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Natural Resource Stewardship and Science

Management of the Kaibab Plateau Bison Herd in Grand Canyon National Park

2018–2019 Operations Report

Natural Resource Report NPS/GRCA/NRR—2020/2167

ON THIS PAGE
It takes a team: some of the 2019 Grand Canyon National Park Bison capture team.
NPS Photo/ Bryan Maul

ON THE COVER
Bison in Little Park, North Rim, Grand Canyon National Park
NPS Photo/ Skye Salganek

Management of the Kaibab Plateau Bison Herd in Grand Canyon National Park

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Miranda L. N. Terwilliger[1], Cynthia R. Hartway[2], Kate A. Schoenecker[3], Gregory Holm[1], Linda C. Zeigenfuss[3], Megan Swan[4], D. Skye Salganek[1], Danielle Buttke[5], DVM[5], and Dana T. Musto[1]

[1]Grand Canyon National Park
Grand Canyon, AZ

[2]Wildlife Conservation Society
Missoula, MT

[3]U.S. Geological Survey, Fort Collins Science Center and
Ecosystem Science and Sustainability, Colorado State University
Fort Collins, CO

[4]Southern Colorado Plateau Inventory & Monitoring Network
National Park Service
Flagstaff, AZ

[5]Biological Resources Division and Wildlife Health Branch and Office of Public Health
National Park Service
Fort Collins, CO

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Executive Summary

The House Rock bison herd on the Kaibab Plateau, hereafter the "Kaibab Plateau bison herd", is descended from a private bison herd which was introduced into Arizona in 1905. It is spatially distinct from the small, present-day herd at House Rock Wildlife Area (HRWA). The State of Arizona recognizes and designates bison within Arizona as wildlife under state law. The herd was managed in the HRWA of the Kaibab National Forest (KNF) by the Arizona Game and Fish Department (AZGFD) from 1926–2009 at a population target of approximately 100 individuals. Since 2010, the herd has primarily resided on the North Rim of Grand Canyon National Park (GRCA).

By 2014 the Kaibab Plateau population was estimated at 400–600 bison and projected to grow as large as 1,500 animals in the next ten years if management actions were not taken. On September 1, 2017, the National Park Service (NPS) Intermountain Regional Director signed a Finding of No Significant Impact (FONSI) for the Initial Bison Herd Reduction Environmental Assessment (EA) at GRCA. AZGFD, US Forest Service (FS), Bureau of Land Management (BLM), and the InterTribal Buffalo Council (ITBC) were Cooperators in the preparation of the EA.

The EA authorized the NPS plan to reduce the bison herd to fewer than 200 animals within five years. Allowable methods of herd reduction include lethal removal with skilled volunteers and non-lethal capture with live transport of bison to willing recipients, including tribes and governmental/non-governmental organizations. AZGFD-managed harvests outside of park boundaries will also contribute to the reduction.

In summer-fall 2018, NPS contractors designed and constructed a corral for capturing live bison in the Little Park Meadow just south of the park's North Rim entrance. NPS Roads crew also constructed a gravel-covered access road to the new corral. Due to impending winter weather and initiation of bison migration to lower pastures, NPS was not able to perform a pilot bison corralling event in 2018.

At a September 2019 pilot bison capture event, the NPS captured 51 live bison, 31 of which were transferred to the Inter-Tribal Buffalo Council (ITBC) under a signed agreement. The ITBC transported and transferred the bison to the Quapaw Tribe in Oklahoma. NPS implemented a pathogen sampling protocol developed by a wildlife veterinarian with the NPS Biological Resources Division and oversaw testing and documentation necessary to move live bison across state lines.

GRCA initiated research with USGS partners to GPS/VHF collar and release bison during corral trapping. The team collared 14 bison and plans to collar another 11 in 2020. Objectives of the research are to evaluate seasonal herd movements, develop a robust and repeatable bison population estimation method, determine potential effects of bison on vegetation, and develop a resource selection model.

Genetic analyses of samples from animals captured in 2019 indicate that the current Kaibab Plateau herd is significantly differentiated from all other Department of Interior (DOI) bison herds tested but

is most genetically similar to the herds at Wind Cave National Park and Wichita Mountain National Wildlife Refuge. The Kaibab Plateau herd also has more unique nuclear DNA alleles than any other sampled DOI bison herd. The level of cattle introgression in nuclear DNA is ~1.6%, on the high end for DOI herds, but roughly equivalent to what has been detected in the herd at Badlands NP (1.3%) and the North Unit herd at Theodore Roosevelt NP (1.4%). However, the level of cattle mitochondrial DNA (inherited through the mother only) for the Kaibab Plateau herd is ~98%, far higher than any of the other DOI herds tested (typically 0–1%).

Some individuals, both within and outside the NPS, have referred to the Kaibab Plateau herd as bison-cattle hybrids, "beefalo," or "cattalo." The new and unprecedented genetic data presented here indicate that such labels are not supported. The evidence now indicates that this herd is more appropriately considered as having value, albeit with challenges, for coordinated conservation of plains bison. This newly informed perspective on this herd does not negate the need to address issues of ecological, natural, and cultural resource damage from a burgeoning bison herd, nor change the need for reduction of the current population.

The NPS is committed to continuing to work with partners, including AZGFD, ITBC, and adjacent land management agencies to achieve bison reduction targets on the North Rim as called for in the 2017 Initial Bison Herd Reduction Plan.

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And thank you to many others un-named who helped us with the myriad of bison related projects at Grand Canyon National Park.

List of Acronyms

AZGFD	Arizona Game and Fish Department
BADL	Badlands National Park (South Dakota), US NPS
BLM	U.S. Bureau of Land Management
BOOK	Book Cliffs (Utah), US BLM
CHIC	Chickasaw National Recreation Area (Oklahoma), US NPS
CSU	Colorado State University
DOI	U.S. Department of the Interior
DNA	Deoxyribonucleic Acid
EA	Environmental Assessment
ELK	Elk Island National Park (Alberta), Canada
FONSI	Finding of No Significant Impact
FTN	Fort Niobrara National Wildlife Refuge (Nebraska), US FWS
FWS	U.S. Fish and Wildlife Service
FS	U.S. Forest Service
GPS/VHF	GPS = Global Positioning System; VHF = Very High Frequency (radio)
GRASS	Grasslands National Park (Saskatchewan), Canada
GRCA or park	Grand Canyon National Park (Arizona), US NPS
GRTS	Generalized Random Tessellation Stratified
HEMO	Henry Mountains (Utah), US BLM
HRWA	House Rock Wildlife Area (Arizona), US FS
ITBC	Inter Tribal Buffalo Council
IMT	Incident Management Team
KNF	Kaibab National Forest (Arizona), US FS
KPH	Kaibab Plateau Herd (formerly the House Rock herd)/ Grand Canyon National Park, US NPS/ Arizona Game and Fish Department (Arizona)
mtDNA	mitochondrial DNA
NBR	National Bison Range (Montana), US FWS
NER	National Elk Refuge, US FWS / Grand Teton National Park, US (Wyoming)
NP	National Park (U.S. or Canadian)
NPP	National Park and Preserve
NPS	U.S. National Park Service
NRA	National Recreation Area
NSM	Neal Smith National Wildlife Refuge (Iowa), US FWS
NWR	National Wildlife Refuge, US FWS
RMA	Rocky Mountain Arsenal National Wildlife Refuge (Colorado), US FWS
SH	Sully's Hill National Wildlife Refuge (North Dakota), US FWS
TAPR	Tallgrass Prairie National Preserve (Kansas), US NPS
THROn	Theodore Roosevelt National Park North Unit (North Dakota), US NPS

THROs	Theodore Roosevelt National Park South Unit (North Dakota), US NPS
UCD-VGL	University of California Veterinary Genetics Laboratory at Davis
USGS	U.S. Geological Survey
WICA	Wind Cave National Park (South Dakota), US NPS
WM	Wichita Mountains Wildlife Refuge (Oklahoma), US FWS
WRST	Wrangell-St. Elias National Park and Preserve (Alaska), US NPS
YELL	Yellowstone National Park (Wyoming/ Montana/ Idaho), US NPS

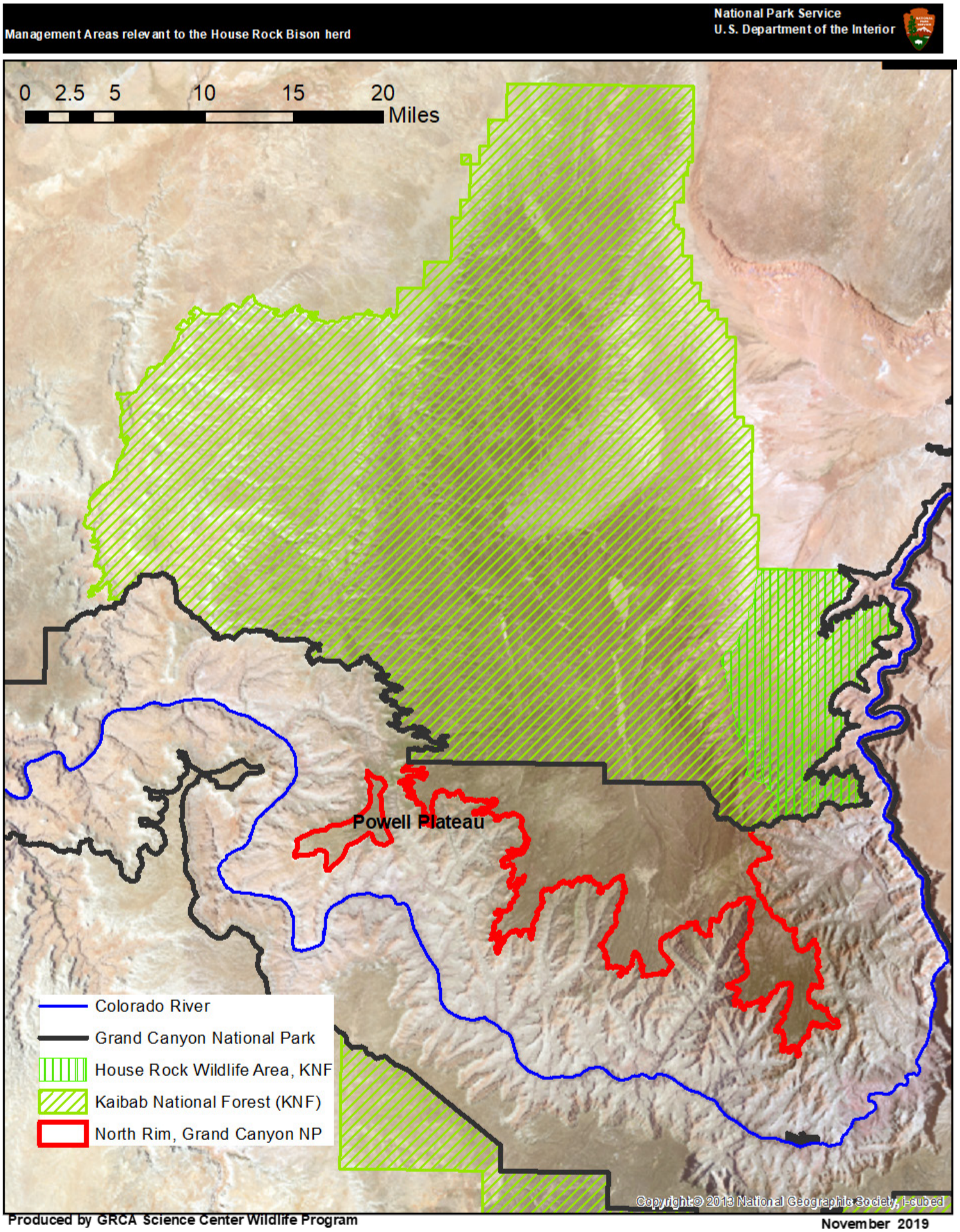

Figure 1. Map of areas of significance to the history and management of the Kaibab Plateau bison herd.

