Reports of cattle DNA do not mean that the genetics of individual bison in this herd are mostly cattle; rather these reports indicate that many animals show evidence of at least some lingering cattle DNA. In simple terms, not unlike other conservation herds, these animals are bison, with some cattle genetics lingering on after a century. Derr et al. (2012) indicate that cattle mitochondrial DNA may influence bison cellular physiology in some cases, yet Hedrick (2010) also notes that 100 hundred year old residual cattle mitochondrial DNA may also now be "neutral," in that it would have no discernable effect on cellular physiology. Issues could potentially arise if introgressed cattle mitochondrial DNA mismatches with bison nuclear DNA, so that cattle mitochondrial DNA are unable to process some gene products from the nucleus as efficiently as bison mitochondrial DNA. It is not clear whether these cellular issues are occurring or to what extent, if any, individual animal physiological processes could be potentially influenced. While mitochondrial DNA influences cellular physiology processes, the vast majority of heritable traits for all eukaryotic organisms are coded by chromosomal DNA. The bison population under consideration exhibits few, if any, phenotypic traits of cattle (pelage, body conformation, etc.), they look and behave like bison, and they produce viable male and female offspring indicating essential functionality of chromosomal DNA.

Small Populations

A small population is an important conservation issue. Historical and contemporary evidence describes how stochastic stressors affect population viability, and the evidence is clear that small populations suffer greater genetic decline and are more vulnerable to ecological disturbances than larger populations. Thus, a small population of 80-200 bison at the west-southwest edge of historic range will be more vulnerable to random environmental and population disturbances and long-term genetic decline as compared to larger bison herds across the historic range. Male competition for mates is an important mechanism in reproductive (natural) selection that functions to maintain genetic diversity, and as an important factor in species evolution. For small bison populations, breeding dominance by individual males has been flagged as a concern (Gates et al. 2010), leading to inbreeding depression and reduced genetic diversity. This phenomenon was statistically modeled to diminish to insignificance once a bison population exceeds 400 (Wilson and Zittlau 2004). In order to address loss of genetics in a small population, Dratch and Gogan (2010) recommend to 1) increase, or at least maintain stable, population size and avoid wide swings in abundance, 2) maintain adult breeding males and approach a 1:1 sex ratio, 3) as needed remove younger animals rather than prime aged adults, and 4) conserve genetic diversity by periodically augmenting with additional animals as a satellite herd to a larger meta-population.

Summary

The team agreed by consensus that though this herd retains relatively higher cattle introgression amongst public conservation herds, the introgression does not appear to restrain them as wild bison and does not seem to have any discernable effects on contemporary reproductive processes and phenotypic expression. Taking into account recent science and science-based guidance about bison genetics described above, the team agreed that the prevailing genetics of the population do not nullify it as an ecologically, socially, and recreationally relevant wild, free-ranging bison herd. Indeed, the prevailing genetics of the current bison population are, if not optimal, not incompatible with NPS, USFS, and AGFD policies and missions for bison conservation. Further, under existing law and policy, GRCA and AGFD can work collaboratively to improve the bison herd's genetics according to best available bison science and genetics management guidance (Gates et al. 2010, Dratch and Gogan 2010, ABS 2011), combined with additional long-term science and monitoring for this herd.

Landscape

The team discussed the spatial extent of a landscape that could be considered for the purposes of managing a multi-jurisdictional wild, free-ranging bison population on USFS and NPS lands. Rough maps and supporting verbal descriptions were initially provided by team members. Bison radio collar data during 2005-2007 indicated seasonal variation in bison distribution (Figure 2), and recent visual observations confirm that bison currently preferentially use certain areas of the North Rim more than others (Grand Canyon National Park 2015). Recent visual observations and hunting records indicate bison also occupy small drainages and meadow habitats north of the park up to Pleasant Valley Meadow.

