July 3, 2023

Memorandum

To: Tyler Abbott, Wyoming Field Supervisor, U.S. Fish and Wildlife Service
Adam Zerrenner, Montana Field Supervisor, U.S. Fish and Wildlife Service
Jim Boyd, Montana Listing/Recovery Biologist, U.S. Fish and Wildlife Service
Kevin Salgado, Wyoming Listing/Recovery Biologist, U.S. Fish and Wildlife Service

From: P. J. White, Natural Resources Program Manager, Yellowstone National Park

Subject: Information for the Species Status Assessment on Yellowstone Bison

The United States Fish and Wildlife Service (USFWS) recently announced they would initiate a status review of Yellowstone bison based on information provided in three petitions received from 2014 to 2018 (USDI, USFWS 2022). A species status assessment begins with the compilation of information, including species' natural history, ecological needs, abundance, distribution, demographics, condition of habitats, and genetic diversity. The assessment then forecasts the viability of the species given various scenarios of future environmental conditions and conservation efforts (USDI, USFWS 2016). The species status assessment is not a decision document; rather it provides biological information, analyses, and predictions to support decisions pursuant to the Endangered Species Act of 1973 (16 USC 1531 *et. seq*.). The species status assessment for Yellowstone bison is scheduled for completion in 2026 (USDI, USFWS 2023).

This document provides relevant information for the status review of Yellowstone bison by the USFWS and a subsequent determination of whether these bison are a distinct population segment, whether they are threatened or endangered, and the extent of their resiliency, redundancy, and representation. In this document, the word 'cull' refers to bison captured for possible inclusion in quarantine (called the Bison Conservation Transfer Program), shipment to slaughter, or shooting on-site. The word 'harvest' refers to bison shot during hunts outside the park by members of American Indian tribes[1] pursuant to long-standing treaties with the federal government and public hunters with permits from Montana Fish, Wildlife and Parks. The word 'removals' refers to the combined numbers of harvests and culls.

Distinct Population Segment

The petitions received by the USFWS suggest Yellowstone bison are a distinct population segment of plains bison and the central and northern breeding herds may be distinct segments as well. A distinct population segment is a discrete and significant segment of a species that can be analyzed as if it were a species under the Endangered Species Act. The USFWS considers two elements when evaluating whether to designate a distinct population segment: the discreteness of the population segment in relation the remainder of the species; and the significance of the population segment to the species (USDI, USFWS and US Department of Commerce, National Oceanic and Atmospheric Administration 1996).

Discreteness

By 1900, there were only about two dozen bison left in the Yellowstone area due to their widespread slaughter by colonists during the 1870s and 1880s. These bison spent winter in the Pelican Valley in the central portion of Yellowstone National Park (YNP) and moved to the Mirror Plateau and upper Lamar

[1] American Indian tribes include any bands, nations, or other organized groups the Secretary of the Interior includes in the Federally Recognized Indian Tribe List Act of 1994, as amended (25 USC 5130-5131).

River drainage in the northeastern portion of YNP during summer (Figure 1; Meagher 1973). To restore bison to the northern portion of YNP, managers relocated 18 females (some pregnant) from northwestern Montana, three males from Texas, and four indigenous calves from the Pelican Valley to northern YNP during the early 1900s. Managers fed these bison during winter at the Buffalo Ranch in the Lamar Valley and herded them to the Mirror Plateau and upper Lamar River area during summer (Meagher 1973). As a result, some of the native Pelican bison likely mixed and bred with the introduced Lamar bison during the breeding season from mid-July to mid-August. Bison numbers increased rapidly to about 1,100 by 1930. In 1936, managers relocated 71 bison from the Lamar Valley to the Hayden Valley and Firehole River area in central YNP, creating the Mary Mountain herd (Meagher 1973).

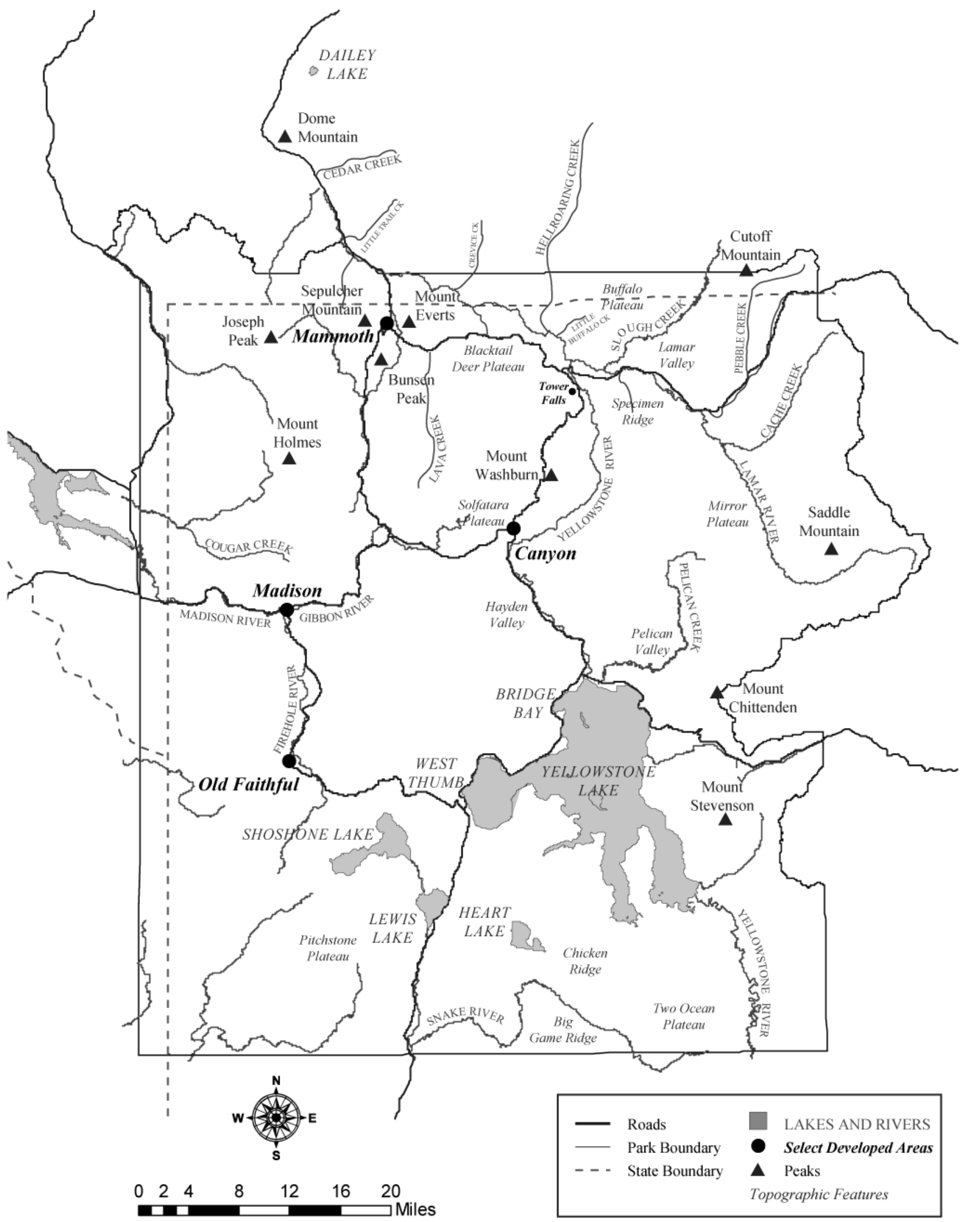

Figure 1. Yellowstone National Park and nearby areas of Montana with geographic features and place names.

Managers stopped feeding and herding bison in the Lamar Valley in 1952, after which bison moved about freely. However, managers shot or captured and shipped about 3,500 bison from this herd between 1930 and 1966 to reduce numbers and remove individuals with the disease brucellosis. For similar reasons, managers removed about 860 Mary Mountain bison and 150 Pelican bison between 1954 and 1966. These removals reduced numbers to about 70 Lamar, 160 Pelican, and 188 Mary Mountain bison by winter in 1968 (Meagher 1973). Thereafter, managers stopped removing bison and allowed numbers to vary in response to forage availability, predation, and weather. Bison numbers increased rapidly to about 1,700 during the 1970s and 3,000 during the 1980s. Some Lamar bison began spending both summer and winter in the Lamar Valley, while others pioneered winter ranges westward along the Yellowstone River towards the northern boundary (Meagher 1989). Pelican bison began moving west to the northern shore of Yellowstone Lake and along the Yellowstone River to the Hayden Valley. Eventually, bison spending winter in the Pelican Valley stopped moving to the Mirror Plateau and upper Lamar River area during summer and mostly remained in the Hayden Valley (Meagher 1998). Thus, there was likely considerable mixing of descendants from the native (Pelican) and introduced (Lamar/Mary Mountain) lineages.

In addition, more bison began moving from the Hayden Valley to the Firehole River area and some continued along the Gibbon and Madison rivers towards the western boundary during winter. Others began moving to northern YNP, likely in response to increasing bison numbers and deep snow depths that reduced forage availability (Meagher 1993, Fuller et al. 2007). A few bison migrated to both the western and northern boundary areas during the same winter. As a result, there was probably further mixing of descendants from the native and introduced lineages and distinguishing between descendants of Lamar, Pelican, and Mary Mountain bison based on their location in the park became impossible. Instead, biologists began counting and referring to bison that spent summer in the central and northern regions of YNP as the central and northern herds, respectively (White et al. 2022a).