Herd History

Miranda Terwilliger and Gregory Holm, Science & Resource Management, Grand Canyon National Park, AZ

Figure 2. Bison in House Rock Valley around 1930. Photo Art Metzger Collection, Northern Arizona University, NAU.PH.90.9.57

The Kaibab Plateau bison herd descended from animals brought to northern Arizona in 1905 to the Grand Canyon Game Preserve, much of which is now Grand Canyon National Park (GRCA or "park" hereafter) by Charles Jesse "Buffalo" Jones, a person now revered for helping save bison from extinction (Easton & Brown 1961, Onstott 1970, Trudeau 2006). Jones attempted to crossbreed the bison with Galloway heifers but this venture was not particularly successful and by 1907 or 1908 the ranching operation went bankrupt (Trudeau 2006). Jones drove off any cattle and successful appearing cross-breeds out of the region in 1909 and sold the remaining 15–20 bison and bison-cattle hybrids to "Uncle Jimmy" James T. Owens (Trudeau 2006, Table 1). Owens, who also served as the Game Warden of the Grand Canyon Game Preserve, managed the that herd until 1926. Owens mostly kept the bison at House Rock Valley (Figure 2) but had permits to graze them on the Walhalla Plateau in the park (Anderson 1998). The Grand Canyon Game Preserve was later superseded by the Kaibab National Forest (KNF, created in 1908) and Grand Canyon National Park (created in 1919) as they are known today. Elements of the Game Preserve were folded into the Kaibab National Forest's enabling legislation although not into the park's enabling legislation.

Table 1. Population estimates for the House Rock bison herd along with where they were primarily located.

YEAR	Estimated Bison	Primary Range Owner	Source
1909	15–20	Grand Canyon Game Preserve	Trudeau 2006
1921	64	GRCA	Permit issued to Jimmy Owens
1926	98	KNF/ AZGFD	Trudeau 2006
1950–1960s	330	KNF/ AZGFD	AZGFD 2002, FS 1984
1970	100	KNF/ AZGFD	AZGFD 2002, Adams & Dood 2011
1998	100	KNF/ AZGFD	AZGFD 2002
2002	130–160	KNF/ GRCA	AZGFD 2002
2010	>300	GRCA/ KNF	Interagency Bison Group 2011
2012	400	GRCA	Interagency Bison Group 2013
2014	400–600	GRCA	Plumb et. al 2016

Bison are recognized as wildlife in the state of Arizona (ARS 17,1). In 1926, the Arizona Game and Fish Department (AZGFD) purchased and began managing the population of 98 bison as a free-ranging wild herd (Table 1). Public culls in a corral began in 1927. Between 1928–1950, the state held a grazing permit for House Rock Valley to pasture up to 250 head of bison (Interagency Bison Group 2013). House Rock Valley consists of 30 acres owned by AZGFD (Adams and Dood 2011) and 53,878 acres managed by the U.S. Forest Service (FS). In 1950, the state entered a formal agreement to manage the bison population on an allotment in what is now known as the House Rock Wildlife Area (HRWA) in the Kaibab National Forest (Figure 1) with the FS, the U.S. Bureau of Land Management (BLM), and affected cattle ranchers (FS 1950). During the 1970s the state managed the population for 100 bison post-cull (AZGFD 2002), in 1982 they introduced free chase hunting (AZGFD 2002), and in 1984 agreed to manage the herd at 75–90 bison post-hunt (FS 1984, Table 1). AZGFD bison count numbers show that from 1990 to 1997, the state-maintained bison herd numbered from between 69 and 96 head, post-hunt (Interagency Bison Group 2013).

By the late 1990s or early 2000s, the bison began dispersing up to the top of the Kaibab Plateau and into GRCA (Weber 2011, Interagency Bison Group 2013). It is thought that several drought seasons, poor range conditions in House Rock Valley, and multiple fires in the Saddle Mountain Wilderness contributed to the bison migration into higher elevation grazing areas on the Kaibab Plateau.

As of 2010, bison ceased returning to the HRWA at all with most bison never leaving the park or venturing farther than 5 miles from the park boundary onto adjacent FS lands (bison satellite collar data and aerial survey data). As of 2012, the herd numbers were estimated at 400 (Interagency Bison Group 2013). The herd now winters primarily on the North Rim's Powell Plateau and other rim edges and uses the North Rim meadows and inter-connected springs during the remainder of the year (pre-2019 collar data).

Outside of park lands, the AZGFD manages an active bison hunt on the Kaibab National Forest (AZGFD 2017, Figure 3). Current hunting regulations allow for harvest almost all year with both bull and cow harvests scheduled (as the House Rock Herd, AZGFD 2019a). Most bison are harvested within 5 miles of the park boundary and animals can be baited in with salt and harvested at watering sites. The bison hunts alone have ceased to be effective as the sole means of managing the population at the target of 100 post-hunt adults.

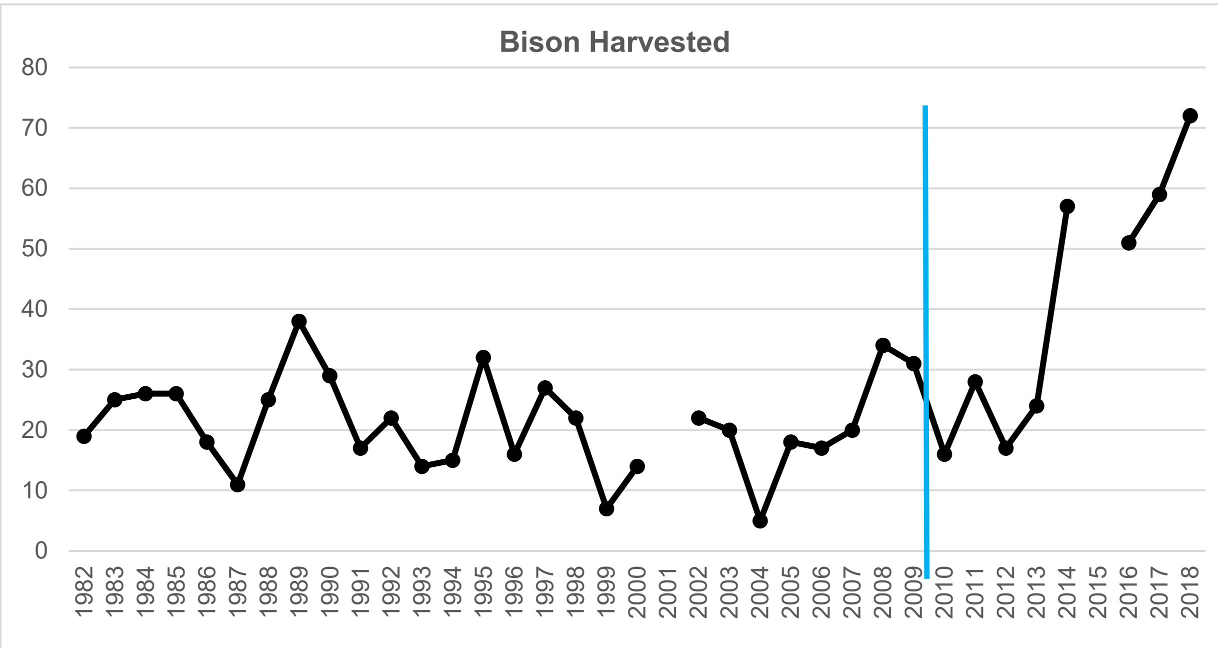

Figure 3. Number of Bison harvested by hunters from the House Rock/ Kaibab Plateau Herd over time (AZGFD 2002, 2015, and 2019b). Blanks represent gaps in the data. The blue line marks where bison stopped returning to the House Rock Wildlife Area completely.

In 2014, managing partners captured and relocated 19 bison back to House Rock Valley where the bison were held in an AZGFD holding pasture for 4 months (Figure 4). The pasture gates were then opened, and all bison independently returned to the North Rim of the park within 24 hours (Holm 2015). By 2014, the herd had grown to an estimated 400–600 animals (Plumb et al. 2016, NPS 2017). Sturm and Holm (2015) suggested that, without additional management, the population could grow as large as 1,200 to 1,500 bison within 10 years. Managing partners (AZGFD, FS, and GRCA) agreed on a target population of 80–200 bison ranging across the 215,000-acre Kaibab Plateau landscape (Plumb et al. 2016, NPS 2017).

Figure 4. Bison in pens at House Rock Wildlife Area after the 2014 relocation attempt. NPS Photo/ Greg Holm

In September 2017, the National Park Service (NPS) Intermountain Regional Director signed a Finding of No Significant Impact (FONSI) for the Initial Bison Herd Reduction Environmental Assessment (EA) at GRCA with the goal of reducing the bison population to fewer than 200 animals over a 5-year period (NPS 2017). The EA, written in cooperation with AZGFD, the FS, the BLM, and the InterTribal Buffalo Council (ITBC), and in consultation with the park's traditionally associated tribes, approved the use of live capture and removal as well as lethal removal using skilled volunteers. The EA also recognized the contribution to herd reduction by state permitted hunting on adjoining KNF lands.

In late 2017, AZGFD introduced 17 yearling pregnant bison cows from the American Prairie Reserve in Montana (Wind Cave National Park lineage) to the HRWA where they have remained fenced for the time being. Therefore, the herd currently on the Kaibab Plateau is referred to as the Kaibab Plateau bison herd (KPH), and the herd currently within House Rock Valley is referred to as the House Rock herd. However, the cooperative goal stated in the EA refers to all bison on the Kaibab Plateau.

Live Capture Operations

Miranda Terwilliger, Gregory Holm, D. Skye Salganek, and D. Musto, Science & Resource Management, Grand Canyon National Park, AZ

In September of 2019, the park implemented a pilot (test) live capture and removal of bison. GRCA partnered with the ITBC (GRCA 2018) to identify and ship selected bison captured on the park to recipient tribes.

Planning

The park engaged various other bison experts in a Technical Workgroup to help inform the capture operations shortly after the FONSI was signed. The workgroup assisted park staff in designing a capture facility. Important features of the design include a capture pen or trap, capture alley, working alleys, squeeze chute with a scale, holding pens, a series of solid panels around the entire structure to limit bison range of vision (to reduce bison stress levels), and catwalks over key alleys to improve employee safety. The capture facility was then built on-site by contractors and completed by mid-October 2018 (Figure 5). Together, the park and ITBC formalized an agreement to assist with the transfer of bison (GRCA 2018).

Figure 5. The newly completed corral and capture facilities in the fall of 2018. NPS Photo/ Greg Holm

The park planned to implement a pilot live capture in 2018 and had created an Incident Management Team (IMT) to manage and plan the operation. Significant operations planning occurred. Due to the timing of the capture infrastructure completion and an early wet, heavy snow, bison had moved on to their winter grounds on the Powell Plateau some 15 miles away (Figure 1, Figure 6). Once on their wintering grounds, bison have not been known to return to the corral area until the spring. GRCA thus postponed the pilot live capture event to fall 2019.

Figure 6. Bison on their wintering grounds at Powell Plateau at the edge of the canyon. While this photo is blurry, it shows how the bison use the extreme edge of the canyon. NPS Aerial Photo/ Brandon Holton

In July of 2019, the park finalized the “Grand Canyon Limited Pilot Bison Reduction Corralling Operations Plan 2019” (Terwilliger and Holm 2019) and Acting Park Superintendent Woody Smeck signed an Incident Management Team (IMT) Designation of Authority on Aug 1, 2019 (GRCA 2019a). Building off the planning from the previous year, the park moved forward toward live capture and corralling in September 2019 and developed an Incident Management Plan (GRCA 2019b).