Team discussion resulted in a consensus vision for bison habitat on the Kaibab National Forest up to 8 miles north of GRCA boundary and that roads and other constructed or natural geologic features could be identified in future conversations to further refine the range limits. The USFS indicated bison have used North Canyon in the past, but due to sensitive riparian resources, the USFS prefers bison not use North Canyon in the future. The NPS likewise indicated expectation for protection of sensitive natural and cultural resources from bison impacts in GRCA. The team discussed that increasing density can lead to dispersal behavior by bison (Plumb et al. 2009); that a bison landscape may be limited by natural features or conversely, at least in part, ultimately determined by the lack thereof; and that bison population density scenarios as described above would be at very low density and well below what occurs in other wild bison populations in the core of continental historic range. Accordingly, bison may continue exhibiting movements such as those from House Rock Valley to Kaibab Plateau, but not density-dependent dispersal movements. In the Kaibab National Forest, there are no natural barriers that are contiguous and that would serve as a barrier to bison movement to the north; and though hunting on lands adjacent to the park could potentially limit bison density and distribution, some exploratory movement behavior may continue to occur. Since bison can exhibit random movement behaviors, it may be worth considering whether there is a need for a designated bison conservation area for the population, with a focus to manage overall distribution while preserving wild bison behavior and movement ecology.