During the past two decades, there were significant movements of bison between central and northern YNP that further mixed descendants of the introduced and native lineages (White et al. 2022a). Two-thirds of adult females fitted with radio-collars in central YNP during 2004 to 2017 moved in groups with hundreds of other female and young bison to northern YNP during winter. About half of these collared females remained in northern YNP at least through the breeding season the following summer (Wallen and White 2015). In addition, bison sampled in central and northern YNP during 2011-2012 did not have distinct mitochondrial genetic make-ups and the native and introduced lineages were found in both regions of the park in about equal proportions (Forgacs et al. 2016). Thus, Yellowstone bison appeared to be a single intermixing population, with movements, breeding, and gene flow between bison originating from central and northern YNP (White and Wallen 2012). Geneticists from Texas A&M University concluded "[o]ur finding that there is no subdivision based on mtDNA [mitochondrial deoxyribonucleic acid] support that Yellowstone bison can be managed - for mitochondrial haplotype diversity - as a single population with multiple breeding segments" (Forgacs et al. 2016).

The Yellowstone bison population is markedly separated from other populations of plains bison and, as a result, there has been no gene flow into the population for numerous generations. Yellowstone bison have rarely dispersed to the nearest population in Grand Teton National Park (about 85 miles), but not vice versa, even though there are no physical barriers to such movements (Wallen and White 2015). Also, there are genetic differences between these populations because the Grand Teton population was founded partially from bison relocated from Theodore Roosevelt National Park, which has a different genetic lineage than Yellowstone bison (Dratch and Gogan 2010).

Significance

Yellowstone bison are significant because they represent a unique genetic lineage with a critical source of genetic material and heritable information for the recovery and evolution of plains bison. They also retain relatively high genetic diversity compared to many other populations (Halbert and Derr 2007, 2008; Hedrick 2009, Dratch and Gogan 2010, Forgacs et al. 2016). In addition, descendants of the indigenous Yellowstone bison have persisted in a unique ecological setting for plains bison and developed adaptive capabilities honed by natural selection (Wallen and White 2015). Hence, the loss of the population would result in a significant gap in the range and adaptive behaviors of plains bison. Furthermore, Yellowstone bison have special significance to many American Indian tribes because they are considered the last living link to the indigenous herds of bison which once roamed across North America (Plumb and Sucec 2006, Wallen et al. 2015b). Yellowstone bison are one of a few unfenced, wild, wide-ranging populations of plains bison in existence today—and the only population large enough to be considered ecologically and genetically viable (Hedrick 2009, Gross et al. 2010). Thus, to many native people and scientists this population represents the only surviving natural occurrence of plains bison (Plumb and Sucec 2006, Freese et al. 2007, Sanderson et al. 2008, Hedrick 2009, Dratch and Gogan 2010, Gross et al. 2010).

Bison sampled in the central and northern regions of YNP during 1997 to 2003 had significantly different distributions of alleles and genotypes based on microsatellite DNA markers and were genetically distinguishable based on 20 alleles only found in one of the two regions (Halbert et al. 2012). Based on these analyses, the petitioners contend Yellowstone bison are comprised of at least two genetically distinct subpopulations that are being differentially affected by culling, which could decrease genetic viability (USDI, USFWS 2015). The human relocation of plains bison from northwestern Montana into the Lamar Valley and Mary Mountain area of YNP (circa 1909 and 1936), with a different genetic lineage than the indigenous bison that spent winter in the Pelican Valley of Yellowstone, created population substructure and regional genetic differentiation in Yellowstone bison (White and Wallen 2012). However, there were significant bison movements and dispersal from central to northern YNP during the past two decades and it would be impossible to recreate genetically distinct herds of the indigenous and introduced genetic lineages given this mixing (White and Wallen 2012, Wallen and White 2015). Instead, the National Park Service (NPS) is allowing ecological processes, such as natural selection, migration, and dispersal, to prevail and influence how population and genetic substructure is maintained rather than actively managing to try and perpetuate an artificially created substructure. It would be impossible to stop bison from moving between the central and northern portions of the park or to force them to remain in a particular region (White and Wallen 2012).

Listing Factors

The petitions received by the USFWS requested Yellowstone bison be listed as threatened or endangered under the Endangered Species Act due to the curtailment of their historic range, lack of access to existing winter range, and loss of genetic diversity due to overutilization through culling and hunting because of the chronic presence of the disease brucellosis in the population (USDI, USFWS 2022). The USFWS can determine a species is threatened or endangered due to one or more of the following factors: A) present or threatened destruction, modification, or curtailment of its habitat or range; B) overutilization for commercial, recreational, scientific, or educational purposes; C) disease or predation; D) inadequacy of existing regulatory mechanisms; and E) other natural or manmade factors affecting its survival (16 USC 1533(a)(1)).

Factor A—Present or Threatened Destruction, Modification, or Curtailment of its Habitat or Range

Range Curtailment—Archaeological and historical records indicate plains bison were living in the area now encompassed by YNP and widespread through the larger ecosystem prior to colonization (Cannon et al. 2020, Whittlesey and Bone 2020). Based on the timing of historical observations and the current behavior of bison and other ungulates such as deer, elk, and pronghorn, it is likely many bison in the area migrated seasonally between productive grasslands and meadows in the mountains during summer and lower elevation valleys and plains in outlying areas during winter (Whittlesey et al. 2018, Whittlesey and Bone 2020). However, the number of bison that spent time in the mountainous area now encompassed by YNP is unknown and sparse archaeological sampling and casual observations cannot be used to estimate population sizes, seasonal movements and migration routes, or periods of occupancy with certainty (Whittlesey et al. 2018, Cannon et al. 2020).

Park biologists developed a rough approximation of the pre-settlement distribution of plains bison in the Yellowstone area (about 20,000 square kilometers) based on written narratives from people traveling through the area but cautioned against interpreting this figure with any degree of accuracy or precision (Plumb et al. 2009:2378; Whittlesey et al. 2018). Regardless, the historic abundance and distribution of plains bison in the Greater Yellowstone Ecosystem[2] was substantially reduced by 1900 due to slaughter by colonists during the 1870s and 1880s, with only about two dozen bison remaining inside YNP by 1900 (Meagher 1973, Whittlesey and Bone 2020). These indigenous bison and about two dozen bison introduced to northern YNP during the early 1900s spent winter in relatively small areas in the Pelican and Lamar valleys, respectively, and migrated to the Mirror Plateau and upper Lamar River drainages during summer (Meagher 1973). Protection and restoration actions over the next century allowed bison to increase in abundance and distribution, which now encompasses about one-half of the park and nearby areas of Montana north and west of the park (Plumb et al. 2009).

The current area used by plains bison in the GYE is roughly about 4,850 square kilometers in Yellowstone and Grand Teton national parks and nearby management areas in Montana and Wyoming, respectively (White et al. 2015). The bison population living in Grand Teton National Park (summer) and the National Elk Refuge (winter) in Wyoming was founded from Yellowstone bison in 1948 and supplemented with bison from Theodore Roosevelt National Park in 1964 (Aune et al. 2010). The bison in Theodore Roosevelt National Park were founded in 1956 with bison from Fort Niobrara National Wildlife Refuge in Nebraska and have a different genetic lineage than Yellowstone bison (Halbert and Derr 2008, Hedrick 2009). Currently, there is no known intermixing of bison (gene flow) between Grand Teton and Yellowstone national parks (Wallen and White 2015).

Limited Distribution—Movements of bison beyond the boundary of YNP are limited to adjacent management areas in Montana (Figures 2 and 3) due to concerns about mingling with cattle and transmitting the bacterial disease brucellosis which can cause abortions (USDI, NPS and USDA, USFS and APHIS 2000; Bidwell 2010). The Interagency Bison Management Plan (IBMP) was adjusted several times during 2005 to 2016 to increase tolerance for bison migrating outside the park (IBMP Agencies 2016). Since 2011, hundreds to more than one thousand bison have migrated outside the park to habitat in the Hebgen and Gardiner basins of Montana during winter (Geremia et al. 2015a, Geremia 2022, 2023). There are additional public lands already protected in the GYE that could support wild bison in the future as conflicts are mediated and tolerance increases (White et al. 2015, USDA, USFS 2022). To date, however, the impacts of conservation and management actions have been to recover a viable, wild population of migratory Yellowstone bison from near extirpation in the late 1800s and substantially increase their distribution in and near YNP, but not fully recover the species throughout the GYE or elsewhere due to a lack of tolerance for wild, unfenced bison outside of parks and preserves (White et al. 2015). The Paradise and Madison valleys north and west of YNP support numerous livestock producers and rural residential development has increased rapidly during the past several decades; both of which are at times incompatible with the conservation of a free-ranging bison population (Haggerty and Travis 2006, Metcalf et al. 2016, Tilt 2020).

[2] The Greater Yellowstone Ecosystem/Area encompasses about 20 million acres in Wyoming, Montana, and Idaho. It includes the headwaters of the Columbia, Snake, and Yellowstone rivers, Grand Teton and Yellowstone National Parks, and the Beaverhead-Deerlodge, Bridger-Teton, Caribou-Targhee, Custer Gallatin, and Shoshone national forests (Keiter 2020).