Baiting

A 2014 attempt at corralling and relocating bison back to House Rock Valley demonstrated that baiting can be an effective way to get bison to a corral site in GRCA (Holm 2015). Bison in Grand Canyon are generally skittish at the approach of humans, except for within the Little Park meadows where the park entrance road passes through and bison are more habituated to human visitation. In addition to bringing bison into the capture pasture, a key goal was to get the bison acclimated both to the capture facilities and to people being around the capture facilities to reduce stress during the actual operation. As the capture facilities were built along a bison trail between key water sources, the bison quickly acclimated to the capture and corral structures in the meadow. The delay of capture for a year also gave the bison more time to get acclimated to the corral structure. In addition, staff began to bait the capture pasture with fresh hay, water, contained salt blocks, and "cake", a bait mixture formulated specifically for bison (see Appendix A, Figure 7). Staff used the same truck at the same two times a day to familiarize the bison with the feeding schedule and the approach vehicle. Water seemed to be the biggest draw for bison particularly during dry spells when they drained the water troughs nightly. Baiting efforts and bison presence were tracked through the operation. In addition, a motion-activated camera was situated so that staff could determine bison presence throughout the day and night.

Figure 7. Dana Musto throws out "cake" while baiting bison into the capture pen. NPS Photo/ Skye Salganek

Capture Operations

Capture operations were planned for early September and were managed by an Incident Management Team (IMT) and guided by an Incident Management Plan (GRCA 2019b). Grand Canyon staff were joined by staff from the KNF, ITBC, and the US Geological Survey (USGS). Additionally, a few invited experts from other bison parks (Yellowstone and Badlands National Parks) and an NPS veterinarian joined to help train and advise the IMT.

Staff arrived on the North Rim, where they camped at the administrative area known as Lindberg Hill. There, staff talked through the process of capture, ran through mock capture and processing exercises, discussed safety, and had an opportunity to ask questions of experts at a bison round table. Baiting continued until enough bison were in the trap to shut the gates. While staff waited for bison to be captured, they assisted in the removal of fencing around springs that had been ineffective at excluding bison.

Bison were captured in the late afternoon of September 13th by the security team, which radioed the news to the IMT. A crew then headed to the capture facility to make safety adjustments to the facility, secure water and feed in the holding pens, to estimate number captured, and to monitor the settling of the bison (Figure 8). The bison were left to acclimate overnight, and processing began the next morning. Processing the captured bison took 1.5 days.

Figure 8. Bison in the capture pen (trap). NPS Photo/ Bryan Maul

Instinctive bison herding behavior and flagging encouraged bison through the working alleys and to a squeeze chute for processing. Once an animal was safely secured in the squeeze chute, biologists collected samples and measurements, marked bison for re-capture tracking, and animals were identified either for removal (shipment) or identified for GPS/VHF collaring and release. Bison identified for removal were prepared by administering vaccinations according to recipient tribal and state requests and sorted into holding pens.

During this capture event 51 bison were handled (Table 2). All bison were classified to age by observations of horns and body size (Table 2, Hornaday 1889, Garretson 1938, Seton 1929). Fourteen animals were also aged by the more reliable method of tooth eruption (Table 2, Frison and Reher 1970). Comparing the aging techniques for those 14 animals, it became clear that a lot of the young animals were larger than expected, thus they may have been estimated to be older than they actually were when using only the horn/ body size method. Based on these results, we recommend using the tooth eruption method to age captured bison in the future. The average weight was 621 pounds with females averaging 663 pounds and males averaging 560 pounds. The largest animal captured was a young adult male at 1,340 pounds followed by a 1,000-pound aged adult female. A total of 31 animals were shipped to the Quapaw Nation in Oklahoma, 2 died, 4 were released due to transportation limitations, and 14 were collared with tracking devices and immediately released.

Table 2. Age classifications of Grand Canyon National Park 2019 captured bison. All bison were aged via body/ horn classification while only a subset was aged using tooth eruption.

Aging via Body/ Horn Classification	Female	Male	Aging via Tooth Eruption	Female	Male
Calf (<1 yr)	5	7	*2yr*	–	3
Yearling (1–2yrs)	5	3	*3yr*	1	1
Spike-Horn (2–4yrs)	0	9	*4yr*	2	1
Young Adult (4–8yrs)	6	2	*5yr*	1	–
Aged Adult (>8yrs)	14	0	5–10 years	5	–
TOTAL	30	21	*TOTAL*	9	5

Bison that were to be shipped were held for 4 days waiting for ITBC contract truckers. Animals were inspected and certified for transport by a locally contracted veterinarian. They were held sorted by size and sex and according to shipment capacity to avoid them causing each other injury. Three small livestock trailers with sliding doors picked the bison up at the capture facility (Figure 9) where they were transported to a facility outside St. George, UT for loading onto a single larger semi-truck for shipment to Oklahoma.

Figure 9. An InterTribal Buffalo Council (ITBC) truck backs up to the chute to load bison. NPS Photo/ Kristen Luetkemeier

The IMT held an after-action review to learn from this initial pilot experience (GRCA 2019c); that review is being incorporated into a future 4-year live capture and removal operating plan. The after-action review covers the lessons learned from the pilot capture along with suggestions and recommendations for future operations (GRCA 2019c). The park is committed to continuing to work with partners, including AZGFD, ITBC, and adjacent land management agencies and tribes to achieve bison reduction targets on the North Rim as called for in the 2017 Initial Bison Herd Reduction Plan (NPS 2017).

Disease Monitoring

Danielle Buttke, Biological Resources Division/ Wildlife Health Branch and Office of Public Health, National Park Service, Fort Collins, CO

Miranda Terwilliger, Science & Resource Management, Grand Canyon National Park, AZ

Hunter harvested animals from the House Rock/ Kaibab Plateau herd have been consistently tested for brucellosis by the state of Arizona since 2012 and none have tested positive (Anne Justice-Allen, AZGFD DMV personal communication). As a closed herd with no new introductions since 2001, the risk of brucellosis introduction is extremely low. All previous introductions have been made from herds that were brucellosis free. Primary disease risks at this time would arise from trespass animals in the park or other wildlife, including arthropod vectors and environmental diseases such as anthrax or leptospirosis (Jones et. *al* 2020). Basic disease and parasite screening occurred for six animals in 2003 with negative results. Currently, the park collects biological samples for disease surveillance during live capture events (Powers 2003; Figure 10). The park also conducts necropsies on freshly dead carcasses when found. To date, there have been no diseases detected from the samples tested.

Figure 10. NPS Veterinarian Dr. Buttke with blood samples for disease surveillance. NPS Photo/ Bryan Maul

While bison brucellosis has been visible and important in other areas of the United States (from an animal health and regulatory perspective), other diseases could pose significant risks to bison conservation. Endemic diseases such as anthrax, hemorrhagic disease, and disease associated with *Mycoplasma bovis*, as well as foreign animal diseases such as foot-and-mouth disease (FMD), heartwater, and Schmallenberg virus could all impact bison herds. Bison are also susceptible to other cattle diseases, such as bovine tuberculosis (TB), paratuberculosis (Johne's disease) and bovine viral diarrhea virus (BVDV), among others, and could serve as a source of disease if infected.

Genetic Testing

Cynthia Hartway, Wildlife Conservation Society, Missoula, MT

Miranda Terwilliger, Science & Resource Management, Grand Canyon National Park, AZ

Introduction

The population size of bison within Grand Canyon National Park is quite large for its current range and given that it occurs at the outermost extreme of the historic bison range (as it is currently known—Plumb et.al 2016). The high abundance is having significant impacts on cultural and natural resources that the Park Service is obligated to protect (NPS 2017). Genetics will not be used in making decisions about immediate bison herd reduction as outlined in the EA (NPS 2017) but should be considered during long-term management of a much smaller bison population.

The Department of the Interior (DOI) oversees the stewardship of approximately half of all the plains bison managed for conservation in North America and has overarching conservation goals for the species (DOI 2008, DOI 2014, Hartway et. 2020). In particular, concerns have been raised about how to maintain or increase levels of genetic diversity within individual bison herds while also reducing levels of cattle introgression (Hedrick 2010, Dratch and Gogan 2010). Whether the Kaibab Plateau bison herd (KPH) is important to the genetic conservation of the other DOI herds, or how this herd could contribute to the recovery of other wild conservation bison herds, will be based on current genetic information. Information on the genetic composition of the Kaibab Plateau Herd is important for partners when deciding whether to receive and integrate them into their own herds. Information about genetics may also have implications for managing the genetic health of the remaining Kaibab Plateau Herd once reduction goals have been met.

As bison numbers dwindled in the late 1800s, a handful of private citizens from Texas to Manitoba captured small numbers of individuals from the wild, ultimately saving the species from extinction (Freese et al. 2007; Dratch and Gogan 2010, Figure 2). While bison numbers have rebounded, concerns remain about the long-term genetic health of conservation bison herds on Department of Interior (DOI) lands, since most DOI herds were founded with small numbers of individuals and some have had only limited genetic exchange since their founding (DOI 2008, Dratch and Gogan 2010). Additionally, attempts to crossbreed bison with domesticated cattle were carried out within some foundational herds in the late 1800s and early 1900s. While these crossbreeding efforts were largely unsuccessful (Halbert and Derr 2007; Hedrick 2010), subsequent mixing of bison from foundational herds during the establishment of new conservation herds in the early 1900s has resulted in residual cattle DNA within DOI herds. Consequently, concerns have been raised about how to maintain or increase levels of genetic diversity within individual bison herds while also reducing levels of cattle introgression (Hedrick 2010, Dratch and Gogan 2010).

The Kaibab Plateau Herd was minimally sampled in 2003 (16 samples from the then "House Rock Bison herd") and the biological samples analyzed by the DNA Technologies Core Lab, College of Veterinary Medicine, Texas A&M University (Derr 2003). These samples confirmed historic records (Mead 2002) about attempts between 1906–1909 to crossbreed the bison with cattle as most bison sampled possessed cattle mitochondrial DNA. They estimated cattle chromosomal nuclear DNA was <2% (Deer 2003, Wakeling 2006, Hedrick 2010).

In 2019, NPS partnered with the Wildlife Conservation Society to collect and analyze up-to-date, standardized genetic data for 16 DOI and 2 Parks Canada herds (Elk Island National Park and Alberta & Grasslands National Park, both in Saskatchewan) to evaluate the within-herd genetic diversity and genetic population structure of these 18 herds (Hartway et al. 2020). Grand Canyon was unable to collect samples in time for this comprehensive DOI genetic analysis (Hartway et al. 2020). However, we were able to collect genetic samples during the capture effort in 2019 and use the same methodologies as in Hartway et. al. (2020) to evaluate the current levels of genetic diversity within the Kaibab Plateau Herd and to assess its genetic relationship to the other evaluated DOI herds. Cattle introgression within the Kaibab Plateau Herd was also compared to available data on levels of cattle introgression for other federal, state and private bison herds (Halbert and Derr 2007; Hedrick 2010; Hartway et al. *unpublished data*).