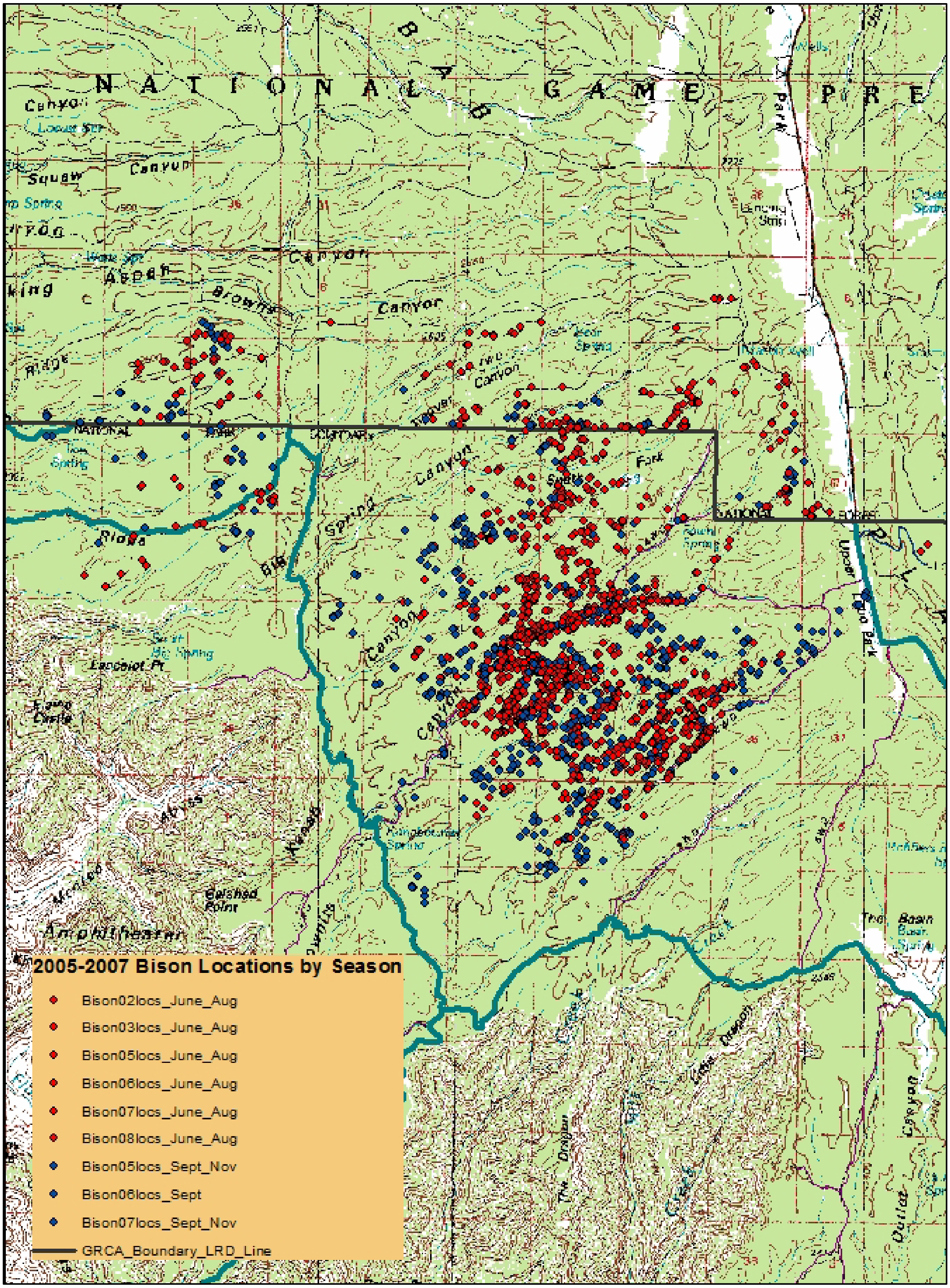

Figure 2. Telemetry locations of bison in the North Rim area of Grand Canyon National Park and Kaibab National Forest during summer-fall 2005-2007.

Summary

Based upon these team discussions, consensus agreement was reached about a potential multi-jurisdictional bison range of approximately 215,000 total acres (Figure 3), comprised of about 54,000 acres on GRCA and about 161,000 on the Kaibab National Forest (Kaibab Plateau about 107,000 acres, and House Rock Wildlife Area about 54,000 acres). The team noted that this landscape is a conceptual design for purposes of interagency discussion and that there will likely be sensitive resources within this large landscape that may require local and site-specific management and protection.