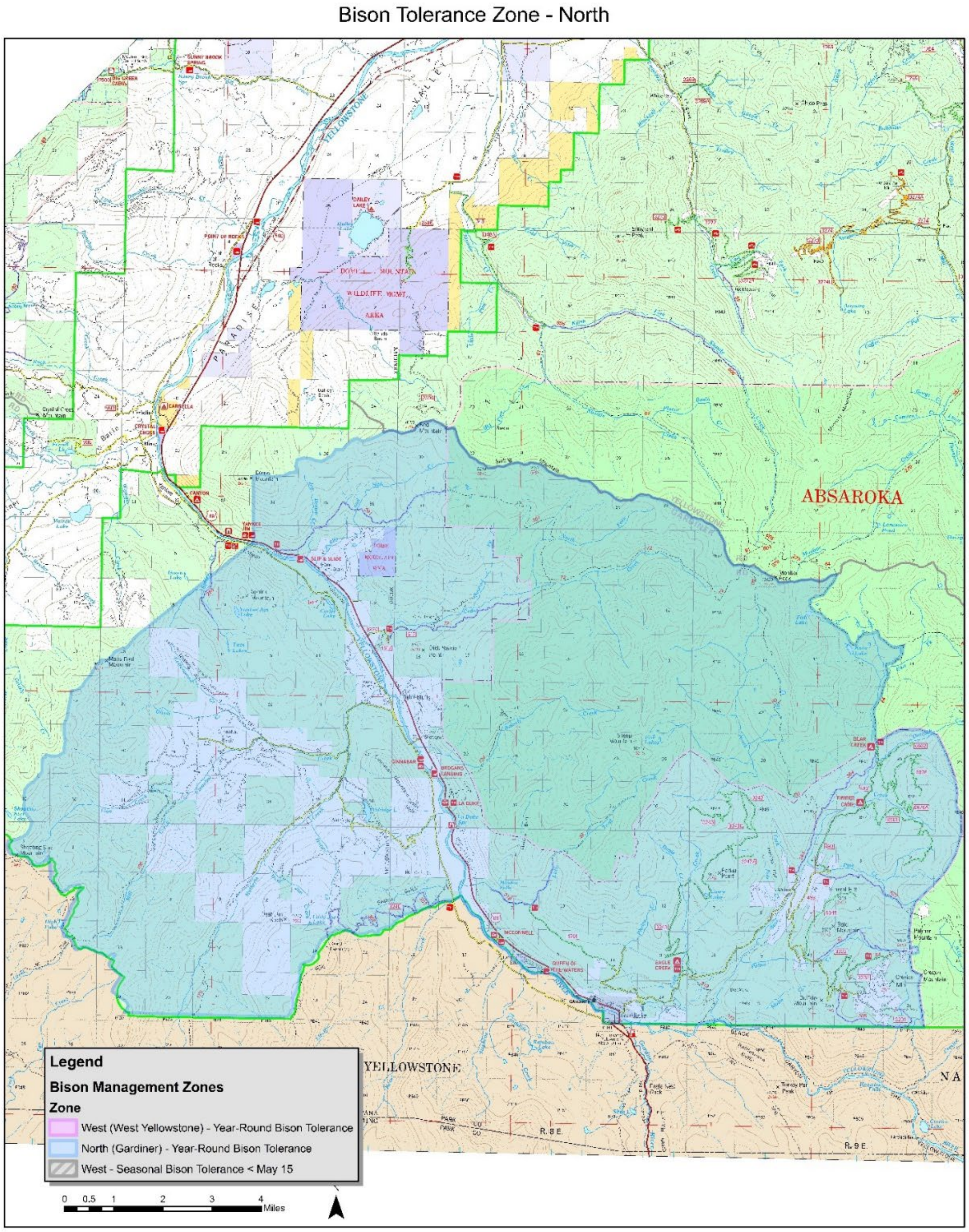

Figure 2. Northern management area in Montana for the Interagency Bison Management Plan (Randy Scarlett, Custer Gallatin National Forest, and Julie Anton Randall, Eco Mare Terra International).

The State of Montana only allows limited numbers of bison in certain areas due to concerns about brucellosis transmission, human safety, and property damage (Bidwell 2010). As a result, culling and harvests are used to limit population growth and the number and distribution of Yellowstone bison in Montana (IBMP Members 2022). However, bison have access year-round to Horse Butte in the Hebgen basin and north along Highway 191 up to and including the Taylor Fork Drainage, as well as the Cabin Creek Wildlife Management Area and the Monument Mountain Unit of the Lee Metcalf Wilderness (Figure 3). North of the park, bison can occupy the Eagle Creek/Bear Creek area and the Absaroka-Beartooth Wilderness year-round without interference. Bull bison are allowed year-round in the Gardiner basin from the park boundary to the southern entrance of Yankee Jim Canyon, while female and young bison can only be in this area during winter (Figure 2; Bullock 2015, IBMP Members 2022).

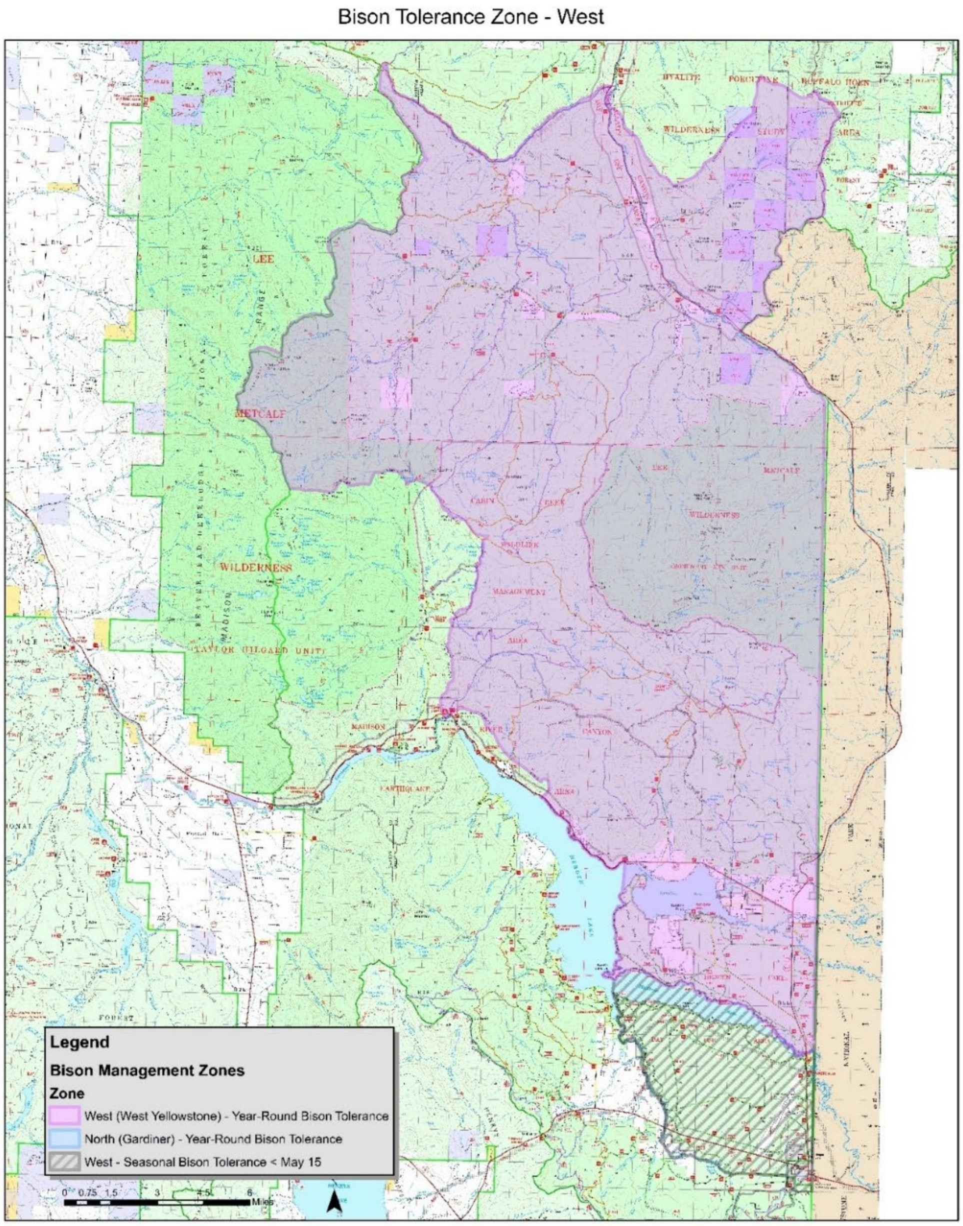

Figure 3. Western management area in Montana for the Interagency Bison Management Plan (Randy Scarlett, Custer Gallatin National Forest, and Julie Anton Randall, Eco Mare Terra International).

Livestock Grazing—Other threats mentioned by the petitioners included (1) livestock grazing through the alteration of plant communities, soil characteristics, and other habitat elements, (2) development and infrastructure such as cultivation, cattle ranching, commercial bison ranching, natural resource extraction, and urban expansion, and (3) the invasion of non-native plant species that alter existing plant communities and soils and impact ungulate foraging (USDI, USFWS 2015). Historic livestock grazing and ranching in areas within (Gardiner basin, Lamar Valley) and around (Madison and Paradise valleys) YNP has altered plant communities, soil characteristics, and other habitat elements (Rush 1932, Marlowe et al. 2016a,b; Hansen and Phillips 2018). Bison are not allowed to occupy areas where cattle are grazing. The federal government and non-governmental groups have worked with lease holders of grazing allotments on public lands to remove livestock grazing from some portions of the GYE to reduce conflicts with grizzly bears, wolves, and other wildlife. These agreements have removed livestock grazing from almost 700,000 acres of habitat in the ecosystem (Wuerthner 2017, National Wildlife Federation 2018, USDA, USFS 2022).