Figure 11. Biologists remove tail hair from a bison for genetic analysis. NPS Photo/ Bryan Maul

Sampling and DNA extraction

We collected bison tail hair samples from 51 unique individuals within the Kaibab Plateau Herd in GRCA in 2019 (Figure 11) and sent them to the University of California at Davis Veterinary Genetics Laboratory (UCD-VGL), the same laboratory that processed samples for the analysis presented in Hartway et al. 2020. UCD-VGL extracted DNA from all samples and provided genotypes for 52 nuclear microsatellite markers optimized for evaluation of genetic diversity

("diversity panel"), and 15 nuclear microsatellites and one mitochondrial DNA marker to detect cattle introgression ("introgression panel"). The diversity panel markers were based on microsatellite panels developed at Texas A&M University (Halbert and Derr 2007, Halbert and Derr 2008); a subset of these markers was adopted as a standard measure of bison genetic diversity and integrity by DOI in 2010 (Dratch and Gogan 2010). The cattle introgression panel was developed from 5 common breeds of cattle (Halbert and Derr 2007) and was used to test for the presence of known nuclear cattle alleles and for the presence of cattle mitochondrial DNA (mtDNA). The small number of loci in the introgression panel makes it appropriate for testing for the presence of introgression at a herd level, but poorly sensitive for detecting introgression in individual animals (Dratch and Gogan 2010).

Genetic Diversity Analysis

UCD-VGL provided estimates of observed heterozygosity (H_O), expected heterozygosity (H_E; Nei 1987), and the mean number of alleles per locus (MNA) for the Kaibab Plateau Herd (Penedo 2019). Observed heterozygosity measures the level of genetic diversity in a population, with values near 1.0 indicating high levels of genetic diversity, and values near 0 indicating low levels of diversity. Expected heterozygosity estimates the level of genetic diversity expected to occur in the population in the absence of other evolutionary influences. Significant deviations between the observed and expected heterozygosity of a population can indicate that evolutionary forces such as inbreeding are affecting the population. To compare the allelic diversity of the Kaibab Plateau Herd to other herds within DOI, allelic richness was calculated (Mousadik and Petit 1996) using the computer software package "hierfstat" (Goudet and Jombart 2015) in R (R core, 2018). Allelic richness is an unbiased estimator of the observed number of alleles per locus, allowing for comparisons across populations.

Genetic Differentiation Analysis

To assess the genetic relatedness of the Kaibab Plateau Herd to the 16 DOI and 2 Parks Canada herds previously genotyped in Hartway et al. (2020), genotype data from all 19 herds were pooled and analyzed using Discriminant Analysis of Principal Components (DAPC; Jombart et al. 2010; Jombart and Ahmed 2011). DAPC is a multivariate method using synthetic variables (discriminant functions) to identify and maximize genetic variation within and between selected groups. The purpose is to identify clusters of genetically related individuals (Jombart et al. 2010; Jombart and Ahmed 2011) across the entire sampled bison population. DAPC analysis was carried out using the software package R "adegent" (Jombart 2008) and was used to transform the data into synthetic variables that best describe variation between clusters, while also minimizing within cluster variance, to assign each individual genetic sample to a genetic cluster. Resultant clusters in a scatterplot of the first and second linear discriminates of DAPC were plotted for a visual representation of the genetic structure of the DOI bison meta-population.

All 19 bison herds were tested for the presence and richness of private alleles using the R software package "poppr" (Kamvar et al. 2014, Kamvar et al. 2015). Private alleles are those found only within a single population (Allendorf et al. 2013), and private allelic richness can provide a simple measure of how distinct a population is from other populations (Kalinowski, 2004).

Cattle Introgression Analysis

Cattle introgression in the Kaibab Plateau Herd was assessed using two measures: the percentage of nuclear alleles in the introgression panel that were of cattle origin; and the percentage of sampled individuals that tested positive for cattle mitochondrial DNA (mtDNA).

Results

Genetic Diversity Analysis

High observed heterozygosity means significant genetic variability in a population, while low observed heterozygosity means little genetic variability in a population. Geneticists compare the observed level of heterozygosity to what is expected (expected heterozygosity) under the Hardy-Weinberg equilibrium, a principle assuming that allele and genotype frequencies in a population will remain constant from generation to generation in the absence of other evolutionary influences. If the observed heterozygosity is significantly lower than the expected heterozygosity, this difference is likely attributed to forces such as inbreeding of a small population, or a population bottleneck. If observed heterozygosity is significantly higher than expected heterozygosity, this result is attributed to the likely mixing of two previously isolated populations, or the intentional addition of individuals with different genetics.

The genetic diversity of the Kaibab Plateau Herd was found to be relatively high. Observed heterozygosity for the Kaibab Plateau Herd was 0.60 (sd=0.1) and expected heterozygosity was 0.60 (sd=0.2). The mean number of alleles per locus was found to be 4.62 (sd=1.4), and allelic richness was 3.85 (sd = 1.0). The Kaibab Plateau Herd has had the intentional addition of individual bison with different genetics (see Cattle Introgression Analysis section, Table 7), which has likely kept the herd genetically healthy and within the range reported for other wild bison herds.

Table 3. A summary of genetic diversity measures for the Kaibab Plateau herd /GRCA, along with 16 other DOI and 2 Parks Canada bison herds. “Sample Size” is the number of genetic samples collected from each herd, “He” is expected heterozygosity; “Ho” is observed heterozygosity; “Ar” is estimated allelic richness, and “MNA” is the uncorrected mean number of alleles per locus.

Herd	Sample Size	H_e (sd)	H_o (sd)	A_r (sd)	MNA (sd)
Badlands NP – BADL	100	0.596 (0.02)	0.584 (0.01)	3.73 (1.1)	4.50 (1.4)
Book Cliffs – BOOK	38	0.657 (0.02)	0.630 (0.01)	4.14 (1.1)	4.83 (1.4)
Chickasaw NRA – CHIC	10	0.480 (0.03)	0.550 (0.02)	2.60 (0.8)	2.60 (0.8)
Elk Island NP – ELK	84	0.634 (0.02)	0.626 (0.01)	4.0 (0.9)	4.79 (1.4)
Ft. Niobrara NW – FTN	357	0.637 (0.02)	0.615 (0.01)	4.04 (1.0)	5.46 (1.7)
Grasslands NP – GRASS	125	0.621 (0.02)	0.609 (0.01)	3.87 (1.0)	4.77 (1.4)

Table 3 (continued). A summary of genetic diversity measures for the Kaibab Plateau herd /GRCA, along with 16 other DOI and 2 Parks Canada bison herds. “Sample Size” is the number of genetic samples collected from each herd, “He” is expected heterozygosity; “Ho” is observed heterozygosity; “Ar” is estimated allelic richness, and “MNA” is the uncorrected mean number of alleles per locus.

Herd	Sample Size	H_e (sd)	H_o (sd)	A_r (sd)	MNA (sd)
Kaibab Plateau / GRCA	**51**	**0.60 (0.02)**	**0.60 (0.01)**	**3.85 (1.0)**	**4.62 (1.4)**
Henry Mtns – HEMO	85	0.556 (0.02)	0.544 (0.01)	3.22 (0.8)	3.73 (1.1)
National Bison Range – NBR	302	0.647 (0.02)	0.642 (0.01)	4.08 (1.1)	5.04 (1.6)
National Elk Refuge/ Grand Teton NP – NER	100	0.526 (0.02)	0.515 (0.01)	2.97 (0.8)	3.75 (1.2)
Neal Smith NWR – NSM	53	0.642 (0.02)	0.647 (0.01)	3.96 (1.0)	4.54 (1.5)
Rocky Mtn Arsenal NWR – RMA	71	0.650 (0.02)	0.643 (0.01)	4.12 (1.0)	5.04 (1.5)
Sully’s Hill NWR – SH	22	0.544 (0.02)	0.557 (0.02)	3.37 (1.0)	3.71 (1.3)
Tallgrass Prairie NP – TAPR	43	0.662 (0.01)	0.647 (0.01)	4.07 (0.9)	4.63 (1.2)
Theodore Roosevelt NP North Unit – THROn	100	0.531 (0.03)	0.529 (0.01)	3.09 (0.9)	3.48 (1.0)
Theodore Roosevelt NP South Unit – THROs	87	0.585 (0.02)	0.569 (0.01)	3.64 (0.9)	4.19 (1.2)
Wichita Mtns. NWR – WM	576	0.597 (0.02)	0.588 (0.01)	3.76 (1.0)	4.87 (1.3)
Wind Cave NP –WICA	100	0.660 (0.01)	0.650 (0.01)	4.04 (0.9)	4.69 (1.3)
Wrangell-St. Elias NPP –WRST	24	0.524 (0.02)	0.503 (0.01)	3.04 (0.8)	3.31 (1.0)
Yellowstone NP – YELL	–	0.615 [A]	0.625 [A]	4.15 [A]	4.84 [A]

[A] From Halbert and Derr (2007)

Genetic Differentiation Analysis

Results from the K-means clustering analysis suggest 12 distinct genetic clusters within the 19 sampled bison populations. The scatter plot in Figure 12a shows the degree of similarity (or differentiation) between the 12 identified genetic clusters, with the discriminant function axes representing the largest between-group variance. Figure 12b shows the number of individuals from each herd assigned to each genetic cluster. DAPC analysis suggests that the Kaibab Plateau Herd is genetically unique from all other DOI and Parks Canada herds sampled, and that the the Kaibab Plateau Herd (Figure 12, cluster 1, label GRCA) is genetically most similar to Wind Cave NP (cluster 8, denoted as WICA) and Wichita Mountains NWR (Figure 12, cluster 3, denoted as WM). Evaluation of private alleles in the nuclear DNA within each herd revealed eight alleles unique to the Kaibab Plateau Herd Table 4), more than any other herds analyzed in this study.

Cattle Introgression Analysis

Analysis of the cattle introgression panel indicated that 1.6% of the nuclear alleles in the introgression panel for the Kaibab Plateau bison herd were of cattle ancestry (Table 5), which indicates that very little cattle DNA remains in the genetic component (nucleus) that determines the physical expression of traits. Ninety eight percent (50 of 51) of the sampled individuals had cattle mitochondrial DNA, which indicates that since the crossbreeding of bison and cattle in 1905–1907, very few female bison from other herds have been introduced to this Kaibab Plateau Herd population (see Cattle Introgression Analysis section, Table 7).