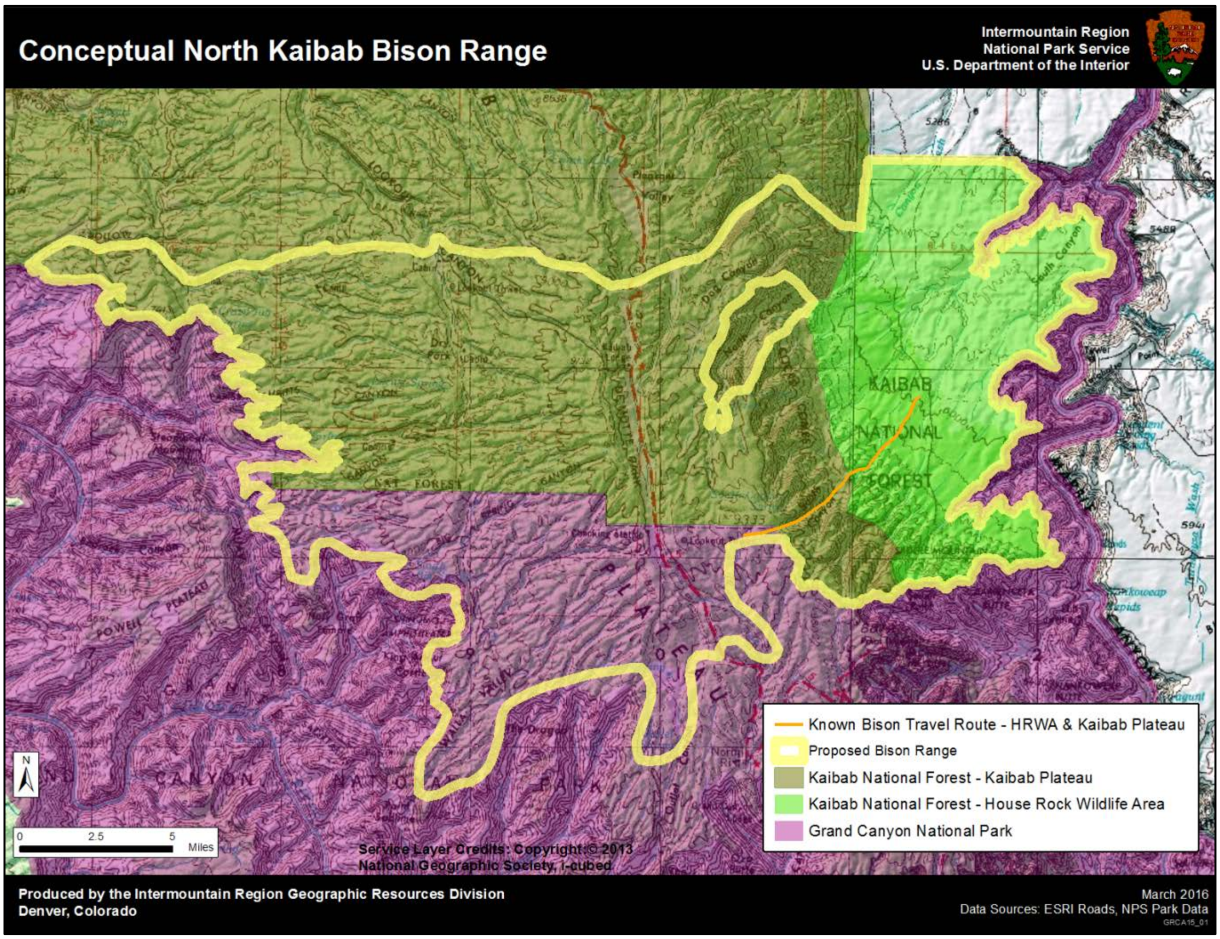

Figure 3. Potential multi-jurisdiction landscape for wild free-ranging bison at Kaibab National Forest, House Rock Wildlife Area and Grand Canyon National Park.

Population Ecology

With input from the team, NPS staff developed a simple deterministic population model to assess how several population management scenarios could affect bison population abundance on GRCA and USFS lands (Sturm and Holm 2015). The model was parameterized with local information where possible, adopted published vital rates where needed (Gates et al. 2010), and was intended for comparing the performance and effectiveness of various initial population reduction scenarios. The model was deterministic in structure for a closed population without random (stochastic) events such as disease, mass mortality or natural disasters. The starting population size was set at 454 individuals pre-calving and 600 individuals post-calving (GRCA and AGFD currently estimate the population at 400-600 bison). Annual population growth rate was set at 15%. Annual reproductive rate for prime aged females increased from 65% at model initiation to 86% after year 6, as the population shifted towards a 1:1 male:female ratio and per hunting mortality objectives described below. Annual natural mortality rate is set at 3% and is distributed according to the ratio 4 calves:1 yearling:1 sub-adult:4 adults. Natural mortality, while low overall, disproportionately affects the very young and the very old members of the population while individuals in the “yearling” and “sub adult” age classes tend to nearly always survive into the next age class. Other parameters are altered between Models 2, 3, and 4 due to the influence of additional sources of mortality or animal removal and are described below. Each model was run for 15 years, or until meeting a population objective of 150 individuals in the pre-calving population. This standardized population target of 150 was established solely for model comparison purpose. Additional model details and quantitative output spreadsheets are available in Sturm and Holm (2015).

Natural Mortality and Hunting

Model version 1 simulated current bison management with annual hunting mortality set at 10%, with a harvest ratio set at 2 bulls:3 cows for the first 6 years, after which the harvest ratio in the model changes to 1 bull:1 cow. The initial 2:3 sex harvest ratio comes from actual hunter harvest information provided by AGFD, which is currently focused on removing females from the population in order to help limit continued population growth. The adjustment to a 1:1 harvest ratio after year 6 serves to maintain balanced sex ratios thereafter. After 15 years, Model 1 does not achieve the modeling population objective of less than 150 individuals in the pre-calving population (Figure 4).