In 1990, the United States Forest Service (USFS) acquired the 3,200-acre OTO Ranch north of the park from the Rocky Mountain Elk Foundation for $3.5 million. The ranch is within a key migration corridor for ungulates and other wildlife seasonally moving to or from YNP. In addition, the Rocky Mountain Elk Foundation assigned 1,508 acres of land on the Royal Teton Ranch north of the park to the USFS in 1999. The United States Department of the Interior (USDI) provided $1.8 million for the acquisition of this conservation easement “to aid and assist in the preservation of the YNP [Yellowstone] bison and other wildlife by setting aside a portion of its lands, in perpetuity, thereby providing in the natural world, a safe haven for the bison.” The easement also facilitated “the use, movement, or migration of the surface estate by bison, elk, bighorn sheep, pronghorns, grizzly bear, black bear or mule deer” and avoided the “destruction or impairment of the natural habitat” (Deed of Conservation Easement, Royal Teton Ranch, Devil’s Slide Area, Security Title 99-114).

There also have been efforts to encourage landowners to voluntarily remove cattle from key areas adjacent to YNP where bison could comingle with them during the brucellosis transmission period. In 2003, grazing permit holders on the Horse Butte peninsula west of YNP agreed with the National Wildlife Federation and USFS to transfer their rights to the nearby Targhee National Forest where bison are not present. In 2008, Montana Fish, Wildlife and Parks signed a 30-year livestock grazing restriction and bison access agreement to remove livestock from the Royal Teton Ranch north of YNP. The NPS provided the federal government's $1.5 million share of the total $3 million cost. This voluntary acquisition of grazing rights enables bison to use additional habitat along the Yellowstone River up to 10 miles away from the park boundary. In 2019, the USFS completed a land exchange to acquire 583 acres of the Slip and Slide Ranch, north of the park in a key migration corridor for ungulates and other wildlife. Combined with previous fee purchases and conservation easements, partnerships between federal and state agencies, private landowners, and non-governmental organizations such as the Rocky Mountain Elk Foundation have conserved about 13,000 acres of habitat for bison and other wildlife in this area, reduced the number of livestock grazing adjacent to YNP, and improved connectivity for migrating bison between the park and the Custer Gallatin National Forest (USDA, USFS 2022).

Development—The natural condition for the native shrub-grass plant association and ungulate guild in northern YNP would be pre-settlement before substantial alteration by colonists and settlers. It is impossible to recreate these conditions given subsequent changes such as the slaughter of large mammals during the 1870s, removal of indigenous people, farming and ranching in and near the park, increasing visitation, and settlement (Meagher and Houston 1998, Cole and Yung 2010, White et al. 2013, Whittlesey et al. 2018). Development has substantially decreased suitable habitat for bison in the GYE (Hansen and Phillips 2018). However, more than 99% of YNP is preserved as wilderness (92%) and undeveloped land (7%). Also, there are almost 11 million acres of other protected federal lands, primarily national forests, surrounding the park in the GYE. The federal agencies have agreed not to increase development, livestock grazing, or roads from circa 1998 levels on about 5.9 million acres in this area to protect secure habitat for grizzly bears (USDI, USFWS 2017).

Invasive Plants—Invasions by more than 185 exotic plant species and a century of climate warming have changed the composition and production of several plant communities and soils in YNP which, in turn, likely has affected ungulate foraging to some extent (Yellowstone Center for Resources 2021, Renkin 2022, Wacker 2022). Invasive nonnative plants infest much of the Stephens Creek Administrative Area, where the bison capture facility is located. Native vegetation is sparse because of historical uses and, more recently, from the horse corrals, bison capture and quarantine facilities, equipment storage, barn and associated buildings, and nursery operations. Nonnative plants include crested wheatgrass, mustard, Kochia, Russian thistle, cheatgrass, and Canada thistle. The surrounding area consists of foothills with widespread nonnative plants and a mixture of native vegetation, including sagebrush, rabbitbrush, greasewood, juniper, cottonwoods, willow, Douglas fir, and a variety of forbs and grasses. There are also terraces near the Yellowstone River and Reese and Stephens Creeks that ranchers cultivated before being included in YNP. Nonnative plants including crested wheatgrass and mustard dominate the vegetation in these areas (Yellowstone Center for Resources 2021, Renkin 2022, Wacker 2022).

In addition, some non-native plants were intentionally introduced to provide forage for bison and other ungulates, including in the Gardiner basin and Lamar Valley which were planted with hay for bison and other wildlife during the first half of the 20th century (White et al. 2022c). Between 1904 and 1952, about 575 acres in the Lamar Valley were cleared of native vegetation and cultivated with nonnative grasses, including oats, smooth brome, clover, dandelion, and timothy, to grow hay in support of bison restoration (Rush 1932, Skinner et al. 1942). These cool-season exotics grow best when the weather is moist and cool because they inefficiently use water (Wacker 2022). Thus, they are well adapted for the cool, wet, nitrogen-rich habitats of the mid- to high-elevations of northern YNP. Moreover, they thrive when grazed and are often more productive than native bunchgrasses (Geremia and Hamilton 2019, 2022). As a result, these cultivars displaced native plants in wet areas across much of northern YNP and now dominate plant communities from Tower Junction to the upper Lamar Valley (Geremia and Hamilton 2019, 2022).

Today, bison intensely graze on grasses that have proliferated from abandoned hayfields in the Lamar Valley during summer. They create grazing lawns of dense, short-statured plants in some areas through intense and repeated grazing. This grazing strategy sustains highly nutritious food through summer by prolonging new plant growth and stimulating nutrient cycling and water-holding potential (Geremia et al. 2019). The deposition of feces and urine into the soil released plants from nitrogen limitation, and precipitation became the primary factor influencing plant growth (Frank et al. 2013 and references therein, Geremia and Hamilton 2019, 2022; Geremia et al. 2019). It may be impossible or cost prohibitive to remove many species of nonnative plants from YNP given their widespread distribution and proliferation in some areas (Yellowstone Center for Resources 2021, White et al. 2022b). Also, it may not be imperative or prudent to attempt to remove all nonnative plant species from areas where many are providing functional ecosystem services, such as healthy soils, water, energy, forage, and nutrients, like native species (Geremia and Hamilton 2019, 2022).

Monitoring between 2015 and 2022 confirmed soil organic matter was stable and within ranges supporting nutrient cycling, water-holding potential, and physical structure (Geremia and Hamilton 2019). Communities intensively grazed by bison sustained plant production comparable to those with a year-long grazing exclusion, although one area of the Lamar Valley showed a gradual decrease in production over time (Geremia 2022). Grasses in the Lamar Valley maintained production under intense grazing, and soil organic matter and nutrients in grazed areas varied little from year to year (Geremia and Hamilton 2019, 2022; Geremia 2022). The plant community contains the same native species at the same sites compared to what grew there in the 1980s, although the composition has shifted somewhat (Frank 2022). These findings are indicative of a highly resilient grazing community of interacting plants and ungulates (Crawley et al. 2021).

The climate of northern YNP has warmed and dried significantly since the 1980s, and this trend is forecast to continue (Tercek et al. 2015, Thoma et al. 2015, Hostetler et al. 2021). This warming has already changed the composition and distribution of vegetation and facilitated the spread of winter annuals in many areas (Yellowstone Center for Resources 2021). Warm-season nonnatives, including desert alyssum and cheatgrass, are gradually invading the warm and dry low-elevation range habitat types and have the potential to displace native plants and unbalance the functional integrity of plant communities (Renkin 2022, Wacker 2022). These plants grow in dry soils, where there is intense competition for moisture. Winter annuals can outcompete native plants by sprouting in autumn, with already germinated annuals then monopolizing early spring pulses of water (Renkin 2022, Wacker 2022). The abundance and distribution of winter annuals will likely depend on how much northern YNP warms and dries in the future. Under some climate scenarios, these plants could disrupt plant communities throughout the low- and mid-elevation valley slope habitat types in northern YNP (Geremia and Hamilton 2019, 2022). These changes could reduce plant production and the forage capacity in the park to support bison and other wildlife, leading to larger migrations during some winters, with some animals being unable to obtain adequate fat and protein reserves for pregnancy and survival (Wilmers et al. 2013, Middleton et al. 2018).

Alternatively, if summers start earlier and are wetter than expected with climate warming, the prolonged periods of warm and wet soils may increase decomposition rates and liberate soil carbon, nitrogen, and phosphorus (Yellowstone Center for Resources 2021). The longer periods of nutrient and water availability would naturally shift plant communities to faster-growing lifeforms, including rhizomatous and shallower rooted forms and nonnative annual plants. Plant production may increase, and more frequent wet years could enhance grazing feedbacks that further promote plant production, especially in higher-elevation wet areas (Yellowstone Center for Resources 2021). Grazing-tolerant, cool-season, nonnative cultivars would continue to spread in wet areas, with this spread enhanced by grazing. There could be an increase in body condition of bison and other ungulates by autumn, which would increase reproductive success and survival, resulting in increased population sizes for these species. More bison may remain in the park during winter due to increased forage availability, and earlier spring migrations to higher elevations would be timed with earlier snow melt (Yellowstone Center for Resources 2021).