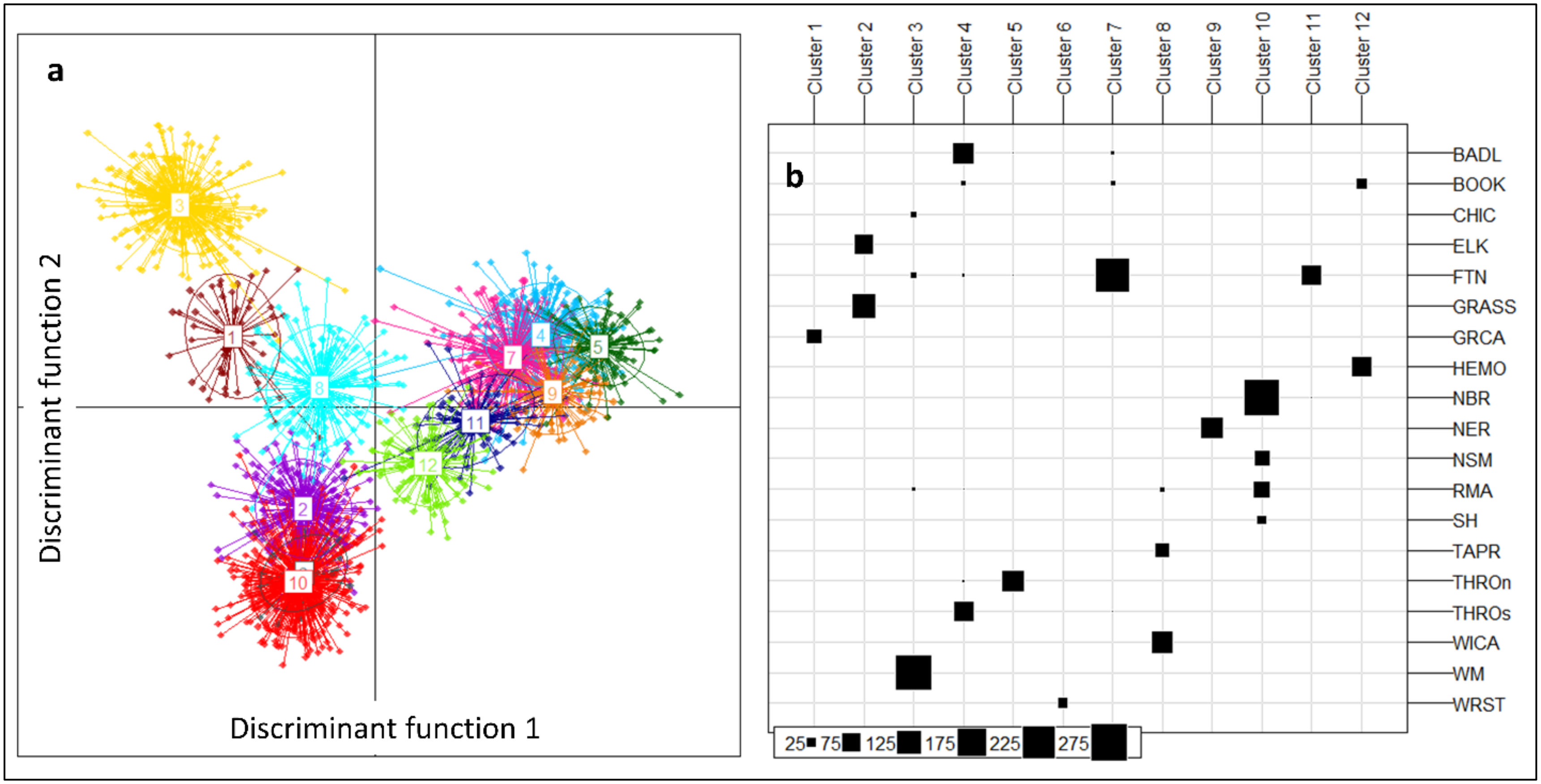

Figure 12. a) The genetic structure of 17 DOI and 2 Parks Canada herds that have been sampled using a standardized genetic panel (cluster #1 represents the Kaibab Plateau Herd/ GRCA samples). Points represent individual bison samples; numbered circles represent the 12 unique genetically differentiated clusters in the bison data; and b) the relative number of individual samples (represented by black squares) from each herd (right axis) assigned to each genetic cluster (top axis).

Table 4. The number of private alleles found within 17 DOI and 2 Parks Canada bison herds, and the identity of each private allele (listed as "locus.allele").

Herd	Number of private alleles	Private alleles (nuclear DNA alleles)
Kaibab Plateau/ GRCA	**8**	**BL1036.187; BM1862.203; BM720.237; BMS1001.110; BMS1001.108; BMS1747.87; BMS1862.146; HUJ246.252**
Grasslands NP	4	BM6017.132; BM720.239; BMS941.79; RM372.144;
Wichita Mtns NWR	4	BM1706.240; BM47.106; BMS812.92; BMS941.77
Ft. Niobrara NWR	3	BM4107.167; BM4107.177; BMS1117.95
National Elk Refuge/ Grand Teton NP	3	BM1225.263; BM2830.140; TGLA44.149
Badlands NPL	2	BM4028.122; BMS2258.136
Book Cliffs	1	BM6017.110
Elk Island NP	1	AGLA232.159
Henry Mtns.	1	RM372.140
National Bison Range	1	BMS510.95
Neal Smith NWR	1	IL4.87
Rocky Mtn. Arsenal NWR	1	BM1824b.202
Wind Cave NP	1	BMS1716.185
Wrangell-St. Elias NPP	1	BM1225.275
Chickasaw NRA	0	–
Sully's Hill	0	–
Tallgrass Prairie NP	0	–
Theodore Roosevelt NP – North	0	–
Theodore Roosevelt NP – South	0	–

Table 5. A comparison of cattle introgression data for the Kaibab Plateau herd to published and unpublished data for 19 other federal, state and private bison herds. Sample size is the number of genetic samples analyzed for each herd; percent cattle nuclear DNA indicates the mean frequency of cattle origin alleles within a 15 marker introgression panel; percent cattle mtDNA indicates the percentage of samples that tested positive for cattle mtDNA.

Herd	Managing Entity	Sample Size	% Cattle nuclear DNA	% Cattle mtDNA
Kaibab Plateau/ GRCA	**Federal + State**	**51**	**1.6**	**98**
Custer State Park [A]	State	34	1.5	21
Theodore Roosevelt NP – North [C]	Federal	100	1.4	0
Badlands NP [C]	Federal	100	1.3	0
Maxwell Game Refuge [A]	Private	39	1.1	18
Fort Niobrara NWR [B]	Federal	367	0.9	0
Theodore Roosevelt NP – South	Federal	87	0.8	0
Wichita Mtns NWR [B]	Federal	352	0.6	0
Santa Catalina Is. [A]	Private	98	0.6	45
Wrangell-St. Elias NPP [C]	Federal	16	0.4	0
Book Cliffs [C]	Federal	24	0.3	16
National Bison Range NWR [B]	Federal	616	0.3	0
Chickasaw NP [C]	Federal	10	0	0
Grand Teton NP [C]	Federal	100	0	0
Henry Mountains [C]	Federal	85	0	0
Tallgrass NP [C]	Federal	43	0	0
Wind Cave NP [C]	Federal	100	0	0
Yellowstone NP [B]	Federal	520	0	0
Texas State Bison Herd [A]	State	36	0	17
Williams Ranch [A]	Private	11	0	100

[A] From Hedrick (2010)

[B] From Halbert and Derr (2007)

[C] Unpublished data from Hartway et al. (in press)

Examining the identity of the individual cattle alleles that have been detected within 13 conservation herds for which we have individual allelic data (9 NPS herds, 2 Bureau of Land Management (BLM) herds, and 2 Parks Canada herds) revealed a total of five alleles of cattle origin in the Kaibab Plateau herd, four of which have not been detected within the other NPS, BLM, or Canadian herds (Table 6).

Table 6. Allele frequencies for 15 nuclear DNA microsatellite markers diagnostic for cattle introgression in bison for 8 NPS, 2 BLM and 2 Parks Canada herds.

Locus	**Allele**	**WRST**	**BADL**	**BOOK**	**KPH**	**ELK**	**GRASS**	**HEMO**	**TAPR**	**THROn**	**THROs**	**WICA**	**CHIC**
AGLA17	215	1	1	1	1	1	1	1	1	1	1	1	1
AGLA293	218	0.58	1	1	0.99	1	0.86	0.95	0.97	1	1	0.93	1
AGLA293	220	0.42	–	–	0.01	–	0.14	0.05	0.03	–	–	0.07	–
BM1314	137	1	1	1	0.84	1	1	1	1	1	1	1	1
BM1314*	**159***	–	–	–	**0.14***	–	–	–	–	–	–	–	–
BM1314*	**157***	–	–	–	**0.02***	–	–	–	–	–	–	–	–
BM4307	185	1	0.57	0.86	0.8	1	0.96	0.94	0.87	0.67	0.74	0.96	0.85
BM4307	187	–	0.28	0.11	0.2	–	0.04	0.06	0.13	0.13	0.17	0.05	0.15
BM4307*	**197***	–	**0.16***	**0.04***	–	–	–	–	–	**0.21***	**0.1***	–	–
BM4513	132	1	0.92	0.93	0.84	1	1	0.89	0.81	0.87	1	0.74	0.95
BM4513	134	–	0.08	0.07	0.16	–	–	0.11	0.19	0.14	–	0.27	0.05
BM7145	108	0.94	0.76	0.84	0.99	1	0.74	0.83	0.67	0.82	0.65	0.64	1
BM7145*	**116***	**0.06***	–	–	**0.01***	–	–	–	–	–	–	–	–
BM7145	110	–	0.25	0.16	–	–	0.26	0.17	0.33	0.19	0.36	0.36	–
BMC3224	176	1	1	1	1	1	1	1	1	1	1	1	1
BMS2270	66	0.66	0.2	0.63	0.74	–	0.7	0.82	0.52	0.05	0.22	0.45	0.5
BMS2270	68	0.34	0.78	0.37	0.26	1	0.3	0.18	0.36	0.95	0.73	0.29	0.3
BMS2270*	**94***	–	**0.03***	–	–	–	–	–	–	–	–	–	–

* Alleles originating in domestic cattle, and their frequencies detected within each bison herd, also shown in bold text.

Table 6 (continued). Allele frequencies for 15 nuclear DNA microsatellite markers diagnostic for cattle introgression in bison for 8 NPS, 2 BLM and 2 Parks Canada herds.

Locus	Allele	WRST	BADL	BOOK	KPH	ELK	GRASS	HEMO	TAPR	THROn	THROs	WICA	CHIC
BMS2270	70	–	–	–	–	–	–	–	0.12	–	0.05	0.27	0.2
BMS4040	75	1	1	1	1	1	1	1	1	1	1	1	1
CSSM36b	158	1	1	1	0.99	1	1	1	1	1	1	1	1
CSSM36b*	**172***	–	–	–	**0.01***	–	–	–	–	–	–	–	–
CSSM42b	169	0.42	0.05	0.08	0.32	0.5	0.06	0.06	–	–	–	0.06	0.2
CSSM42b	171	0.46	0.26	0.28	0.11	0.5	0.26	0.26	0.19	0.4	0.44	0.24	0.25
CSSM42b	167	0.12	0.69	0.64	0.57	–	0.68	0.68	0.81	0.61	0.57	0.71	0.55
RM185	92	1	1	1	0.93	1	0.94	1	1	1	1	1	1
RM185*	**104***	–	–	–	**0.07***	–	–	–	–	–	–	–	–
RM185	94	–	–	–	–	–	0.06	–	–	–	–	–	–
RM500	123	1	1	1	1	1	1	1	1	1	1	1	1
SPS113b	130	0.62	0.86	0.34	0.57	0.5	0.62	0.01	0.57	0.42	0.62	0.55	0.5
SPS113b	132	0.1	0.15	0.66	0.43	0.5	0.37	0.99	0.43	0.58	0.38	0.45	0.5
SPS113b	128	0.28	–	–	–	–	0.01	–	–	–	–	–	–
TGLA227b	73	0.92	0.95	0.87	0.96	1	0.92	0.81	0.67	0.98	0.97	0.67	1

* Alleles originating in domestic cattle, and their frequencies detected within each bison herd, also shown in bold text.

Our genetic analyses suggested that the Kaibab Plateau Herd has relatively high levels of genetic diversity and is genetically distinct from the other 16 DOI and 2 Parks Canada herds that have previously been sampled with the same standardized protocols. This distinct genetic identity is further confirmed by the identification of eight private nuclear DNA alleles within the Kaibab Plateau Herd, more than any of the other herds sampled. Genetically, the Kaibab Plateau Herd is most similar to Wind Cave NP and Wichita Mountains NWR, likely a result of the transfers of individuals from these herds into the Kaibab Plateau Herd over the past 90 years (Table 7). The relatively high number of private alleles may be an enduring signal of the unusual mix of bison founders used to start this herd, including descendants of bison from the Texas panhandle, or may simply reflect founder effects and relative isolation from other DOI herds. The degree to which the genetic differentiation of the Kaibab Plateau Herd reflects unique founders, founder effects, or genetic drift cannot be determined with the data available.