Natural Mortality, Hunting and Live Animal Capture-Removal

Model version 2 incorporates live animal capture and removal with an assumption that 10% of the total bison population would not be available for live capture and removal since they occur in remote areas where such activities could not be implemented. Model 2 differentially applied reproduction, survival and mortality rates to two separate cohorts – those available or not available for capture. Capture and removal rate was set at 30% annually for all age and sex class cohorts except adult males, which was set at 15% annually, since a number of adult males may not be available for capture due to their size and related safety concerns. This resulted in about 150 animals removed in year one, and thereafter the number of animals captured declined annually as this cohort size declined. The initial cohort of 10% of the population not available for capture increased in the same manner as did the total population under Model 1. After 15 years, Model 2 does not achieve the modeling objective of less than 150 individuals in the pre-calving population (Figure 4).

Natural Mortality, Hunting, and Skilled Volunteers

Model version 3 incorporates NPS use of skilled volunteers to lethally remove bison in the park. In this model, the entire bison population would be subjected to either skilled volunteer inside the park or hunting outside the park. Skilled volunteer lethal removal and hunting is set at 15% annually, with hunting success increased over Model 1 due to the effect of skilled volunteer causing bison to disperse outside of GRCA where they can then be hunted. As the population declines, the total number of animals taken annually by skilled volunteers and hunters similarly declines. Skilled volunteer and hunting harvests are set to affect only sub-adult and adult age classes and the harvest sex ratio is set at 3males:5 females through year 3 after which the ratio adjusted to 1 male:1 female. This initial harvest sex ratio is intended to drive down the reproductive capacity of the population and then the adjusted ratio is intended to maintain balanced sex ratios thereafter. In Model 3 this adjustment occurs in year 3, as opposed to year 6 in Models 1 and 2, since the influence of both hunting and skilled volunteer sharpshooting are shown to affect the population sex ratio more quickly. Model 3 achieved the population objective of less than 150 individuals in the pre-calving population in year 10 (Figure 4).

Natural Mortality, Hunting, Live Animal Capture-Removal, and Skilled Volunteers

Model version 4 combines Models 2 and 3. By year 3, Model 4 has achieved the population objective of 150 individuals in the pre-calving population (Figure 4).

Summary

Model 1 reveals that the population would continue to increase after 15 years. Model 2 reveals that addition of live animal capture and removal initially acts to drive down the total population through year 8, at which time the population cohort that is not available for capture begins to drive population abundance back up. Model 2 also reveals a substantial reduction of the cohort available for capture activities by year 15, after not achieving the modeling population objective. Model 3 achieved the population objective in year 10, after removal of combined total of approximately 1,100 bison by skilled volunteers in the park and hunters outside the park. Model 4 achieved the population objective in year 3, with an estimated removal of a combined total of 332 bison by skilled volunteers inside the park and hunters outside the park, and an additional 275 bison removed by live capture.