Factor B—Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

The petitioners indicated culling negatively impacts the bison population by decreasing genetic viability, selecting for traits that decrease fitness, and altering the sex ratio. The petitions suggested genetic viability may be degraded through the disproportionate culling of migratory animals, which would favor less migratory bison, select for a mitochondrial gene defect that impairs aerobic capacity and disrupts cold tolerance (Pringle 2011), skew sex ratios, and disproportionately remove bison from central YNP (USDI, USFWS 2015). Bison sampled in the central and northern regions of YNP during 1997 to 2003 had significantly different distributions of alleles and genotypes based on microsatellite DNA markers and were genetically distinguishable based on 20 alleles only found in one of the two regions (Halbert et al. 2012). Based on these analyses, the petitioners concluded Yellowstone bison are comprised of at least two genetically distinct subpopulations that are being differentially affected by culling, which could decrease genetic viability (USDI, USFWS 2015).

Culling has Decreased Genetic Viability—Research does not support the contention of a recent loss of genetic viability in Yellowstone bison due to culling. The Yellowstone population contains two genetic lineages of bison that contribute to relatively high genetic diversity. Circa 1900, there were about two dozen indigenous bison remaining in the central region (Pelican Valley during winter) of YNP. As a result, managers created another breeding herd in the northern portion of the park (Lamar Valley) during 1902 to 1909 with 18 female bison from northwestern Montana, 3 male bison from Texas, and four indigenous calves (Meagher 1973). After several decades, the indigenous and reintroduced herds began mixing and interbreeding, which increased as bison numbers and movements increased (Meagher 1973, Meagher et al. 2002). In recent decades, as bison numbers increased, many hundreds dispersed from central to northern YNP and subsequently bred and produced calves; thus, there was significant mixing, breeding, and gene flow between bison originating from these two regions (Fuller et al. 2007, White and Wallen 2012, Wallen and White 2015).

Recent genetic analyses of mitochondrial haplotypes from bison sampled in central and northern YNP did not detect subpopulations but did detect two independent lineages in approximately equal proportions from the indigenous bison originally in central YNP during winter and the female bison introduced into northern YNP from northwestern Montana in 1902 (Forgacs et al. 2016). These geneticists from Texas A&M University identified 10 different mitochondrial DNA haplotypes and an overall haplotype diversity of 0.78 in Yellowstone bison, indicating a healthy, genetically diverse population (Forgacs et al. 2016). Between two and five groups of related alleles based on neutral markers exist across the park, and allelic diversity, allele frequencies, and inbreeding levels have remained similar during the IBMP era based on 44 microsatellites across the bison genome (Geremia 2022). Yellowstone bison should retain this diversity for centuries if numbers average at least 3,000 to 3,500 bison, there is intermixing and gene flow between bison from the two primary breeding herds, and removal are mainly juveniles (Pérez-Figueroa et al. 2012).

Culling Decreases Migratory Tendencies—Culling bison at the boundary of YNP selectively removes migratory bison. The IBMP was designed to avoid management actions within the interior of the park to limit adverse effects to other cultural and natural resources and visitor experience (USDI, NPS and USDA, USFS, APHIS 2000; White et al. 2011). However, there is no evidence Yellowstone bison are losing their ability to migrate. Under the IBMP, hundreds to more than one thousand bison have migrated outside YNP and into Montana during winter, depending on bison density, forage production and availability, snow cover, and other factors (Geremia et al. 2011, 2014, 2015a). In recent decades, Yellowstone bison have migrated farther than at any time since the massive slaughter of bison in the middle to late 1800s, with tolerance for these bison in Montana increasing since 2011 (Bullock 2015, Geremia et al. 2015a, IBMP Agencies 2016). More than 4,100 bison migrated north of Mammoth, Wyoming, in YNP during the prolonged, severe winter of 2023, which was twice the previous high of about 2,000 bison in 2008 (Geremia 2023).

Mitochondrial Gene Defect—Pringle (2011) suggested some Yellowstone bison with haplotype 6 in their mitochondrial genome carry a double mutation that affects one gene for cytochrome b and another for ATP6. He suggested this inherited mutation was primarily found in bison in the central region of YNP and would adversely affect the production and transport of energy within cells and aerobic capacity (Pringle 2011). Recent evidence from geneticists at Texas A&M University suggests descendants of bison introduced to northern YNP in 1902 from the Pablo-Allard herd in northwestern Montana and, subsequently, the Mary Mountain area in central YNP in 1936, have the mutation identified by Pringle (2011), while descendants from the indigenous bison do not (Forgacs et al. 2016). If the double mutations in the bison introduced from the Pablo-Allard herd were expressed and caused the detrimental effects hypothesized by Pringle (2011), over time there should have been a substantial reduction in the frequency of genetic haplotypes with these mutations due to strong negative selection (Forgacs et al. 2016). However, geneticists at Texas A&M University found the two independent genetic lineages from the indigenous bison and the bison introduced into YNP from northwestern Montana in 1902 were still present in approximately equal proportions more than a century later. They concluded "[d]ue to the statistically non-significant change in haplotype frequencies in the Yellowstone population ($p = 0.412$) based on Fisher's exact test and the lack of any kind of reported lesion or disease that affect a large proportion of Yellowstone bison, we did not find evidence to support Pringle's hypothesis" (Forgacs et al. 2016). In other words, there does not appear to be any strong negative selective forces occurring in this population that influence mitochondrial haplotype frequencies.

Culling Alters Bison Sex Ratios—Culling tends to remove more female and young bison because they tend to migrate to lower elevations during winter and be captured more than adult males (White et al. 2011). Park biologists want to maintain a balanced sex ratio of about 50% males and 50% females to support mate competition and allow natural selection to affect population genetics (Pérez-Figueroa et al. 2012, Geremia 2022). They also try to maintain an age structure of about 70% adults and 30% juveniles, which is based on the expected population composition given age-specific birth and survival rates (Geremia et al. 2015b, Hobbs et al. 2015, Geremia 2022). Over the last five years, the sex ratio averaged 52% males and 48% females, which is near the objective, though males were overrepresented in the central herd (five-year average of 144:100) and slightly underrepresented in the northern herd (five-year average 98:100). The age structure of the population was also near the objective with about 28% juveniles and 72% adults over the past five years. Juveniles made up 24% of animals in the central herd (five-year average) compared to 29% in the northern breeding area (Geremia 2022).

Culling Disproportionately Removes More Bison from Central Yellowstone—Bison are intensively managed at times near the boundary of YNP, and culls of more than 1,000 bison in winters 2006 and 2008 may have differentially affected bison from the central region of the park by removing more females and dampening productivity (White et al. 2011, Halbert et al. 2012). However, recent monitoring suggests there was substantial mixing, breeding, and gene flow between descendants of bison from the indigenous and introduced lineages during the past two decades (White and Wallen 2012, Wallen and White 2015, Forgacs et al. 2016). The population has a relatively high potential growth rate and has recovered rapidly from decreases in abundance due to culling or natural mortality (White et al. 2011, Geremia 2022). Geneticists from Texas A&M University (Forgacs et al. 2016) concluded "[t]he status of the Yellowstone bison population based on our findings of high [mitochondrial] haplotype diversity and lack of population subdivision appears to be genetically healthy, especially for a population with a history of intensive management that included periods of extreme reductions in size. In recent years, as the number of bison has grown exponentially and more bison leave the park during the winter, culling of animals to control their abundance and distribution has become necessary. Our finding that there is no subdivision based on mtDNA support that Yellowstone bison can be managed - for mitochondrial haplotype diversity - as a single population with multiple breeding segments." Since 2017, park biologists have recommended population management removals focus on bison living in northern YNP, not the central breeding herd (Geremia 2022). About 1,550 bison were removed during winter 2022-2023, including about 1,500 bison near the northern boundary of YNP. Aerial distribution flights suggest most of these animals were from the northern breeding herd (Geremia 2023).

<u>Factor C—Disease or Predation</u>

The petitioners suggested diseases, such as hemorrhagic septicemia and malignant catarrhal fever, pose a direct threat to Yellowstone bison, while the impacts of brucellosis indirectly threaten bison due to limitations on bison distribution and population size to limit transmission risk to cattle.

Disease Outbreaks—There were several outbreaks of hemorrhagic septicemia in the Lamar herd that killed 15% of the bison in 1911 and 9% in 1919 and 1923 (Skinner et al. 1942, Plumb and Sucec 2006). There have been no subsequent outbreaks. In 2003, an outbreak of malignant catarrhal fever in southern Idaho killed 51% of the bison in a feedlot that had been exposed to domestic sheep for two weeks (Li et al. 2006). However, park biologists are not aware of any imminent threats to Yellowstone bison from hemorrhagic septicemia or malignant catarrhal fever. Biologists monitor animals placed in the Bison Conservation Transfer Program (quarantine) for diseases of high health concern, including brucellosis, Johne's disease, and *Mycoplasma bovis*. In addition, anthrax caused by the spore-forming bacterium, *Bacillus anthracis*, can cause large, rapid and deadly outbreaks, usually during hot, dry weather preceded by flooding or substantial rainfall. Although outbreaks have not occurred in YNP, they have occurred in southwestern Montana near the park boundary. Hot, dry conditions in the park often coincide with the breeding season for bison when they aggregate in the Lamar and Hayden valleys. The unpredictability and potential severity of an anthrax outbreak requires preparedness, and the NPS has developed a framework for responding effectively and rapidly to an outbreak (Treanor and White 2019).