Table 7. Origin (in 1905) and augmentation history of the Kaibab Plateau herd (formerly the House Rock herd) that now occupies the northern rim of Grand Canyon (Trudeau 2006, Sisk et al. 2009, AZGFD 2017).

Date	Number	Sex	Origin
1905	56	Unknown mixture	Mixed origins*
1929	4	4 bulls	Wind Cave NP, SD
1942	12	12 bulls	Wichita Mountain NWR, OK
1946	6	6 bulls	Wichita Mountain NWR, OK
1956	10	10 bulls	Wichita Mountain NWR, OK
1980	3	3 unknown	National Bison Range, MT
2001	5	2 cows, 3 bulls	Henry Mountains, UT

* Remnants of a herd owned by “Buffalo Jones”, thought to include bison-cattle hybrids and bison descended from the Pablo herd of Horse Island, MT; the Corbin herd (multiple origins); the Jones herd of Garden City, KS (Texas origins); and, allegedly, Monterrey, Mexico (Trudeau 2006, Sisk et al. 2009, AZGFD 2017).

However, the relatively high levels of genetic diversity within the Kaibab Plateau Herd suggest that periodic augmentations of bison from Wind Cave NP and Wichita Mountains NWR have protected this herd from diversity loss due to genetic drift. The level of cattle introgression within the 15 nuclear DNA markers tested for the Kaibab Plateau Herd (~1.6%) is comparable to that detected in the Custer State Park (~1.5%), Theodore Roosevelt NP North Unit (~1.4%), and Badlands NP herds (~1.3%) However, the percentage of individuals in the Kaibab Plateau Herd with cattle mtDNA is higher than all other DOI herds. Of the publicly available data on herds, only the private Maxwell Ranch herd has a higher level of cattle mtDNA (100% cattle mtDNA; Table 5). Taken together, these genetic indicators speak to the unique foundational and augmentation history of the Kaibab Plateau Herd and suggest management options for the reduction of cattle alleles within this herd.

The difference in the relatively low percentage of cattle alleles detected in the nuclear DNA of Kaibab Plateau Herd (1.6%) compared to the large percentage of individuals with cattle mtDNA (98%) in this herd has previously been noted by Hedrick (2010). Hedrick posited that this difference is likely a consequence of the founding of the Kaibab Plateau Herd (then the House Rock herd) with the offspring of crossing experiments between domestic cattle and bison, in which all mothers were cattle, and all fathers were bison bulls. The two types of markers (nuclear and mitochondrial) currently used to detect cattle introgression differ in how they are passed down from generation to generation. Nuclear DNA is passed down by each parent, while mtDNA is unilaterally passed down through the female (mother). Historic cattle-bison crossing experiments only succeeded when the mother was a cow (cattle) and the father a bison, and only the female offspring of such crosses survived. Thus, first-generation (F1) hybrid offspring would have 50% cattle nuclear DNA and cattle mtDNA from their mothers. If these F1 offspring were backcrossed with a male bison, each offspring should have 25% cattle nuclear DNA and 100% cattle mtDNA. Hedrick (2010) suggested that, over generations, genetic drift and natural selection against DNA linked to nuclear cattle markers could have led to decreases in nuclear DNA to < 2% in the Kaibab Plateau Herd. However, if all mtDNA in the herd is solely of cattle origin, there can be no selection against cattle mtDNA, resulting in persistently high levels of cattle mtDNA.

The differences in how these types of DNA are inherited should be taken into consideration if managers wish to reduce cattle gene introgression within the Kaibab Plateau Herd. Historically, almost all augmentations to the Kaibab Plateau Herd have been bison bulls (Table 7). Augmentations with male bison can decrease the level of cattle alleles in the nuclear DNA, but do not affect the incidence of cattle mtDNA, since mtDNA is only passed down through the female line. Management actions that target females with cattle mtDNA for removals, and use females carrying bison mtDNA to augment the genetics of the Kaibab Plateau Herd, could slowly reduce the proportion of cattle mtDNA within the Kaibab Plateau Herd (Dratch and Gogan 2010, Plumb et al. 2016). Finally, the small number of loci used in the introgression panel is appropriate for testing for the presence of introgression at a herd level but is poorly sensitive at detecting introgression in individual animals (Dratch and Gogan 2010). New, more sensitive technologies to detect cattle introgression are expected to become available in the future (i.e., single nucleotide polymorphism [SNPs]), allowing for more detection of cattle genes in individual animals, and for refined management options to benefit conservation of all DOI bison.

Population Size & Distribution Study (Ongoing)

Kate Schoenecker, U.S. Geological Survey, Fort Collins Science Center and Ecosystem Science and Sustainability, Colorado State University, Ft. Collins, CO

Miranda Terwilliger, Science & Resource Management, Grand Canyon National Park, AZ

D. Skye Salganek, Science & Resource Management, Grand Canyon National Park, AZ

The park is partnering with the US Geological Survey (USGS) and Colorado State University (CSU) to better understand the Kaibab Plateau Herd population with the overarching research goal of developing specific tools for GRCA to manage bison and monitor habitat changes into the future. The study will determine with a high degree of certainty how many bison are currently on the landscape by developing an accurate and repeatable aerial population estimation technique and determining the seasonal distribution of bison. This data will be used to measure outcomes of herd reduction on bison movement patterns and resource use. Radio collars that we placed on wild-ranging bison will collect GPS data at a 2-hour fix rate so bison seasonal movements can be examined, and habitat and resource selection can be determined (Figure 13).

Figure 13. NPS and USGS biologists put a tracking collar on a captured bison. DOI Photo/ Zoey Sawicki

Population Estimation

Bison on the Kaibab Plateau will be counted using simultaneous double-observer models which have been successfully applied to multiple other North American large herbivores (Schoenecker et al. 2018, Schoenecker and Lubow 2016, Griffin et al. 2013, Lubow and Ransom 2016). In 2018, NPS and USGS biologists flew a fixed wing aerial survey, and in 2019 they flew a helicopter double-observer survey (Figure 14). Based on what we learned in those surveys, we expect to fly similar surveys in 2020 to collect additional data that will enable us to build a population estimation model calibrated for the specific habitat on the North Rim. We conducted the March 2019 survey using detailed field methods described in Ekernas et al. (2019) and Schoenecker et al. (2018). In order to estimate sighting probabilities for bison, we will analyze data using methods in Ekernas and Lubow (2019) to correct raw counts for systematic biases (undercounts) that are known to occur in aerial surveys (Schoenecker and Lubow 2016, Lubow and Ransom 2016), and to provide confidence intervals (which are measures of uncertainty) associated with the abundance estimates. Having radio-collared bison will improve population estimates further, because they add an additional correction factor to the model.

Figure 14. A group of bison viewed from above during an aerial survey. DOI photo/ Kate Schoenecker

Demography

To determine bison population growth rate, we recorded the composition of bison groups, and calculated Lamda (Λ) with adult:calf ratios following DeCesare et al. (2012). In 2019, we conducted group counts and classifications over a 3-week period starting in mid-July, recording groups visiting meadows in Little Park and the Basin (Figure 15). Body size, and horn size and shape were used to determine approximate age of the bison. For each count, we classified bison as calves, adult females (cows), adult males (bulls), adults of unknown sex, and yearlings. For quality assurance, two technicians counted the same group and compared numbers. If there was a disparity in classification data, they repeated the counts until each category was within four animals per cohort and then averaged the results.

Figure 15. Skye Salganek conducts a classification survey in Little Park in 2019. NPS Photo/ Dana Musto

Conducting counts of multiple groups during the same day proved problematic due to the lack of functioning Geographic Positioning System (GPS) bison collars (only 2 functioning collars were on bison during this time period) and the few reliable observation areas. Additionally, the North Rim’s heavily forested habitat created challenges for conducting on the ground classifications for as many groups as possible during a day. During this time period, 19 groups were classified. The largest group observed was 259 individuals and included 53 calves. Our ability to correctly classify these bison should improve with additional handling of animals during captures and learning how tooth aging relates to horn/ body sizes in this population.

Effects of Bison on Habitat (Ongoing)

Dana Musto, Science & Resource Management, Grand Canyon National Park, AZ

D. Skye Salganek, Science & Resource Management, Grand Canyon National Park, AZ

Megan Swan, Southern Colorado Plateau Inventory & Monitoring Network, National Park Service, Flagstaff, AZ

Linda C. Zeignenfuss, U.S. Geological Survey, Fort Collins, CO

Miranda Terwilliger, Science & Resource Management, Grand Canyon National Park, AZ

Kate Schoenecker, U.S. Geological Survey, Fort Collins Science Center and Ecosystem Science and Sustainability, Colorado State University, Fort Collins, CO

Figure 16. Bison in Little Park meadow, North Rim, Grand Canyon. NPS Photo/ Skye Salganek

The Kaibab Plateau is an uplifted mesa of mixed conifer habitat surrounded by very different habitats at lower elevations. The plateau, with elevation ranging between 6,000 to 9,215 feet, is bordered on the south by the Grand Canyon, on the east and the west by tributary canyons of the Colorado River, and on the north by tiers of uplifted cliffs. House Rock Valley lies to the northeast. The Kaibab Plateau is known for its high elevation meadows interspersed within large areas of mixed conifer forest. Resource managers from the National Park Service and U.S. Forest Service need information about potential effects of bison presence (Figure 16) on the Kaibab Plateau to habitat, archeological sites, and springs.

Meadow Resources

Bison population effects on North Rim springs and meadows are readily apparent within the park boundaries, evidenced by reduced vegetation height, trampling, trails, and wallows. The park lacks data on meadow vegetation that would allow staff to quantify effects of an increasing bison population on vegetation in the park. In 2019, wildlife staff at the park, in cooperation with the Southern Colorado Plateau Inventory and Monitoring Network, the Grand Canyon Conservancy

Field Institute, and the USGS, undertook a project to begin vegetation monitoring in high elevation meadows using volunteers (Swan et al. 2019).

Site Selection

Meadows were identified using the Grand Canyon National Park-Grand Canyon / Parashant National Monument vegetation classification and mapping project (Kearsley et al. 2015). Using this map, all associations within the Southern Rocky Mountain Montane-Subalpine Grassland group were included. Areas were removed that were greater than 1.5k from the nearest road as well as polygons that had an area of < 2 ha unless those polygons were within 25m of another meadow polygon within this Association.

Generalized Random Tessellation Stratified (GRTS) design (Stevens and Olsen 2004) was used to generate a random set of sampling points, and the 'spsurvey' package (Kincaid and Olsen 2011) within R software to run GRTS to select point locations to serve as the origin of each sampling site (Figure 17).