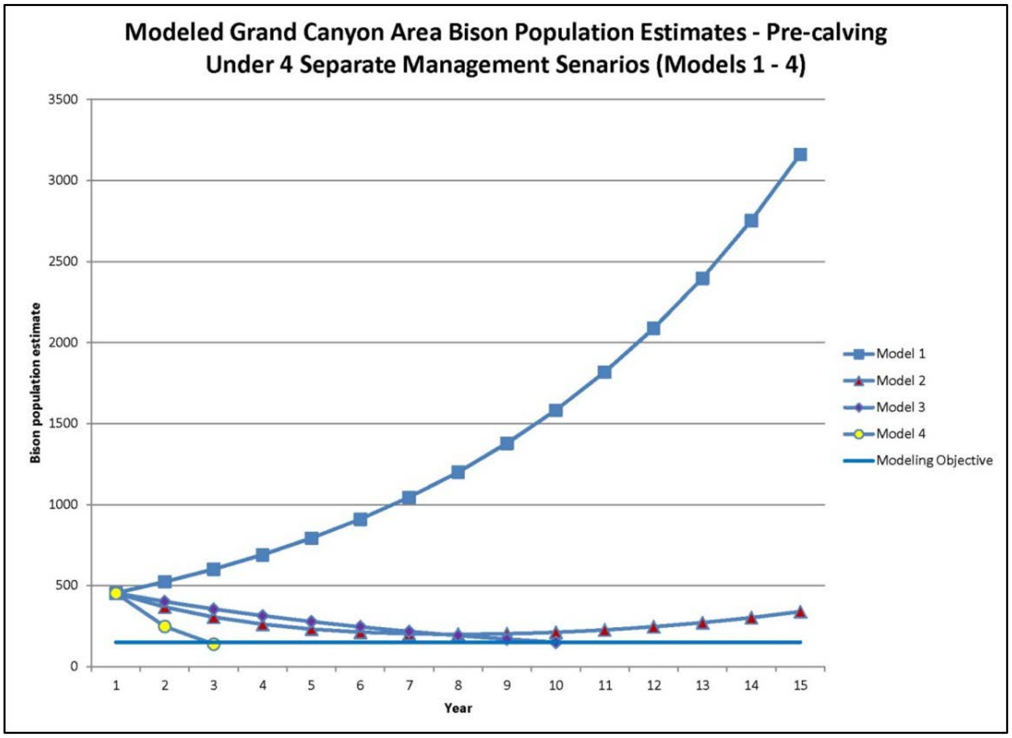

Figure 4. Modelled bison population estimates under four management scenarios: Model 1 includes natural mortality and hunting outside Grand Canyon National Park; Model 2 includes natural mortality, hunting outside Grand Canyon National Park, and live animal capture and removal, Model 3 includes natural mortality, hunting outside Grand Canyon National Park, and skilled volunteers in Grand Canyon National Park; and Model 4 combines Model 2 and 3. The graph shows a modeling objective of 150 individuals in the pre-calving population. Models were run for 15 years or until population objective was achieved.

Additional Considerations

The team discussed IUCN bison population management guidelines (Gates et al. 2010) that may be applicable for bison management planning at GRCA and USFS lands. The team agreed that IUCN considerations for when it is "necessary to remove a large portion of the population to meet management goals," and for when "managers must carefully evaluate their goals and the specific situation to achieve the best outcome" (Appendix 1.) should be taken into account for a population objective of 80-200 bison. The team discussed that potential near-term bison management activities to reduce the current abundance of 400-600 bison towards a population objective of 80-200, and implementation of other actions such as protecting sensitive natural and cultural resources, should be implemented with consideration for maintaining a single population across the entire landscape, that maintains representative population demographic structure and important population seasonal behaviors such as rut and birth synchrony to the extent practical.

Potential initial population reduction actions should distribute their effects across the population as feasible, including distributing population reduction actions across the landscape to the extent possible. In other words, it is important that a resulting long term population be proportionally comprised of individuals from across the larger population. In addition, the team supported the IUCN guideline, to the extent possible, that "preferential removal of related individuals … should be avoided" since it can "lead to losses in genetic diversity and effective population size." In addition to envisioning a satellite herd to a larger meta-population (per Dratch and Gogan 2010, Gates et al. 2010), it may be worth considering an adaptive management approach wherein 80-200 bison are the initial conservative estimate of abundance, and long-term abundance is evaluated through testing hypotheses concerning ecological effects of increasing population size.