Culling to Suppress Brucellosis Prevalence—The IBMP has not focused on brucellosis suppression since at least 2014, when the NPS decided not to implement the remote vaccination of bison for brucellosis (USDI, NPS 2014). Currently, captured bison are not culled based on being previously exposed to brucellosis. Instead, groups of bison are captured with the intent to place eligible bison testing negative for brucellosis exposure in the Bison Conservation Transfer Program (Geremia 2022). Bison testing seropositive for brucellosis in quarantine are killed onsite or shipped to slaughter (USDI, NPS 2018).

Concerns about Brucellosis Limit Bison Abundance and Distribution—As described previously, tolerance for Yellowstone bison is limited to the park and nearby areas in Montana. For many decades, arguments against tolerance for bison in states surrounding the park were presented in terms of the risk of brucellosis transmission to cattle and effects to the livestock industry and state economies (Bidwell 2010). As elk were demonstrated to be the only transmission vectors to date, however, arguments shifted more towards concerns about bison competing with cattle for grass, human safety, and property damage (White et al. 2015, National Academies of Sciences, Engineering, and Medicine 2017). During 2008 to 2022, counts of Yellowstone bison after calving increased from about 2,970 to 5,940, which is the largest number since the late 1800s and far larger than any other wild, unfenced population of plains bison (Geremia 2022). Hundreds to more than one thousand bison have migrated outside YNP and into Montana during winter, depending on bison density, forage production and availability, snow cover, and other factors (Geremia et al. 2011, 2014, 2015a; Geremia 2023).

<u>Factor D—Inadequacy of Existing Regulatory Mechanisms</u>

The petitioners believe existing federal and state regulatory mechanisms for bison conservation are inadequate. They suggest the IBMP is a threat to Yellowstone bison because of activities related to culling and brucellosis management, citing Halbert et al. (2012:368) that "[t]he continued practice of culling bison without regard to possible subpopulation structure has the potentially negative long-term consequences of reducing genetic diversity and permanently changing the genetic constitution within subpopulations and across the Yellowstone metapopulation."

Existing Regulatory Mechanisms are Inadequate—Under the IBMP, bison counts increased from about 2,700 in 2000 to 5,940 in summer 2022 (Geremia 2022). The potential concerns of Halbert et al. (2012) about reductions in genetic diversity and subpopulation structure have not been detected during subsequent research. In 2011-2012, geneticists identified 10 different mitochondrial DNA haplotypes in Yellowstone bison and an overall haplotype diversity of 0.78, indicating a healthy, diverse population (Forgacs et al. 2016). Yellowstone bison should retain this diversity for centuries if numbers average at least 3,000 to 3,500 bison, there is intermixing and gene flow between bison from the two primary breeding herds, and removal are mainly juveniles (Pérez-Figueroa et al. 2012). Studies indicate a high portion of adults produce offspring during their lifetimes (Herman et al. 2014). Between two and five groups of related alleles based on neutral markers exist across the park, and allelic diversity, allele frequencies, and inbreeding levels remained similar over more than two decades based on 44 microsatellites across the bison genome (Geremia 2022). Also, bison from both the native and introduced lineages remain in the population in approximately equal distributions based on mitochondrial DNA (Forgacs et al. 2016).

The severe, prolonged winter of 2022-2023 provided a sort of 'worst case' scenario for testing the adequacy of regulatory mechanisms at sustaining a viable population of bison while maintaining a low risk of brucellosis transmission from bison to cattle. The bison count during summer 2022 was the highest in recent history (near 6,000) and park biologists recommended removing animals near the northern park boundary through captures and harvests to reduce population growth, support the Bison Conservation Transfer Program and tribal treaty hunts, and reduce conflicts from bison exiting the park (Geremia 2022). However, biologists cautioned against removing more than 25% of the population (~1,500 bison) to avoid unintended consequences on sustainability and future tribal hunting opportunities and transfers of live bison to tribes (Geremia 2022).

The subsequent winter was the most severe of the IBMP era (2001-2023), with snow pack about 199% at Tower Junction in northern YNP and snow water equivalent about 156% at West Yellowstone, Montana (Geremia 2023). More than 4,100 bison migrated north of Mammoth, Wyoming, in YNP during the prolonged, severe winter, which was twice the previous high of about 2,000 bison in 2008 (Geremia 2023). More than 100 bison were outside the park in Montana on 83 days, 250 bison on 52 days, 500 bison on 23 days, and 1,000 bison on 3 days (Geremia 2023). However, there was no mingling of bison and cattle. The NPS ceased culling and the tribes decreased hunting substantially as they approached the upper recommended level (1,500) of removals. Though a total of about 1,550 bison were removed, more than 4,000 bison remained in the population, which was higher than the 3,500 lower limit for bison that park biologists have recommended maintaining in the population to sustain a viable population and retain existing genetic diversity (Pérez- Figueroa et al. 2012, USDI, NPS 2023). Thus, existing mechanisms worked to conserve a viable bison population with no transmission of brucellosis from bison to cattle.

Under the IBMP, the NPS has lead responsibility for implementing bison management actions inside YNP while the State of Montana has lead responsibility outside the park (IBMP Members 2022). The NPS does not have regulatory authority or jurisdiction over hunts that occur outside YNP (Sholly 2020), and hunts conducted on national forests under permits through Montana or tribes exercising their treaty rights do not require authorization from the USFS (Erickson 2019). As a result, some people have questioned how the federal government can ensure the bison population is not reduced to unsustainable levels by actions taken by other agencies or tribes outside the park. Most bison removals outside the park take place on national forest lands. If necessary, the USFS can preempt or supersede state laws and policy to meet its statutory and trust obligations regarding issues such as public safety and natural resource protection after consultation with the states (43 USC 1732). In addition, United States Supreme Court has indicated off-reservation treaty-based hunting rights do not guarantee Indians "absolute freedom" from regulation: "[w]e have repeatedly reaffirmed state authority to impose reasonable and necessary nondiscriminatory regulations on Indian hunting, fishing, and gathering rights in the interest of conservation. … This "conservation necessity" standard accommodates both the State's interest in management of its natural resources and the Chippewa's [tribe's] federally guaranteed treaty rights" (*Mille Lacs*, 526 US, 204-205). The Supreme Court later suggested during oral arguments for another case that the conservation necessity doctrine may be applicable to federal and state interests such as safety, mitigation of wildlife disease, and duration of hunting seasons, though they did not rule on these matters (*Herrera*, 138 S. Ct. 2707 (No. 17-532).

Bison Management Focuses on Managing Brucellosis Transmission Risk to Cattle—The IBMP was designed to ensure Yellowstone bison did not transmit brucellosis to cattle in Montana, while conserving about 3,000 bison in late winter and spring (which equates to about 3,600 to 3,700 bison after calving depending on the composition and growth rate of the population; Angliss 2003) and attempting to reduce the prevalence of brucellosis in bison through test-and-slaughter and vaccination (USDI, NPS and USDA, USFS, APHIS 2000). The federal government and State of Montana agreed to several goals, three of which are related to brucellosis transmission. The goals included specific commitments relating to the size of the bison herd; a clearly defined boundary line beyond which the agencies will not tolerate bison; provisions for public safety and the protection of private property; agency actions showing a commitment toward the eventual elimination of brucellosis in bison; protection of livestock from the risk of brucellosis; actions to help protect the brucellosis class-free status of Montana; and maintenance of a viable population of wild bison in biological, genetic, and ecological terms.

The primary strategy used to prevent direct brucellosis transmission from Yellowstone bison to cattle is to maintain separation between them, which has been successful with no detected transmissions. As mentioned previously, managers have not focused on brucellosis suppression since at least 2014, when the NPS decided not to implement the remote vaccination of bison for brucellosis, and currently, bison are not culled based on their brucellosis exposure status (USDI, NPS 2014; Geremia 2022). The State of Montana only allows limited numbers of bison in certain areas and the federal government cannot force the state to tolerate more migrating bison; it is their decision (Bullock 2015). Allowing mass migrations of bison into local communities and areas with cattle, without management intervention, would thwart conservation efforts by reducing regional support (White et al. 2015, Metcalf et al. 2016). Thus, agencies involved with the management of Yellowstone bison have agreed to regulate the size of the population (IBMP Members 2022).

Factor E—Other Natural or Manmade Factors Affecting its Survival

The petitioners indicated Yellowstone bison are threatened with a loss of genetic diversity and a loss of evolutionary potential due to domestication, human selection, and hybridization with cattle. In addition, they forecast climate warming will result in decreased precipitation, increased temperatures, and widespread drought that will cause bison to disperse south into Grand Teton National Park and the National Elk Refuge, where they could potentially interbreed with bison that may carry some genes from cattle (USDI, USFWS 2015).

Domestication—Concerns about confining wild bison for months or years during winter operations or quarantine appear to be unfounded. Bison introduced to northern YNP in the early 1900s were confined, fed, herded, and protected for decades to proliferate their numbers before managers decided they should live in a more natural state (Meagher 1973). Thereafter, these bison have been wild, wide-ranging, and subject to forces of natural selection and, today, their descendants are considered an excellent example of wild bison (Freese et al. 2007, White et al. 2015). This successful restoration suggests there is no reason bison completing quarantine in a few years or less would not retain or redevelop their wild behaviors, and no reason they should not be used to augment or establish wild herds of bison in appropriate areas. Video tapes of managers at the Fort Peck Indian Reservation attempting to capture Yellowstone bison relocated from quarantine clearly show released animals are not docile or habituated (Rather 2014). Furthermore, judicial evaluations have concluded Yellowstone bison completing quarantine are wild animals (*Citizens for Balanced Use et al. v. Director Maurier, Montana Department of Fish, Wildlife & Parks et al.*; Montana Seventeenth Judicial District, Blaine County; Cause No. DV–2012-1 [2012, 2014], overturned No. DA 12-0306 [Montana Supreme Court 2012]).