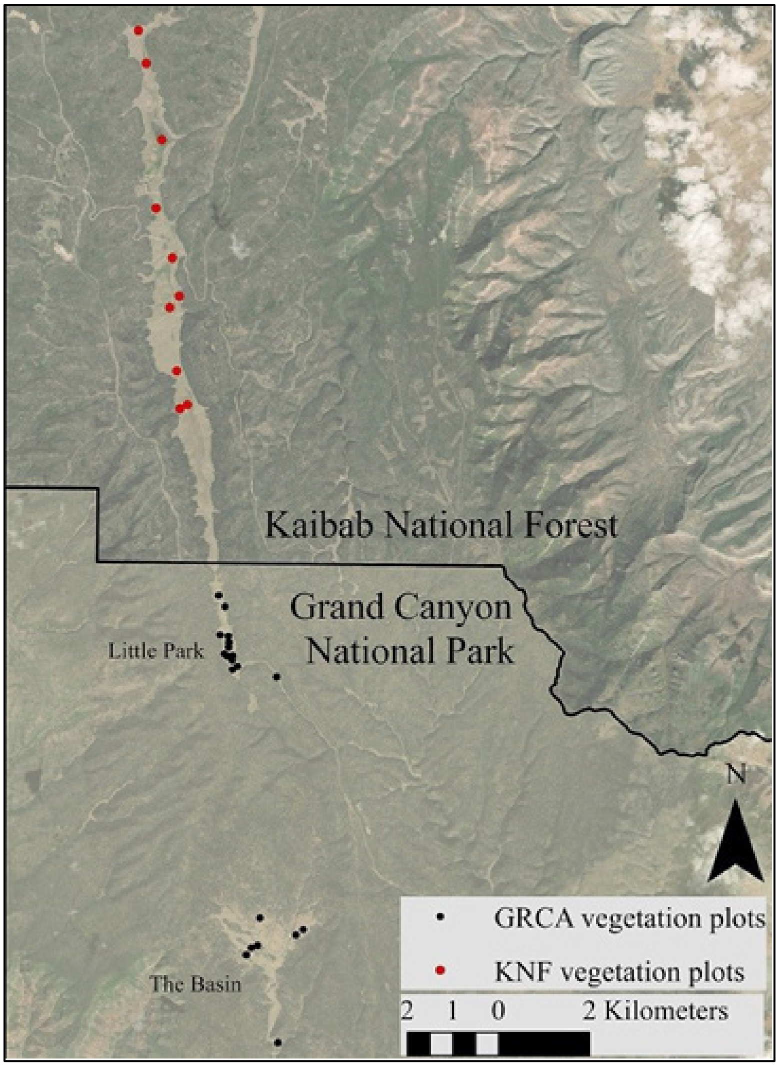

Figure 17. Randomly placed meadow monitoring sites on the Kaibab Plateau on National Park (GRCA, with bison) and National Forest (KNF, no bison) lands.

Comparison plots were selected on the neighboring Kaibab National Forest (NF) as control "non-bison grazed" areas (note: these areas were not within any cattle grazing allotments). Kaibab NF plots were determined by using the "create random points" feature in ArcMap (ESRI, ArcGIS version 10.5.1) in the meadows surrounding highway 67 between VT Hill and the boundary between Grand Canyon National Park and Kaibab National Forest. A random azimuth was identified for each plot using the feature "RANDBETWEEN" in Microsoft Excel.

Field Methods

Since the only existing vegetation monitoring in North Rim meadows were created by the park fire effects program, it was decided to use modified methods for brush plots from the Fire Monitoring handbook (NPS 2003) to keep the data comparable. For each plot, a point-intercept and a belt-transect survey were conducted to measure plant diversity, abundance, vegetation height, presence of bison scat, and bison wallows. In 2019, data were recorded along 30-meter line transects, 10 in no-bison meadows, and 15 in bison-present meadows. This first year was a pilot study to evaluate candidate field methods and complete a preliminary assessment of bison effects (Figure 18). Additional measurements will be taken from a statistically robust sample size. Transects were sampled using the standard point intercept method (Swan et al. 2019).

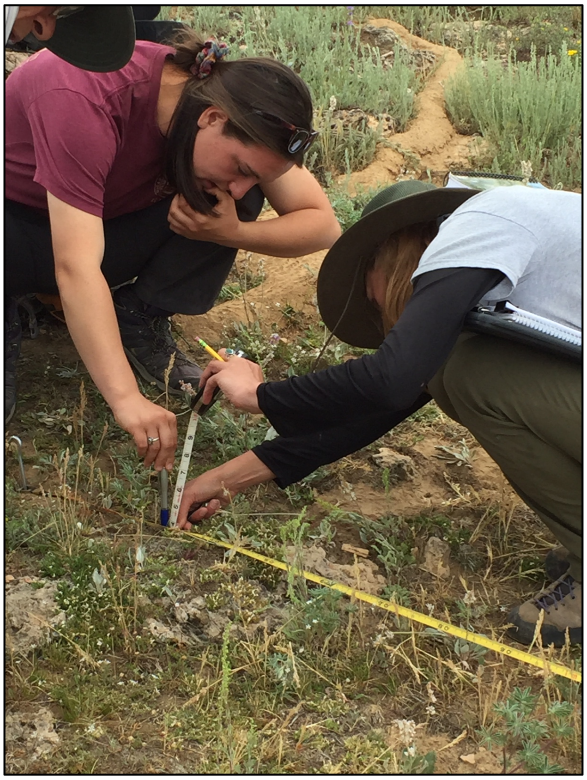

Figure 18. Staff performing vegetation monitoring. NPS photo/ Greg Holm

In 2019, nine park staff, including wildlife and vegetation seasonal staff and interns, joined a staff member and two volunteers from Grand Canyon Conservancy Field Institute for four days of data collection in the field from July 30–August 2, 2019. Subsequently, Forest Service (FS) biologists joined park staff in completing additional transects and assisting with plant identification training. The Basin was ideal for learning plant identification because there were more flowers and seeds present than in heavily grazed Little Park sites.

Statistical Analyses

For the first evaluation of bison effects on vegetation, a non-parametric Mann-Whitney test was used for unpaired samples due to non-normal distribution of data and unequal sample sizes. The Jaccard's and Sorenson's methods were used to calculate indices of community similarity between major sample areas with no-bison and those with bison. Species richness, relative cover by species and lifeform, bare ground cover, and height of graminoids (sward height) was compared. Species frequency as the percentage of belt transects where a species was present was also calculated.

Findings/ Preliminary Results

There was no difference in overall species richness (mean number of species present) between meadows with bison (GRCA) and meadows with no bison (KNF) in the plots measured in 2019 (Figure 19). Kaibab NF transects had greater than 50% species overlap with Little Park transects and were most similar (Table 8). Not surprising, mean height of graminoids (sward height) was >10 cm shorter on sites with bison grazing. [No bison = 22.2 +/− 3.0 cm, Bison = 9.0 +/− 0.6 cm; Wilcoxon test P<0.001]. There was greater cover of forbs and lower cover of graminoids on sites measured in 2019 that had bison grazing (Figure 19). The Basin area of GRCA had low overlap (similarity) of species with Little Park and the Kaibab NF sites (Table 9). Three grass species/ genus had significantly higher cover on sites with no bison: *Elymus elymoides* (P=0.006), no bison = 4.2 +/− 1.3%, *Agrostis idahoensis* (P=0.001), no bison = 1.5 +/− 0.5%, *Fescue* spp. Cover was three times higher in areas with no bison (P=0.004), no bison = 12.4 +/− 3.1%, bison =4.8 +/− 2.1%.

Table 8. Dominant plant species by site.

Little Park (GRCA – with bison)	Basin (GRCA – with bison)	Kaibab NF (no bison)
Poa fendleriana (7.2%)	*Poa fendleriana* (9.0%)	*Festuca* spp. – primarily *F. idahoensis* (12.4%)
Festuca spp. (7.0%)	*Arenaria fendleri* (8.0%)	*Carex* spp. (7.4%)
Erigeron formosissimus (6.1%)	*Solidago nana* (7.8%)	*Poa* spp. (6.6%)
Antennaria rosea (5.7%)	*Heterotheca* spp. (7.8%)	*Alopecurus aequalis* (5.0%)
Arenaria fendleri (4.6%)	*Bouteloua gracilis* (538%)	*Arenaria fendleri* (4.6%)

Table 9. Indices of Plant Community Similarity.

Sites that were compared	Sorensen's Index	Jaccard's Index
Little Park (bison) & Kaibab NF (no bison)	71%	55%
Basin (bison) & Kaibab NF (no bison)	57%	40%
Little Park (bison) & Basin (bison)	50%	34%
Bison (little Park & Basin) & No Bison (Kaibab NF)	68%	52%

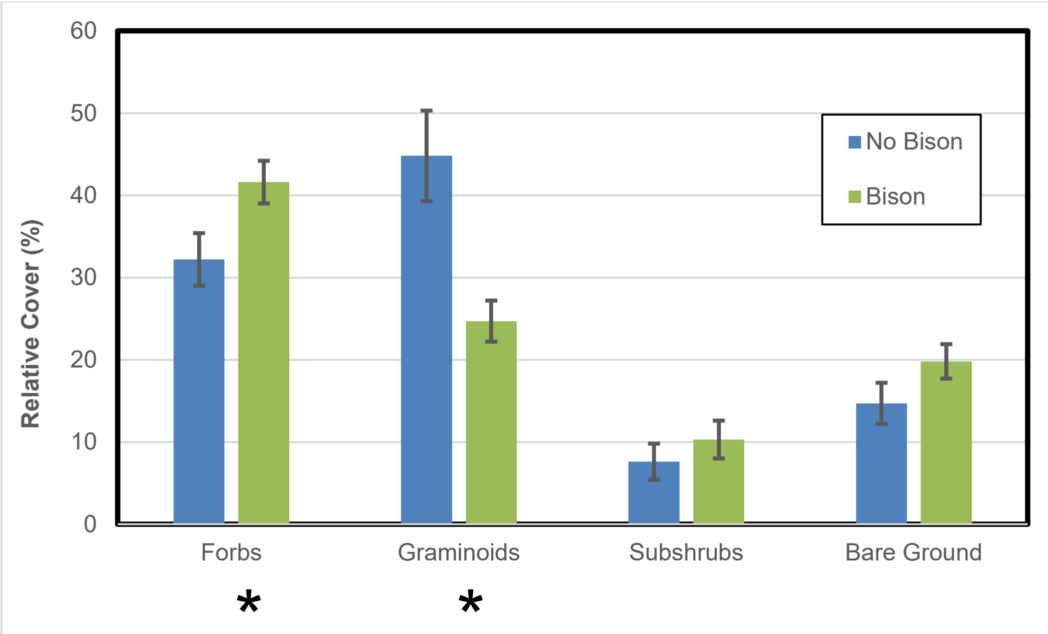

Figure 19. Vegetation Cover by Functional Group. * means significantly different (P<0.05)

Next Steps

This was a first attempt to collect vegetation data comparing areas with and without bison. Some areas on the KNF were measured after a large rainfall event, which may have added height and cover to those sites, whereas the GRCA sites had already been measured. Staff will be able to control for these events by pairing the timing of measurements better in the future and will develop a study design that accounts for current vegetation composition and similarity of sites. This first year of measurements (2019) was conducted to provide some evidence of bison effects and greater direction about how to proceed in the coming years.

Future work intends to establish a rigorous monitoring design to control for more aspects of plant variability. In this way conclusions will be more interpretable. We plan to set up grazing cages on the Kaibab Plateau (both GRCA and the KNF) in areas with and without bison to measure peak production and take plant samples to determine nutrient cycling in 2020. There are also plans to establish six 0.3-ha ungulate grazing exclosures in sensitive meadow vegetation communities on the North Rim for long-term monitoring. The park will also continue monitoring meadows using belt transects.

Spring Resources

Water is a limiting resource in the Grand Canyon ecosystem. The only perennial water sources on the North Rim are sinkhole ponds found scattered throughout the Plateau and small springs most often found in faults and valleys of the Kaibab limestone formation (Reimondo 2012). Ponds are formed in karstic sinkholes lined with fine sediments that reduce infiltration and depend on local precipitation to maintain the standing water (Weng and Jackson 1999). Surface levels of these ponds fluctuate seasonally, influenced by evaporation, evapotranspiration, infiltration, and precipitation and are largely dependent on snowmelt recharge of groundwater (Reimondo 2012). Bison use these sites heavily and there is a visual difference between bison/ non-bison used areas (Figure 20).

Figure 20. Crystal pond in 2010 on the left (no bison use) and in 2014 on the right (high bison use). NPS Photo/ Evan Reimondo.