Summary

Following a potential initial population reduction, the team agreed by consensus that hunting on USFS lands should be the primary long-term population management activity, that management should strive to maintain or restore ecological objectives while protecting sensitive resources and values, and that there should be long-term population ecology and genetics monitoring. In the long term, serving as a satellite herd to a larger meta-population (that could provide for periodic population genetics supplementation as a surrogate for periodic natural immigration of new unrelated individuals) may be needed to maintain long-term ecological integrity and improve the genetics of this bison population at the west-southwestern edge of the historic range.

Looking Forward

Until very recently, discussion about bison at Kaibab National Forest and GRCA has focused on looking backwards to before European settlement in northern Arizona, when bison may have only been present periodically and at very low abundance; to when bison were brought to northern Arizona in the early 20th century for ultimately failed domestic production; to when Arizona undertook responsibility for bison as wildlife at the House Rock Wildlife Area on USFS lands; and to more recently when wild bison decided to move on their own to the Kaibab Plateau and GRCA. Based upon these retrospectives, for some time, GRCA communicated to the public and inter-agency partners that wild, free-ranging bison that reside on GRCA lands were non-native hybrid animals not appropriate for consideration under NPS wildlife conservation policies.

In 2008, DOI launched a Bison Conservation Initiative intended to rethink and revitalize how federal bureaus and their partners conceive, plan, and implement cooperative bison conservation (DOI 2008). In 2011, the NPS issued a Call to Action to encourage parks to rethink how they can innovate in cooperation with partners and the public to more fully accomplish both the park and agency missions (NPS 2011). This NPS Call to Action specifically identified innovative and cooperative bison conservation at a larger landscape level as a high priority for the agency. In 2014, DOI issued a comprehensive report about bison conservation (DOI 2014) and the NPS issued a comprehensive report on ungulate management in parks (NPS 2014) that both identified a high priority for innovative and forward-looking bison conservation. Building upon the revitalization of agency and departmental initiatives, international collaborative bison conservation across the North American historic range was formally discussed at the 21st Meeting of the Canada/Mexico/U.S. Trilateral Committee for Wildlife and Ecosystem Conservation and Management in Ottawa, Canada in May 2016.

It can be difficult to challenge entrenched dogma and move forward with updated perspectives. At the request of NPS leadership, this report is a deliberate effort to assess the state of the knowledge about wild, free-ranging bison in northern Arizona. The team recognized that science of bison at the west-southwest edge of their historic range is less developed than the science of bison elsewhere in the historic range. The team also recognized that there exists a wide array of perspectives about bison in northern Arizona. The team sought to adhere to the admonition of Sinclair (1991) to avoid confusing scientific inferences for wildlife management with societal value judgements, while purposefully discussing key bison topics from their agency perspectives at the intersection of best available science, fidelity to law, and long-term public interest. A combination of new scientific thinking and information, clear statements of agency policies, and a national revitalization of bison conservation, led the team to deliberately reassess some of the heretofore retrospective narratives about bison in northern Arizona, and ultimately resolve by consensus that there is plenty of room within NPS, USFS and AGFD laws, regulations, policies, and priorities for forward looking collaborative wild bison conservation on some GRCA and Kaibab National Forest lands.

As a contribution to ongoing bison management planning at GRCA, this report describes how a team of wildlife biologists from the NPS, USFS and AGFD convened, deliberated, and ultimately agreed by full consensus that: 1) the wild, free-ranging wild bison that may occupy GRCA North Rim and adjacent USFS jurisdictions are native wildlife at the west-southwest edge of their continental historic range; 2) the genetics of the current herd can be improved and are not in conflict with NPS, USFS, and AGFD missions and policies; 3) a large landscape (about 215,000 acres) on GRCA and Kaibab National Forest lands is potentially suitable for cooperative bison management and protection of sensitive resources and values; 4) a very low density of 80-200 bison (0.0004 – 0.001 bison/ac) initially best addresses a suite of interagency bison management considerations; 5) initial population reduction to reach population objectives would be best achieved via a combined approach of live animal capture-removal, combined with skilled volunteer lethal removal on GRCA lands and licensed hunters on USFS lands; so that in the long-term hunting outside the park can serve as the primary population management approach, and 6) both the near- and long-term population management should take into account and strive to simultaneously protect sensitive resources and values and address small population conservation concerns, objectives and guidelines.