Human Selection—Yellowstone bison are not facing imminent threats to their genetic health and viability as suggested by the petitioners. However, humans have removed (through hunter harvests and culls) about 11,470 bison since 2001, which exceeds deaths from natural causes such as injuries, predation, and starvation (Geremia 2022, 2023). The NPS captured and culled bison in northern YNP during the winters of 2003, 2004, 2006, 2008, 2011, 2014 to 2020, 2022, and 2023. Public and tribal hunters harvested about 2,930 bison in Montana during winters from 2001 through 2022, and around 1,100 bison in the winter of 2022-2023. In 2011 and 2023, the NPS held about 800 bison in captivity and fed them hay for several weeks to prevent mass migrations north of the park. These bison were released during spring, but confinement and feeding conflict with the management of bison as wildlife and could lead to food-conditioning, disease transmission during confinement, and disruption of traditional migratory patterns if conducted frequently. As a result, the NPS has recommended treating bison more like other wildlife in states surrounding YNP and supported increased tolerance for wild bison in suitable portions of the GYE

(White et al. 2015). In addition, the Custer Gallatin National Forest adopted a new Land Management Plan that includes components supporting habitat improvement projects to create or connect suitable bison habitat with enough bison present and distributed year-round to provide a self-sustaining population on the national forest in conjunction with bison herds in YNP (USDA, USFS 2022).

Hybridization with Cattle—Geneticists at Texas A&M University recently published findings that all bison in North American have some level of cattle introgression, including Yellowstone bison (Stroupe et al. 2022). A low level of cattle introgression in Yellowstone bison was detected by complete genome sequencing, which provided a conclusive description of the genetic makeup of 25 bison that were descendants from five remnant privately owned historic herds in the late 1800s, Yellowstone bison, or four cattle breeds (Stroupe et al. 2022). The detection of a low-level of cattle genes in Yellowstone bison is not surprising given the introduction of bison from other remnant herds into the park during the early 1900s to facilitate restoration and enhance genetic diversity following their slaughter and near extirpation by colonists in the late 1800s (Meagher 1973). Private bison managers often cross-bred bison and cattle, and in the early 1900s, park managers brought 21 privately owned bison into YNP to captively breed bison when they feared this last wild herd may go extinct. It appears at least one of these bison was hybridized with cattle genes (Stroupe et al. 2022). While this finding is disappointing, it does not substantially diminish the conservation value of Yellowstone bison, which remain the closest ancestral connection to the animals that once roamed North America (Plumb and Sucec 2006). Yellowstone bison are valuable because they live in herds of several thousands of individuals, moving and grazing across migratory landscapes, competing with other herbivores, and coping with predators and disease (White et al. 2015). Letting nature influence Yellowstone bison allows the fittest to survive, helping them adapt to the environment as it changes, which should remove any genes, including cattle-related genes, that reduce their fitness.

Climate Warming and Bison Dispersal to Grand Teton National Park—As mentioned previously, Yellowstone bison have rarely dispersed to the nearest population in Grand Teton National Park, even though there are no physical barriers to such movements (Wallen and White 2015). The petitioners concerns about the potential effects of climate warming on bison and their movements are speculative, but plains bison are resilient and historically lived across North America from desert to near arctic climes. Evidence indicates there has been a substantial increase in the amount of carbon dioxide in the atmosphere over the past two centuries (Friedlingstein et al. 2019). Elevated carbon dioxide can increase plant growth by reducing water loss and facilitating photosynthesis. This increase may have indirectly contributed to more grass production and abundant forage for ungulates in YNP, especially in wetter areas where nonnative, cool-season grasses were planted for hay during the early 1900s and subsequently spread (Frank 2022). However, variations in precipitation and temperature strongly influence soil moisture, which can limit grass production (Frank et al. 2013 and references therein; Geremia and Hamilton 2019, 2022).

Average annual temperatures in the GYE increased about 2.3°F from 1950 to 2018, with a longer snow-free season (Hostetler et al. 2021). In northern YNP, these changes resulted in less snow at lower elevations, earlier snowmelt and plant growth, longer and drier growing seasons, and more frequent drought (Tercek et al. 2015, Thoma et al. 2015, Yellowstone Center for Resources 2021). The regional warming trend is predicted to continue, with an increase in mean annual temperatures of about another 2°F across all seasons, milder winters with fewer days below freezing, earlier spring vegetation green-up, and more frequent drought (Hostetler et al. 2021). However, there is uncertainty around these predictions and somewhat divergent outcomes are possible.

Continuing trends toward warmer and drier conditions with more frequent drought could worsen the spread of invasive plants, such as winter annuals, and threaten some native bunchgrass communities that provide food for bison in the warmest and driest areas and regions with historical (tilling/plowing) and contemporary (roads) soil disturbance (Yellowstone Center for Resources 2021). Fires should continue to be infrequent in grassland and shrubland areas, mostly moving rapidly at low intensity. An increased frequency of fires could make grassland communities more vulnerable to the spread of nonnative grasses (Yellowstone Center for Resources 2021). These changes could reduce plant production and the forage capacity of the park to support bison and other wildlife, leading to larger migrations during some winters, with some animals being unable to obtain adequate fat and protein reserves for pregnancy and survival (Wilmers et al. 2013, Geremia et al. 2014, Middleton et al. 2018). However, warmer temperatures have already resulted in lower snowpack and soil moisture at elevations between 5,000 and 7,000 feet (Thoma et al. 2015, Hostetler et al. 2021), and bison may respond to less snow on their winter ranges by remaining longer at higher elevations in the park and migrating to lower elevations near the boundary later in the winter.

If summers are hotter and drier than predicted, plant production across grasslands and shrub steppe could decrease as a result of reduced soil moisture which, in turn, would limit absorption of water and nutrients by plants and indirectly lower soil decomposition rates. Shorter, ephemeral pulses of nutrient availability in wet grassland areas could promote the growth of drought-tolerant plants, including annuals, winter annuals, and slow-growing graminoids (Yellowstone Center for Resources 2021). Thus, shrub and bunchgrass-dominated plant communities in dry upslope areas on the Blacktail Deer Plateau, Little America, and the slopes of the Lamar Valley could convert to infestations of annual plants with hotter and drier conditions. Increased fire frequency and intensity in ungrazed and lightly grazed areas could facilitate these plant community changes. Under this scenario, the numbers of bison could decrease from lower landscape-level plant production, which would contribute to decreased body condition, pregnancy, and survival (Yellowstone Center for Resources 2021). More intense droughts would further limit forage availability in late summer and winter. There could be mass migrations of bison and other ungulates from the park during limited forage years, with more ungulates remaining outside the park on agricultural land (Yellowstone Center for Resources 2021).

If summers start earlier and are wetter than predicted, the prolonged periods of warm and wet soils may increase decomposition rates and liberate soil carbon, nitrogen, and phosphorus. The longer periods of nutrient and water availability would naturally shift plant communities to faster-growing lifeforms, including rhizomatous and shallower rooted forms and nonnative annual plants (Yellowstone Center for Resources 2021). Plant production may increase, and more frequent wet years could enhance grazing feedbacks that further promote plant production, especially in higher-elevation wet areas. Grazing-tolerant, cool-season, nonnative cultivars would continue to spread in wet areas, with this spread enhanced by grazing (Yellowstone Center for Resources 2021). There could be an increase in body condition of bison and other ungulates by autumn, which would increase reproductive success and survival, resulting in increased population sizes for these species. More bison may remain in the park during winter due to increased forage availability, and earlier spring migrations to higher elevations would be timed with earlier snow melt (Yellowstone Center for Resources 2021).

Species Status Assessment

A species status assessment evaluates the conservation biology principles of resiliency, redundancy, and representation, and forecasts the viability of the species (or distinct population segment) over time for various scenarios of future environmental conditions and conservation efforts (Gates and Ellison 2010, USDI, USFWS 2016). Resiliency refers to sustaining populations with a high probability of persisting for centuries due to their large size and high potential growth rate, which would enable them to withstand and recover from unpredictable events such as severe weather or disease outbreaks. Redundancy refers to the preservation of a sufficient number of large, connected populations to withstand local catastrophic events, such as a virulent disease outbreak or large winterkill (starvation) in a single population. Representation refers to preserving populations across the range of environments (habitats) historically used by the species to preserve genetic diversity, local adaptive capabilities, and enhance the likelihood of adaptation to future changes in environmental conditions, such as climate change (Gates and Ellison 2010, USDI, USFWS 2016).

Resiliency

Plains bison were nearly extirpated during the middle to late 1800s as millions were shot by colonists and settlers in western North America. Only about two dozen bison remained in the Yellowstone area by 1900, all within the newly created (1872) national park (Meagher 1973). The bacterial disease brucellosis that causes abortions was inadvertently introduced into bison and elk in the Yellowstone area during the early 1900s when humans brought domestic cattle for meat and milk (Meagher and Meyer 1994). However, the dedicated protection and restoration of this population over the next century gradually increased numbers to about 5,000 bison inside YNP by 2005. During 2012 to 2022, bison summer counts averaged about 5,000 and ranged between 4,200 and 6,000 (Geremia 2022).