Reimondo's 2012 Master's thesis looked at effects of bison on these springs. That study found that bison use is strongly correlated with reduced vegetative cover, increased exposure of bare soil, and decreased plant height. These relationships are also apparent in comparative site photographs (Figure 21). He found no significant relationship between bison use and species richness nor was soil compaction detected; however, there were strong trends of decreased species richness and higher soil bulk density with increasing bison use at spring sites. It was expected that effects would grow as the herd size increased.

Figure 21. Image from a motion detecting camera deployed at a spring shows the ineffectiveness of fencing—there are as many bison inside the fence as outside. NPS Photo.

In 2017, the park deployed game cameras at springs on the North Rim to determine extent of use and the park attempted to fence off several water sources from the bison. Since 2018 was an unusually dry year and bison were particularly motivated to access these water sources, fencing had limited success (Figure 19). In 2019, staff removed damaged fencing from some of these sites and plan to remove more in 2020.

Disturbance and Wallow Mapping

Grand Canyon partnered with USGS to enlist a NASA DEVELOP team (program located at Colorado State University) to evaluate whether disturbances on the north rim could be measured and quantified from satellite data. Of interest was whether an increase in wallows could be discerned, and if effects of bison herbivory could be seen. The goal was to determine whether impacts to soils and vegetation could be mapped from satellite data. Results were mixed. Wallows were not able to be detected because the imagery pixel size was too coarse to clearly distinguish them. Disturbance from bison herbivory was masked by the signature of disturbance from fire and drought. In other words, drought and fire have impacts that are easier to detect on the landscape than bison herbivory, using satellite imagery techniques used by the NASA DEVELOP team.

In 2019, park staff began mapping bison wallow size (length and depth) and distribution on foot to better understand how they are distributed across the landscape. We will continue measuring new wallows and monitoring the size of older wallows in 2020.

Bison Trail Mapping

Biologists have noted that bison have created impressive trail networks through densely forested areas connecting meadows and water sources on the North Rim. Because these trails mostly occur under dense forest cover, staff have primarily mapped them on foot. Park staff hope to be able to detect bison use of these trails using the GPS collars. Additionally, biologists are interested in knowing the route bison take to and from Powell Plateau, as there is a rather steep valley in between the plateau and the rest of the North Rim habitat. If there is a pinch point somewhere, it could facilitate the use of camera traps to better gauge population demographics.

Seasonal Distribution and Habitat Selection

With 14 GPS collars currently deployed (Figure 22), and up to 16 more set for deployment in 2020, biologists will be better able to model seasonal and annual habitat selection and range. The bison location data at a fix rate of every 2-hours will provide locations (fixed points) that bison "use," and staff will generate random locations to assess habitat "available" to bison. Using estimates of vegetation type at used and available locations and using resource selection function (RSF) methods (Manly et al. 2002), staff will be able to better define bison selection of vegetation types. The RSF model will be fully developed and completed after a minimum of 2 years of GPS data are collected from collared bison.

Figure 22. Distinctive bison-created trail. NPS Photo/ Phillip Andrews.

Human/ Bison Conflict

Miranda Terwilliger, Science & Resource Management, Grand Canyon National Park, AZ

In most places on the North Rim, bison are quite skittish around people. However, bison are habituated to people along Little Park meadow, which the North Rim entrance road bisects. Visitors often cause “bison jams” here that can impede the flow of traffic. In 2019, the park had the first ever attempt of a visitor trying to “rescue” an orphaned calf. In response to that incident, the park modified some of its educational tools about safe distances and wildlife, including expanding the messaging about safe wildlife distances to include bison (Figure 23). This will allow park staff to give the same consistent messaging about how to avoid interacting too closely with wildlife. Entrance fee staff handed out the “Bison Wildlife Petting Chart” (Figure 24) that appeared on NPS social media when there were a lot of bison near the North Rim entrance to educate visitors with a little humor.

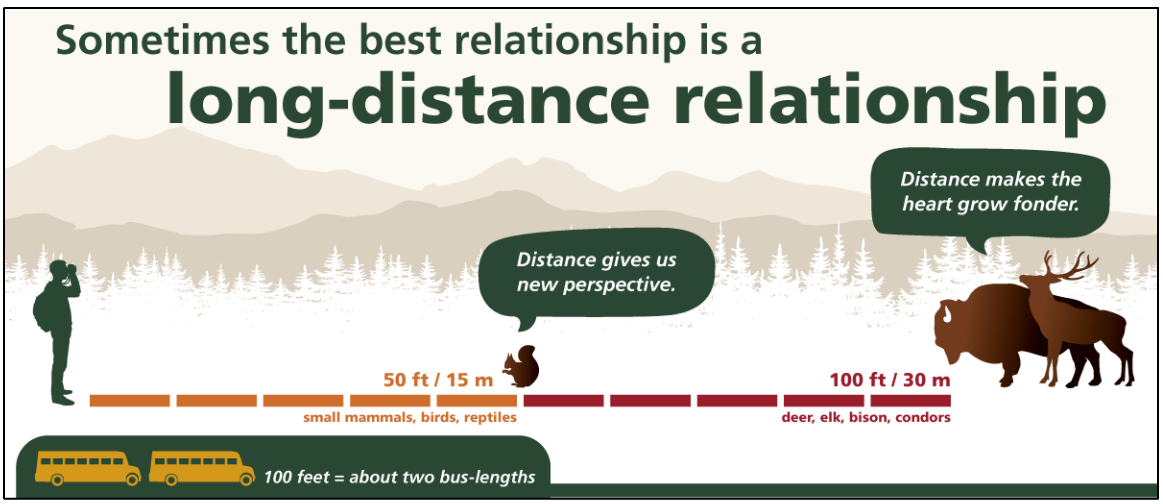

Figure 23. National Park Service messaging for wildlife safe distances.

In addition, the park needs to re-assess the need and location of signs warning of bison along the North Rim entrance road corridor. There is currently only one bison warning sign on the south end of Little Park meadow. The park will evaluate the need for more signs and review a recommendation to reduce the night-time speed limit, as that is when most bison-vehicular accidents occur. These collisions usually cause great vehicular damage and are often fatal to the bison.

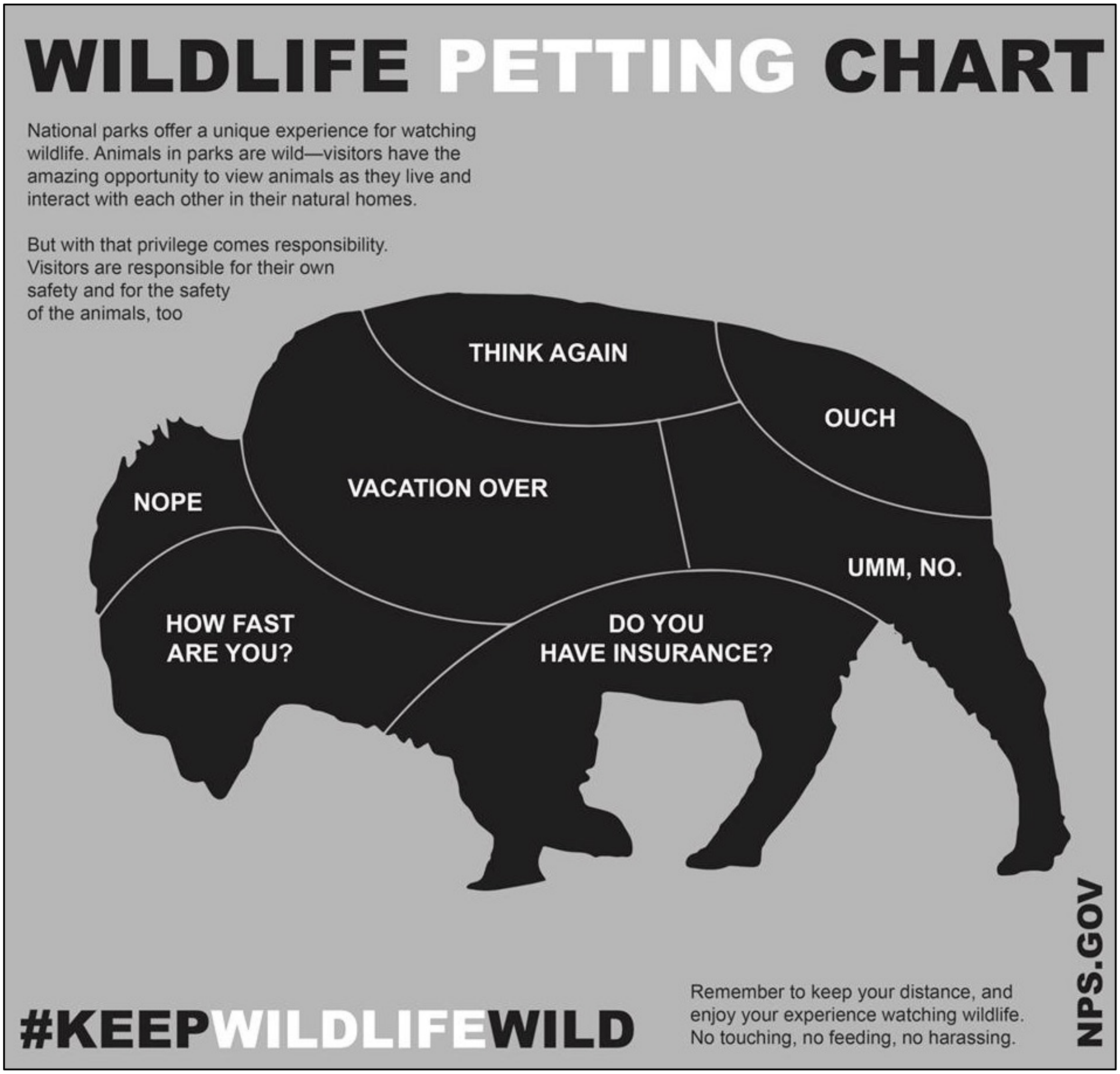

Figure 24. A National Park Service social media post to help the public learn to keep their distance from wildlife.

Genetic Glossary

allele: alternative form of a gene. The term is used in this report in reference to variation in short tandem repeat segments of DNA, rather than coding regions relating to phenotype.

allelic diversity: a measure of genetic diversity based on the average number of alleles per locus present in a population.

genetic bottleneck: the loss of genetic variation experienced by populations that undergo a marked reduction in effective population size.

genetic drift*:* random changes in allele frequencies in populations between generations due to binomial sampling of genes during meiosis. Genetic drift is more pronounced in small populations.

heterozygosity (H): a measure of genetic variation that accounts for either the observed (H_O) or expected (H_e) proportion of individuals in a population that are heterozygotes.

introgression: the incorporation of genes from one population to another through hybridization that results in fertile offspring that further hybridize and backcross.

locus: the position on a chromosome of a gene or other marker.

microsatellite: tandemly repeated DNA consisting of short sequences of one to six nucleotides repeated between approximately five and 100 times.

mitochondrial DNA (mtDNA): This DNA is inherited solely from the mother and consists of only one chromosome. It contains only 37 genes. All changes in mtDNA comes from mutations and it mutates very, very slowly. This resistance to change makes it great for tracing ancestry. Your mtDNA is nearly identical to the mtDNA of your straight-line maternal ancestor who lived thousands of years ago, and it is also identical to thousands of people living today.

nuclear DNA (or nuclear deoxyribonucleic acid): This DNA consists of 46 chromosomes and contains 20,000–25,000 genes. This is the DNA that encodes the majority of the genome in mammals (and others) and thus is responsible for physical characteristics. It is inherited from both parents. It is more susceptible to random and environmental change.

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Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

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