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Appendix 1. IUCN Herd Reduction Guidelines

The following is an excerpt from the 2010 IUCN report (Gates et al. 2010).

9.2.8 Herd size reduction

Bison have a high intrinsic reproductive rate and bison herds generally grow rapidly (see Chapter 6). Therefore, when resources are limited, bison herds often exceed the carrying capacity of their environment and begin to have negative impacts on other grazers and native plant species. As a result, most bison herds are subjected to some level of culling (=periodic removals) to maintain a suitable population size (Table 9.4). In extreme cases, it may be necessary to remove a large proportion of the population to meet management goals. For example, if bison have not been culled from a herd in several years, the herd may have nearly doubled in size, and it may threaten the survival of other species. In these cases, extreme caution should be taken to remove bison in a manner that will minimally influence herd and germplasm composition according to the following guidelines. Some discretion is needed in applying these guidelines. For example, it is important to avoid social disruption while simultaneously removing animals from all segments of the population. Managers must carefully evaluate their goals and the specific situation to achieve the best outcome (Table 9.4).

Table 9.4 *Important considerations for culling bison herds. See section 9.2.8 for explanation.*

Consideration	Description
Genetic diversity	When removing a large proportion of a herd, the primary threat to long-term preservation of the herd is a loss of genetic diversity that can be very difficult, if not impossible, to restore. Therefore, thorough genetic evaluation (e.g., section 9.2.3), is necessary before, during, and after planned large-scale herd reductions. The primary genetic considerations should be the overall maintenance of mitochondrial and nuclear diversity, such that the genetic architecture of the herd is maintained during and after the reduction period. Routine examination of culled animals during the reduction period will allow for detection—and hopefully correction— of “biased” removals, such as removal of a sibship or multigenerational family groups. Preferential removal of related individuals can lead to losses in genetic diversity and effective population size and should be avoided (Frankham 1995).
Herd composition	If, prior to removals, the herd has the desired composition, bison should be removed proportionally from all age and sex classes to avoid disruption of social behaviours and demographic structure. If the current herd structure is substantially different from that desired (e.g. section 9.2), animals may be preferentially removed from certain classes. In the case of disproportional removals, particularly care should be taken to assess and mitigate the potential effects of removals on social structure and genetic diversity.
Population substructure	Population substructure is likely important in many bison populations (see section 9.2). The presence of distinct subpopulations should be carefully evaluated prior to large-scale herd reductions and accommodated in planned reductions.
Time scale	Bison should be removed at regular intervals (rather than large, occasional events) to minimise potentially irreversible impacts on social structure and genetic diversity The exact time period for removals will likely be different for each situation and will depend on such factors as total herd size, the total number of animals to be removed, and the resources available (e.g., facilities, manpower).

Table 9.4 (continued) *Important considerations for culling bison herds. See section 9.2.8 for explanation.*

Consideration	Description
Assess effects of management actions	Before and after management actions are implemented, thorough genetic, health, and demographic monitoring is necessary to evaluate recovery efforts, and to detect the need for alternative management strategies. Small populations are especially sensitive to management changes, and comprehensive monitoring may be necessary for some time to ensure the recovery of such herds. Sections 9.2,1, 9.2.3, and 9.5.2 summarise information that should be monitored to detect changes in a timely manner. Especially for small herds, the overall health of the herd should be continuously monitored to detect and treat any heritable or transmissible diseases that may impede recovery efforts.

ON THE BACK COVER
Bison at Grand Canyon National Park
Credit: National Park Service

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National Park Service
U.S. Department of the Interior

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