Yellowstone bison are one of a few wild, migratory populations of plains bison and the only population large enough to be considered ecologically and genetically viable (Hedrick 2009, Gross et al. 2010). The population has two primary breeding herds with modest reproduction and high survival of adults and young. As a result, numbers increase rapidly when conditions are good, with an average growth rate of 15% during 2001 to 2022 after adjusting for management removals (Geremia et al. 2015c, Geremia 2022). However, bison survival and calving are lower during and after severe winters, respectively, with a population growth rate of less than 4% after such winters in 2005-2006, 2007-2008, and 2010-2011 (Geremia 2023). The population has recovered rapidly from substantial decreases in abundance during some winters (White et al. 2011, 2015; Geremia 2022). Geneticists from Texas A&M University concluded the population "appears to be genetically healthy, especially for a population with a history of intensive management that included periods of extreme reductions in size" (Forgacs et al. 2016).

For further recovery in the GYE, plains bison need similar access to habitat that other wildlife species such as elk are given without human intrusion, including year-round access to many USFS and other public lands in the ecosystem that are outside the NPS's jurisdiction (White et al. 2015b). Montana has allowed more tolerance for bison adjacent to YNP to facilitate conservation and hunting, including year-round in some areas (Bullock 2015). Public opinion is shifting toward more tolerance for bison in the GYE (Tulchin Research 2015); however, state and local governments and many private landowners do not support more tolerance for bison on public lands further from the park (Metcalf et al. 2016). Also, the continuing development of open space on private lands surrounding the park degrades and fragments habitat and migration corridors for wildlife, including bison (Hansen and Phillips 2018). As a result, it is unlikely additional tolerance for bison on public lands in the states surrounding YNP would keep pace with the potential growth of this population given the extremely high survival of calves and adults. In turn, it is foreseeable that Yellowstone bison will need to be continually culled and harvested from the population to limit abundance and distribution which will, in turn, limit recovery (White et al. 2015b).

Redundancy

The Yellowstone bison population is spatially separated from other populations of plains bison and, as a result, there has been no gene flow into the population for numerous generations (Wallen and White 2015). The nearest wild plains bison population is about 85 miles south in Grand Teton National Park and the National Elk Refuge, but Yellowstone bison have rarely dispersed there, and not vice versa, even though there are no physical barriers to such movements (Plumb and Sucec 2006, Wallen and White 2015). There are genetic differences between these populations because the Grand Teton population was founded partially from bison relocated from Theodore Roosevelt National Park, which has a different genetic lineage than Yellowstone bison (Dratch and Gogan 2010). There is limited opportunity for

Yellowstone bison to disperse and expand their range in Montana because the Paradise and Madison valleys north and west of YNP support numerous livestock producers and rural residential development has increased rapidly during the past several decades; both of which are at times incompatible with the conservation and restoration of a free-ranging bison population (Haggerty and Travis 2006, Metcalf et al. 2016, Tilt 2020). Furthermore, Idaho and Wyoming have indicated they do not want wild bison outside of parks and refuges (Wallen et al. 2015a).

To mitigate the possible effects of genetic drift and protect against the loss of a unique genetic lineage, Geneticist Dr. Philip Hedrick at the University of Arizona indicated (2009:419) "[i]dentified differentiated populations (clusters) should be replicated with at least one other physically separated population with an effective population size of 1000. If it is not possible to have this replicated population in 1 location, then it could be in 2 or 3 locations with significant genetic exchange between them." Descendants of primarily indigenous bison from YNP were used to augment plains bison populations in Fort Niobrara National Wildlife Refuge in Nebraska, Grand Teton National Park/National Elk Refuge in Wyoming, National Bison Range in Montana, and Wind Cave National Park in South Dakota (Plumb and Sucec 2006, Halbert and Derr 2008, Hedrick 2009, Dratch and Gogan 2010, Stroupe et al. 2022). Also, several satellite populations of bison from the Yellowstone lineages were established on the Book Cliffs and Henry Mountains in Utah, Vermejo Ranch in New Mexico, and Flying D Ranch in Montana.

In 2010, a 5-year quarantine feasibility study with Yellowstone bison was successfully concluded, with the surviving bison and their offspring being declared brucellosis-free (Clarke et al. 2014). Montana relocated 87 bison completing quarantine to the Green Ranch in Montana in 2010 and sent another 61 bison to the Fort Peck Indian Reservation in 2012. In 2014, Montana sent the original quarantined bison plus 25% of the offspring (139 total) at the Green Ranch to the Assiniboine and Sioux Tribes at Fort Peck. Since 2019, the Bison Conservation Transfer Program, implemented by the NPS and APHIS, has sent about 300 brucellosis-free Yellowstone bison to Fort Peck for one year of assurance testing and eventual release. The ITBC has transferred more than 170 bison of Yellowstone-origin from Fort Peck to 23 tribes across 12 states. Collectively, these populations total many thousands of bison. Geneticists from Colorado State University found "[g]enetic diversity levels in the quarantined herd were high and comparable to the YNP [Yellowstone] parent herd, suggesting a low risk of genetic loss in the near future. Based on these findings, the genetic diversity currently available within the BQFS [satellite] herd will provide a strong foundation for bison reintroduced herds and for the preservation of the species" (Herman et al. 2014:335).

Only a few unfenced, wide-ranging populations of plains bison exist in the United States besides Yellowstone bison, including Book Cliffs, Henry Mountains, Grand Teton, and Wrangell-St. Elias. All these populations are relatively small with less than 1,000 bison (Dratch and Gogan 2010). Furthermore, most other conservation herds of bison on public lands also have low population sizes, along with limited distributions, protection from natural selection factors like large predators, and skewed sex and age ratios maintained to ease management (McDonald 2001). Additional wild, wide-ranging populations subject to the forces of natural selection need to be augmented or established at other sites to preserve the species. This would reduce the reliance on Yellowstone and a few other populations to preserve the species in the wild (White et al. 2015b).

Representation

Yellowstone bison represent a unique source of genetic diversity, not replicated among other Department of Interior populations, with high genetic diversity compared to many other populations (Hedrick 2009, Dratch and Gogan 2010). Yellowstone bison retain one of the highest levels of heterozygosity and allelic diversity in any conservation population of plains bison, and several geneticists have concluded abundance and gene flow among breeding herds are high enough to avoid inbreeding depression and maintain genetic variation (Hedrick 2009, Dratch and Gogan 2010, Gross et al. 2010, Pérez-Figueroa et al. 2012). Parentage analyses by Colorado State University indicated a high portion of adults contribute offspring to the population during their lifetimes (Herman et al. 2014). Also, geneticists at the University of Montana concluded mate competition among males was likely moderate to high, which should contribute to sustaining genetic variation for centuries (Pérez-Figueroa et al. 2012). In addition, geneticists from Texas A&M University conducted whole genome sequencing (mitochondrial DNA) with samples collected from contemporary bison in YNP, as well as two museum specimens from the Lamar Valley in northern Wyoming in 1856 and southern Montana in 1886 near the northern boundary of the park. Haplotypes in contemporary descendants of the indigenous bison were like those in the museum specimens (Forgacs et al. 2016).

To preserve genetic variation over centuries, the *Bison Conservation Initiative* by the U.S. Department of the Interior and the *North American Conservation Strategy for Bison* by the International Union for the Conservation of Nature recommend that population (or subpopulation) sizes should be at least 1,000 bison, with approximately equal sex ratios to ensure considerable competition between breeding bulls (Dratch and Gogan 2010, Gross et al. 2010). Yellowstone bison are the only population of plains bison within their original range that meet these objectives, with hundreds to thousands of bison congregating in the central and northern regions of the park during the breeding season and hundreds of mature males competing for breeding opportunities. In addition, Hedrick (2009:419) indicated "[i]ndividual herds or clusters [of plains bison] should have an effective population size of 1000 (census number of 2000–3000) to avoid inbreeding depression and maintain genetic variation. If it is not possible to have this primary herd in 1 location, then it could be in 2 or 3 locations with significant genetic exchange between them. Note that this is larger than any of the plains bison herds except for Yellowstone NP [National Park] and any of the wood bison herds except for Wood Buffalo NP and Mackenzie Bison Sanctuary in Canada." Recent monitoring suggests there were significant movements, breeding, and gene flow between bison originating from central and northern YNP during the past two decades (White and Wallen 2012, Wallen and White 2015, Forgacs et al. 2016).

Yellowstone bison are one of only a few unfenced, wild, wide-ranging populations of plains bison in existence. They move across extensive portions of the unique landscape within and near YNP, with a full suite of native ungulates and predators, while being exposed to natural selection factors (Plumb et al. 2009, White et al. 2015b). Within the interior of the park, bison live in an environment not dominated by humans and whose behaviors, movements, survival, and reproduction are predominantly affected by their own daily decisions and natural selection (White 2016). As a result, Yellowstone bison have retained adaptive capabilities that are diminished in many other bison herds across North America managed like domesticated livestock in fenced pastures with human-induced seasonal movements among pastures, no predators, selective culling of older bulls to facilitate easier management, and selection for the retention of rare alleles—the function and importance of which have not been identified (McDonald 2001, White and Wallen 2012, White et al. 2015b).

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